

Vol. 50 • No. 2

February 2007

# Microwave Journal

## RF Components and Systems

### EM Enables Classic Filter Technique

### Microwaves Across the Pacific

### RF MEMS: Ready for Prime Time



horizon house  
h<sup>®</sup>  
Founded in 1958

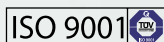
[www.mwjjournal.com](http://www.mwjjournal.com)



# prepare to engage



Prepare yourself for a new kind of relationship with San-tron. A relationship that combines experience and service with a passion to earn your business. Over the last 50 years, we've taken pride in being a trusted supplier of standard and custom engineered coaxial solutions. We have an extensive catalog of products from SMA to LC to cable assemblies and our custom engineering capabilities are unsurpassed. Engage with us today, and experience the quality, service, selection, and pricing you're looking for.



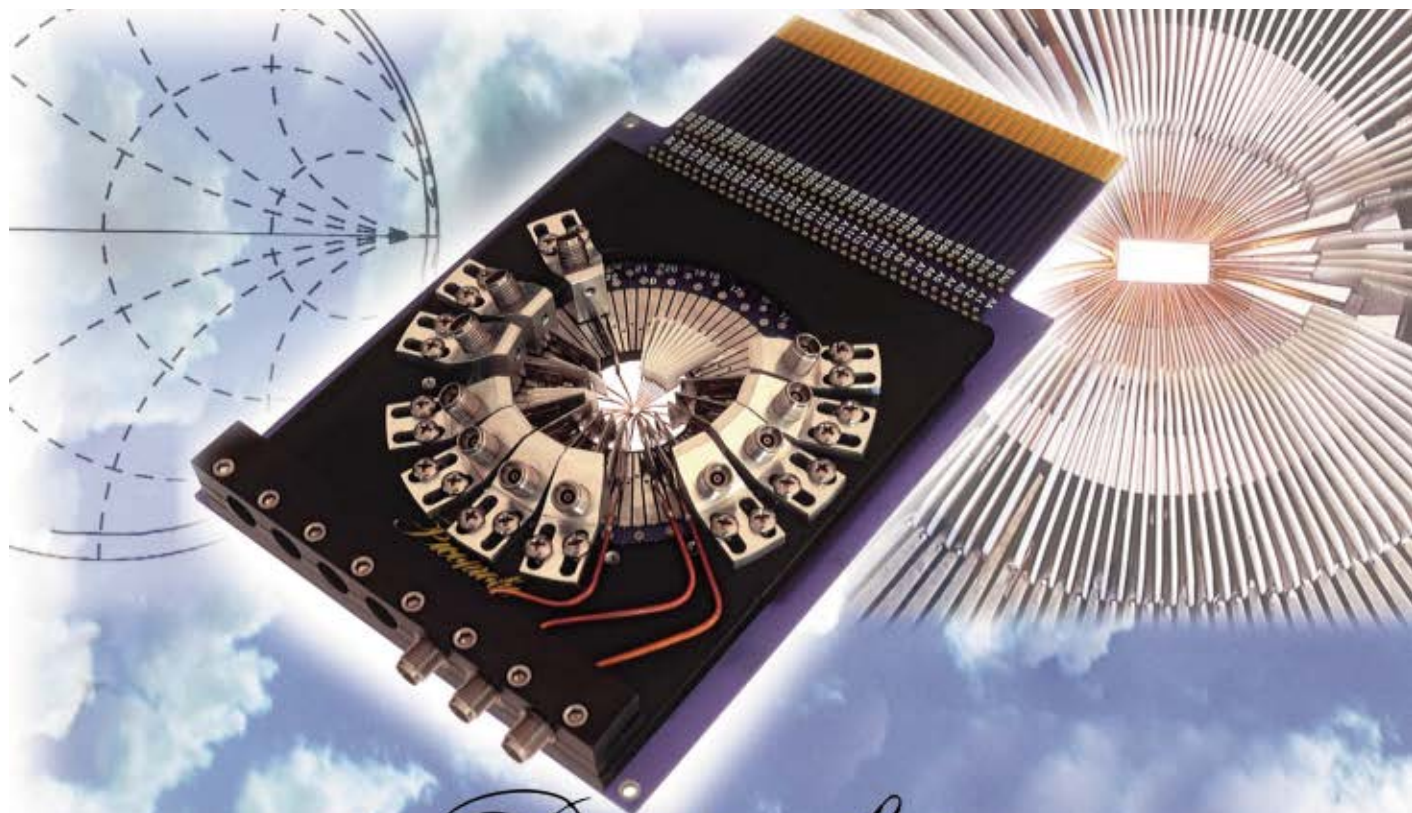
[www.santron.com](http://www.santron.com)

978-356-1585



Visit <http://mwj.hotims.com/11713-124> or use RS# 124 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)





*Picoprobe®*

**Picoprobe elevates probe cards to a higher level...**

**(...110 GHz to be exact.)**

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



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



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.



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

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

Telephone (239) 643-4400 • Fax (239) 643-4403 • E-mail [email@ggb.com](mailto:email@ggb.com) • [www.picoprobe.com](http://www.picoprobe.com)

Visit <http://mwj.hotims.com/11713-55> or use RS# 55 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)

**THE WORLD'S LARGEST SELECTION**

# **POWER SPLITTERS/ COMBINERS**

**IN STOCK**



**2kHz to 12.6GHz from 79¢**

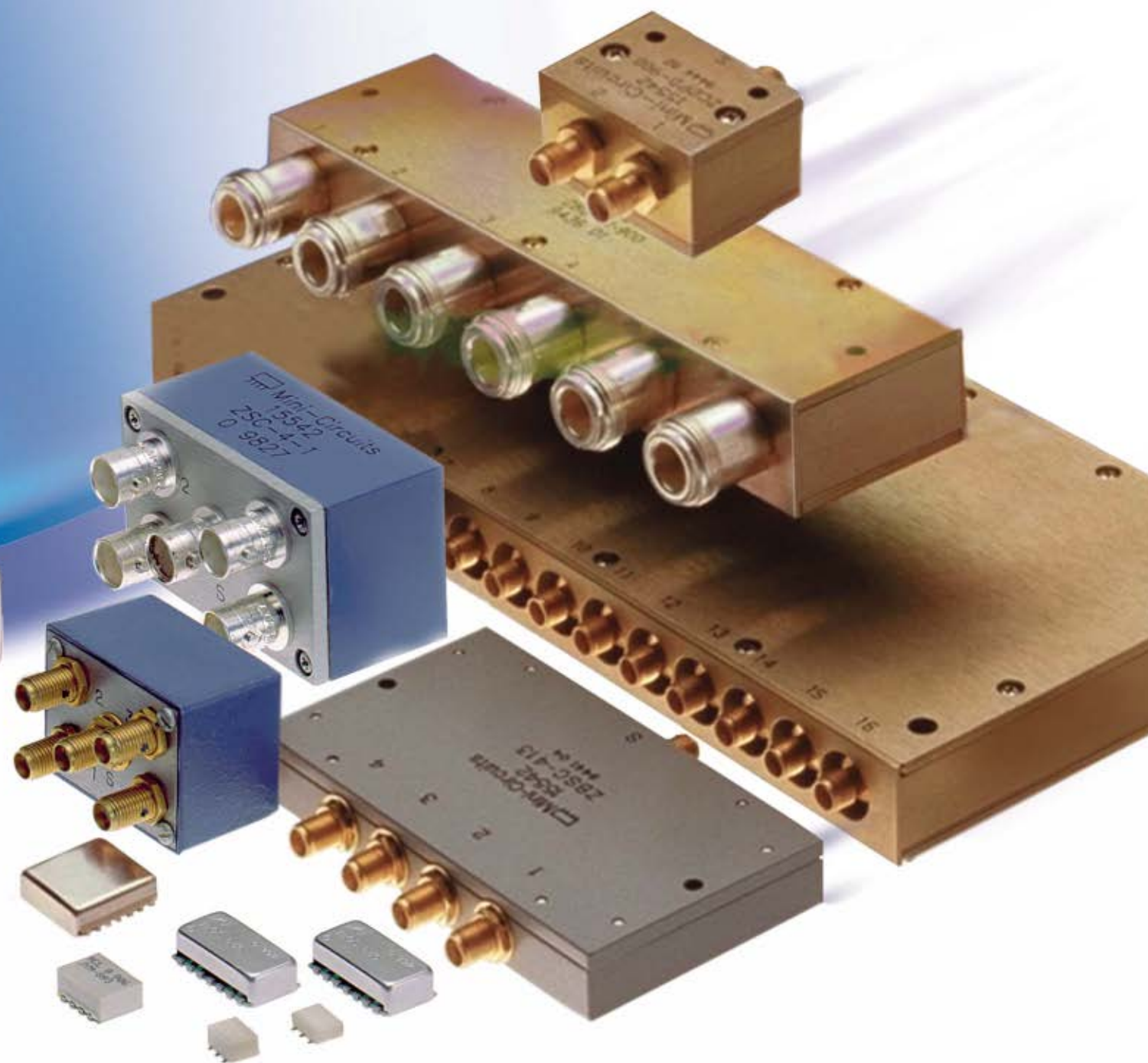


**RoHS models available, consult factory.**

Need just the right surface mount, coaxial, thru mount, or flat pack power splitter or combiner for your project? Mini-Circuits is on the case offering you thousands of high performance, cost-effective models off-the-shelf and immediately available for your military and commercial applications. Choose from 2 and 3way to 48way; 0°, 90°, 180°; 50&75 ohms covering 2kHz to 12.6GHz and beyond, all characterized with detailed data and performance curves available to you in a flash 24/7 on "The Yoni Search Engine" at the Mini-Circuits web site. Surface mount products include highly reliable LTCC designs giving you extremely small size, ultra-low profile, excellent stability over temperature, and high performance repeatability. Tough built coaxial models are available with SMA, BNC, TNC, and Type-N connectors and include broadband ZX10 units standing less than  $\frac{3}{4}$ " in size. And when it comes to your custom needs...just let us know what you're looking for and our development team will go to work! Add our 1 year guarantee, knowledgeable applications support, and value pricing, and the decision is easy. Contact Mini-Circuits today!

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





**Mini-Circuits®**  
ISO 9001 ISO 14001 CERTIFIED

**ALL NEW**  
**minicircuits.com**

P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661 For detailed performance specs & shopping online see Mini-Circuits web site



The Design Engineers Search Engine Provides ACTUAL Data Instantly From MINI-CIRCUITS At: [www.minicircuits.com](http://www.minicircuits.com)

**RF/IF MICROWAVE COMPONENTS**

194 Rev H

Visit <http://mwj.hotims.com/11713-78> or use RS# 78 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)

# FOR 60 YEARS CUSTOMER SATISFACTION HAS BEEN OUR GUARANTEE

Simple Reasons Why You Should Choose **Dow-Key®**

## 1 **PRODUCT INNOVATION**

- 5 Million Cycle Products
- DC to 40 GHz Coaxial Switches
- 2.6 to 70 GHz Waveguide Switches
- PXI Broadband Modules
- High Power, PCB Mounted, Miniature Switches
- Switching Networks (Solid State, MEMS & Coaxial)
- Design Flexibility for Custom Solutions
- Space Qualified High Power Switches

## 2 **SHORT DELIVERY LEAD TIME**

- Kanban System Offers Stock to 2 Week Delivery on Selected SPDT, DPDT and SP6T Switches

## 3 **CUSTOMER FOCUS**

- Superior Customer Support
- Customer Recognition as "Switch Supplier of Choice" for 5 Consecutive Years
- Star Supplier Award Recipient



(805) 650-0260

[askdkmj2@dowkey.com](mailto:askdkmj2@dowkey.com)

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

Visit <http://mwj.hotims.com/11713-39> or  
use RS# 39 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)



AS9100/ISO9001:2000  
Hold Cert. No. FM 86698



**Dow-Key® Microwave**  
CORPORATION

A **DOVER** COMPANY





## Filter Solutions

Interference Mitigation

Fault Detection and Surge Protection

Elliptic Response

Low Loss



## Product Spotlight



## ESMR Duplexer for 800 MHz Band Reconfiguration

In response to the FCC mandate for signal spectrum separation of incompatible wireless technologies, K&L has added an 800 MHz duplexer to its product portfolio that has been specifically designed to eliminate interference with lower SMR spectrum and Public Safety radios.

## Filter Wizard<sup>SM</sup>

K&L Microwave's Filter Wizard<sup>SM</sup> software simplifies selection of the right filter product for your application from a vast number of designs. Provide desired specifications, and Filter Wizard<sup>SM</sup> returns response data and outline drawings for matching products. Visit [www.klfilterwizard.com](http://www.klfilterwizard.com) today!



*microwave products*  
group

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

Visit <http://mwj.hotims.com/11713-67> or use RS# 67 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)



ISO 9001 Registered  
ISO 14001 Registered

# WE DESIGN OUR COMPONENTS TO WORK IN THE MOST EXTREME CONDITIONS



## Narda Power Dividers and Combiners

- DC to 40 GHz
- Octave, multi-octave and ultra broadband models
- 2-way, 3-way, 4-way, 6-way, 8-way and 16-way models
- High power and special applications
- Economical models for wireless applications

## Because Component Failure Is Not An Option.

Dependability in extreme conditions is just one of the many reasons design and manufacturing engineers make **Narda Power Dividers and Combiners** their first choice. Narda offers hundreds of standard off-the-shelf designs that meet most requirements. Our power dividers exhibit superior isolation, minimum insertion loss and excellent phase and amplitude balance. They are available in a number of frequency ranges with many RF connector options.

Please visit our web site to view detailed specifications of our large selection of power dividers. We're sure you'll find one that meets your exact requirements.

# narda

an  communications company

435 Moreland Road, Hauppauge, New York 11788  
USA Tel: 631.231.1700 • Int'l Tel: 631.231.1390  
Fax: 631.231.1711  
e-mail: [nardaeast@L-3com.com](mailto:nardaeast@L-3com.com)  
[www.nardamicrowave.com](http://www.nardamicrowave.com)





# Looking for the perfect tuner?

## Some tuners just work better than others.

Thanks to Maury Microwave's new automated high-gamma tuners (HGT™) you're able to cover all the requirements of impedance matching and in-fixture and on-wafer loadpull.

Whether you're involved in fab operations, modeling, design, production test or multiple tasks, the HGT™ is the solution for all your loadpull needs.

With the industry's highest accuracy and best calibration you'll have more time to design — knowing they will work right the first time.

### The Maury HGT™ Advantage

- 200:1 VSWR for Sub 1Ω Loadpull – ideal for GSM/EDGE, WCDMA, WiFi, and WiMax
- Ultra-High Matching Range for GaN, GaAs, LDMOS, and Deep Submicron CMOS Characterization
- Simultaneous Ultra-High Matching and Low Vibration
- 825 MHz to 6.0 GHz Frequency Coverage
- USB interface for Simple, Fast and Reliable Control
- DLL Control for Automated Applications



HGT™ Model Number*	Frequency Range (GHz)	Matching Range Min	Matching Range Typ	Vector Repeatability dB (Typ)	$\Delta G_t$ dB (Typ)	Power Capability
MT981HU_†	0.825–5.6	100:1	200:1	-40	±0.3	200 W CW 2.5 kW PEP
MT981HU_†	1.8–6.0	100:1	200:1			

\* Connector sizes available: 7mm, 14mm or 7-16mm

† Contact Maury Microwave for specific model numbers

Contact Maury Microwave today for more information and to schedule a **FREE** in-house demo!



**MAURY MICROWAVE CORPORATION**

2900 Inland Empire Blvd., Ontario, CA 91764

Tel: 909-987-4715

E-mail: [loadpull@maurymw.com](mailto:loadpull@maurymw.com)

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

Visit <http://mwj.hotims.com/11713-73> or use RS# 73 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)



# Microwave Journal

FEBRUARY 2007 VOL. 50 • NO. 2

## FEATURES

### SPECIAL REPORT

#### 15 IMS 2007: Microwaves Across the Pacific

Wayne A. Shiroma, General Chair, IMS 2007

An introductory message from this year's International Microwave Symposium general chairman regarding IMS 2007, to be held June 3–8, in Honolulu, Hawaii

### COVER FEATURE

#### 24 RF MEMS: Ready for Prime Time

John McKillop, TeraVista Technologies Inc.

In-depth look at the past, present and future of radio frequency microelectromechanical systems switch technology

### TECHNICAL FEATURES

#### 68 A CMOS Frequency Synthesizer with Self-biasing Current Source for a 5 GHz Wireless LAN Receiver

C. Quemada, H. Solar and G. Bistué, Centro de Estudios e Investigaciones Técnicas de Gipuzkoa; J. de No and I. Sancho, Escuela Superior de Ingenieros Industriales de San Sebastián

Description of a fully integrated 3.2 GHz synthesizer with a self-biasing current source for a 5 GHz wireless LAN receiver

#### 102 Design of a Novel Quad-band Microstrip BPF Using Quarter-wavelength Stepped-impedance Resonators

Chung-I G. Hsu, Da-Yeh University; Ching-Her Lee and He-Kai Jhuang, National Changhua University of Education

Introduction to a quad-band microstrip bandpass filter designed to pass signals in the GPS L1 channel, ISM, WiMAX and WLAN bands

#### 116 A Compact Microstrip Stepped-impedance Resonator and Filter

Jian-kang Xiao, South China University of Technology; Shi-wei Ma, Shanghai Key Laboratory of Power Station Automation Technology; Ying Li, Shanghai University

Design and analysis of a double-T-shaped microstrip bandstop filter, a double-H-shaped microstrip bandpass filter and a hairpin SIR bandpass filter

50 Years  
of Publishing  
Excellence

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

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

©2007 by Horizon House Publications Inc.

Horizon House also publishes *Telecommunications*®

Posted under Canadian international publications mail agreement #0738654







## The stringent performance requirements of WiMAX require a M/A-COM solution

Part Number	Freq (GHz)	Gain	P1dB	Pout	Ids/Voltage
-------------	------------	------	------	------	-------------

### Driver Amplifiers

MAAMSS0072	2.3-2.7/3.3-3.7	24/22	27/27	20/20	235/5
MAAMSS0073	2.3-2.7/3.3-3.7	22/20	30/30	23/23	490/5
MAAPSS0096	4.9-6.0	20.5	28	19	230/5

### Class A/B Amplifiers

MAAPSS0103	2.3-2.7	34	32	26	600/5
MAAPSS0104	3.3-3.8	32	32	26	600/5
MAAP-007899	5.7-5.9 (per 200 MHz bandwidth)	23	28	21	475/5

Packages for parts listed above are 4 mm PQFN

The IEEE 802.16 standards-based wireless technology is envisioned for a variety of applications: providing high-speed access to underserved areas, larger footprint "hotspots", backhaul of Wi-Fi and cellular traffic, and business connectivity.

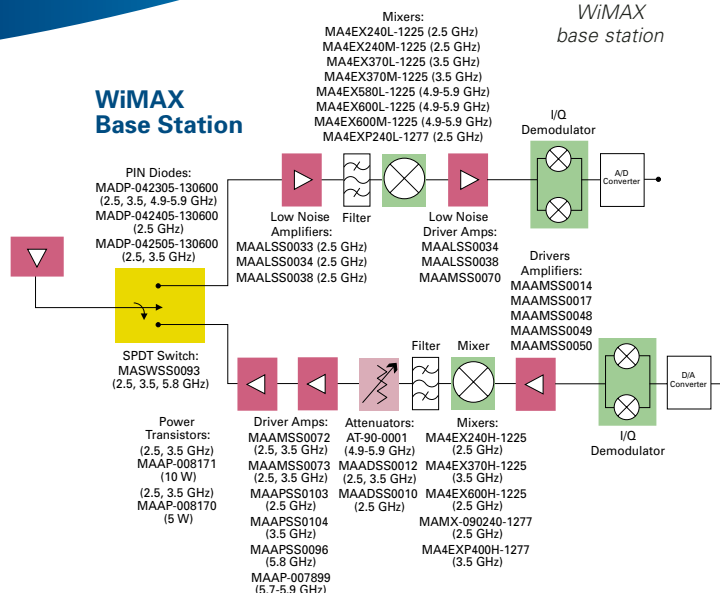
M/A-COM provides one of the broadest lines of reliable WiMAX RF components including amplifiers, attenuators, drivers, mixers, circulators, and switches for the 2.5, 3.5 and 5 GHz frequency bands for CPE, mobile and base station applications.

For complete information visit [www.macom.com](http://www.macom.com) or contact our sales office.

North America 800.366.2266 • Europe +44 (0) 1908.574200  
• Asia/Pacific +81.44.844.8296 • [www.macom.com](http://www.macom.com)

M/A-COM and Tyco are trademarks.  
WiMAX is a trademark of the WiMAX Forum.

Products available for WiMAX base station



**tyco**  
Electronics

*a vital part of your world*

Visit <http://mwj.hotims.com/11713-71> or use RS# 71 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)

# Microwave Journal

## FEATURES

### TECHNICAL FEATURES

#### 128 A 40 to 900 MHz CMOS Broadband Differential LNA for a DTV RF Tuner

*D.R. Huang and H.R. Chuang, National Cheng Kung University; Y.K. Chu, Himax Technologies; C.L. Lu, Kun Shan University*

Description of a 40 to 900 MHz CMOS broadband differential low noise amplifier with gain control for a DTV radio frequency tuner application

#### 138 EM Enables Classic Filter Technique

*Randy Rhea, Susina LLC*

Use of electromagnetic simulation in aiding the general procedure, a classic technique for filter design

#### 148 Concept and Method of High Efficiency in a Precision Ka-band Subminiature Coaxial Connector

*Jae-Ho Yoon, Won-Yong Cho, Ah-Rah Koh, Seung-Jun Lee, Bhanu Shrestha, Gary P. Kennedy and Nam-Young Kim, Kwangwoon University*

Design and fabrication of a miniature SMA connector for use at Ka-band using the characteristic impedance of a coaxial line, a discontinuous transmission line and the characteristics of dielectric bead-air line interfaces

### PRODUCT FEATURES

#### 158 A Low Noise PHEMT Device

*Filtronic Compound Semiconductors Ltd.*

Introduction to a small, low cost low noise amplifier with low DC power consumption usable from frequencies of 900 MHz to 5.8 GHz

#### 170 An LTCC Mixer for Instrumentation and Military Applications

*Mini-Circuits*

Use of low temperature-cofired-ceramic technology, semiconductor technology and a highly manufacturable circuit layout in the development of a high performance passive mixer

## DEPARTMENTS

16 . . . Ask Harlan

19 . . . Coming Events

20 . . . Workshops & Courses

43 . . . Defense News

47 . . . International Report

51 . . . Commercial Market

56 . . . Around the Circuit

176 . . . Software Update

182 . . . New Products

190 . . . New Literature

192 . . . The Book End

194 . . . Ad Index

198 . . . Sales Reps

## THIS MONTH ON THE WEB

Visit [www.mwjjournal.com](http://www.mwjjournal.com) for the latest industry news and exclusive on-line articles

### RFID: A Tale of Four Continents

RFID is being adopted worldwide but with very great differences of emphasis as revealed by the IDTechEx knowledge base of over 2450 case studies in 92 countries. This is a tale of four, very different continents.

**IDTechEx**

### WHITE PAPER

#### Passive Phase Shifters and Their Applications in RF Front-end Circuits

By Brian Kearns and  
Brendan McDonald  
TDK Electronics Ireland Ltd.

Introduction to a two-port chip component designed to be matched to 50  $\Omega$  terminations at each of the two ports.

#### Defense Spending Increases Provide Robust Market for Compound Semiconductors

*Radar, Communications,  
Smart Munitions and Electronic  
Warfare Contract Awards  
Exceed \$16 B in 2006*

Strategy Analytics projects that the market for GaAs devices will see continued growth at a CAAGR of 8% through to 2010.

**STRATEGYANALYTICS**  
INSIGHTS FOR SUCCESS



# 6 GHz MCX & MMCX



## Space and budget saving Push-on connectors

Tensolite's solution for applications demanding maximum RF performance and design flexibility in the smallest format. Tensolite's MCX and MMCX connectors are rated up to 6 GHz. They are designed for 75 & 50 ohm impedances and have reliable coupling methods. They are designed for use in applications where space and weight considerations are crucial.

( 8 6 6 ) 2 8 2 - 4 7 0 8

( 5 6 2 ) 4 9 4 - 0 9 5 5 ( f a x )

T e n s o l i t e . c o m

**Tensolite**  
A CARLISLE Company

Visit <http://mwj.hotims.com/11713-141> or use RS# 141 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)





# Big Performance Small Packages



## High Performance Ceramic Filters for Wireless, Commercial, and Military Applications

- \* 300 - 7000 MHz
- \* Bandpass or Bandreject
- \* Surface Mount or Connectorized



- \* Low Cost
- \* Rapid Delivery
- \* Tape and Reel Available

Visit <http://mwj.hotims.com/11713-107> or  
use RS# 107 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)



Approvals  
Quality System Registration  
ISO 9001-2000 Registered



## Reactel, Incorporated

Reactel, Incorporated • 8031 Cessna Avenue • Gaithersburg, Maryland 20879 • Phone: (301) 519-3660  
Fax: (301) 519-2447 • [ceramic@reactel.com](mailto:ceramic@reactel.com) • E-mail [catalog@reactel.com](mailto:catalog@reactel.com) to receive your Reactel Product Catalog  
or go online to [www.reactel.com](http://www.reactel.com) to download your copy today.



# IMS 2007: MICROWAVES ACROSS THE PACIFIC



**F**ive months from now, Honolulu, HI will be the host city for what is widely regarded as the most prestigious microwave industry gathering in the world: the 2007 International Microwave Symposium (IMS 2007), to be held June 3–8, 2007.

IMS 2007 is the largest international conference devoted to the research, development and application of RF and microwave theory and techniques, and is expected to draw over 10,000 participants and 400 exhibiting companies from around the world. This conference is organized and sponsored by the Microwave Theory and Techniques Society (MTT-S) of the Institute of Electrical and Electronics Engineers (IEEE).

IMS 2007 marks the 50<sup>th</sup> year that MTT-S has sponsored this symposium, and coincidentally it is being held in the 50<sup>th</sup> state of the US. It is also the first time that this symposium is being held off of the North American continent. Hawaii has long been regarded as the Crossroads of the Pacific, and both the *Microwave Journal* and the IMS 2007 Steering Committee are using this opportunity to bridge East and West by encouraging attendees and exhibitors to interact in what is now a global microwave village.

From all indications we have had so far, IMS 2007 will be a well-attended event. We received 1039 technical paper submissions, higher than any other IMS year except for IMS 2003 (Philadelphia, PA), which received 1100. By comparison, the very well at-

tended IMS 2005 (Long Beach, CA) and IMS 2006 (San Francisco, CA) received 984 and 982 submissions, respectively. Thirty-two percent of our paper submissions are from the US, and 30 percent are from Asian-Pacific Rim countries, again indicating the strong IMS 2007 participation from Asia. RFIC 2007, held in conjunction with IMS, received an all-time record of 350 papers, representing a 30 percent increase over last year.

Under the leadership of UCLA Professor Tatsuo Itoh, the Technical Program Committee is assembling a top-notch technical program that includes the usual array of technical papers, workshops, panel sessions and focused/special sessions. For the first time in recent IMS history, we will offer short courses from world-class experts that allow participants to receive IEEE continuing education units. We will also offer an expanded interactive forum in the morning and afternoon.

Our hotel rooms are selling at such a brisk pace that we are negotiating with hotels for larger room blocks to accommodate the demand. We are also planning an extensive guest program that the whole family can enjoy.

All in all, we anticipate IMS 2007 to be the microwave blockbuster event of the year. All of us on the IMS 2007 Steering Committee, the IEEE MTT-S and *Microwave Journal* look forward to seeing you in Hawaii this June. Aloha!

**WAYNE A. SHIROMA**  
*General Chair, IMS 2007*

## CERNEX, Inc

### Your Ultimate Source For FET & MMIC Amplifiers Ferrite and waveguide products



#### Broad-Band Low Noise Amplifiers

(Octave/Multi-octave)  
35KHz-50GHz; 1.5db for 0.5-2GHz; 3db for 0.5-18GHz;  
2db for 2-8GHz; 3db for 2-20GHz;  
4db for 2-28.5GHz; 2.5db for 6-18GHz;  
3db for 18-26.5GHz; 4db for 18-40GHz

#### Narrow-Band Low Noise Amplifiers

0.5-110 GHz  
Noise figure as low as 0.3 dB for cellular & PCS  
Bands; 0.4db for L & S Band; 0.5db for C-Band;  
0.6db for X-Band; 0.7db for Ku-Band.  
1db for K-band; 2.5db for Ka-Band

#### Broad-Band High Power Amplifiers

0.1-30.0 GHz (Octave & Multi-octave)  
0.1-0.5GHz(30W), 0.5-2GHz(20W), 1-2GHz 100W  
2-4GHz(100W), 2-8GHz(20W), 3.7-12GHz(10W),  
4-8GHz(20W), 5-15GHz(10W), 6-18GHz(20W),  
8-12GHz (50W), 18-26.5GHz (10W)

#### Narrow-Band Power Amplifiers

0.5-110 GHz  
Up to 500W output power @ P1dB for L, S, & C-Band.  
5W @ Ka-band

#### Active & Passive Frequency Multipliers

0.5-325 GHz  
Multiplication factors up to X27

#### Isolators & Circulators up to 140GHz



Drop-in and coax Isolators and circulators.  
High power coax isolators and circulators.  
Waveguide Isolators and circulators

#### Waveguide Products up to 325GHz



Visit our Website for more information  
@ [www.cernex.com](http://www.cernex.com)

**CERNEX, Inc**

766 San Aleso Ave., Sunnyvale, CA 94085

Tel: (408) 541-9226/Fax: (408) 541-9229

E-mail: [Cernex@cernex.com](mailto:Cernex@cernex.com)



"Ask Harlan," a technical question and answer session with Harlan Howe, Jr., an industry veteran and long-time *Microwave Journal* editor, has been a regular part of our web site ([www.mwjjournal.com](http://www.mwjjournal.com)) for almost three years now. In an effort to better combine the editorial content of our magazine with our newly developed and retooled on-line presence, we have decided to develop Harlan's RF and microwave engineering advice into a monthly feature.

**How it works:** Harlan has selected one question from his "Ask Harlan" column to be featured in the magazine. Please visit [www.mwjjournal.com/askharlan](http://www.mwjjournal.com/askharlan) to provide an answer to this month's featured question (see below). Harlan will be monitoring the responses and will ultimately choose the best answer to the question. Although all of the responses to the featured question will be posted on our web site, we plan to publish the winning answer in the April issue. All responses must be submitted by **March 6, 2007**, to be eligible for the participation of the February question.

The winning response will win a free book from Artech House, along with an "I Asked Harlan!" t-shirt. In addition, everyone who submits a legitimate response will be sent an "I Asked Harlan!" t-shirt.

## December Question and Winning Response

### The December question was submitted by Shanthi B. from Commercial Cellphone Makers:

Dear Harlan,

Why is the open/short/thru method the most preferred calibration method for RF measurements?

### The winning response to the December question is from Roger Chandra of Aero Inc.:

There are mainly five reasons why it is preferred: 1.) This is the simplest method known for making RF measurements; 2.) The time needed for making a measurement is much less than any other known method; 3.) The results are very accurate and all benchmarking studies have proven that; 4.) The measurement setup and calibration methods of the instruments are relatively easy; 5.) Last but not the least, the cost involved is also less.

### Harlan's response:

Dear Shanthi,

It is the most preferred because it is simple, fast, accurate and the calibration fixtures are relatively inexpensive to make and stable over time.

### This Month's Question of the Month (answer on-line at [www.mwjjournal.com/askharlan](http://www.mwjjournal.com/askharlan))

### Peter Saul from Saul Research has submitted this month's question:

Dear Harlan,

What happened to the "Hula Hoop" antenna, AKA DDDR? It was reported in the 1960s, but not since. It appears from the references (*Microwave Journal*, Vol. 6, No. 11, November 1963, pp. 89-90; how can I get a copy?) to have had lots of promise.

If your response is selected as the winner, you'll receive a free book of your choice from Artech House. Visit the Artech House on-line bookstore at [www.artechhouse.com](http://www.artechhouse.com) for details on hundreds of professional-level books in microwave engineering and related areas (maximum prize retail value \$150).

## STAFF

**PUBLISHER:** CARL SHEFFRES  
**ASSOCIATE PUBLISHER:** EDWARD JOHNSON  
**EDITOR:** HARLAN HOWE, JR.  
**MANAGING EDITOR:** KEITH W. MOORE  
**TECHNICAL EDITOR:** FRANK M. BASHORE  
**ASSOCIATE TECHNICAL EDITOR:** DAN MASSÉ  
**STAFF EDITOR:** JENNIFER DiMARCO  
**EDITORIAL ASSISTANT:** BARBARA WALSH  
**CONSULTING EDITOR:** HOWARD I. ELLOWITZ  
**CONSULTING EDITOR:** PETER STAECKER  
**CONSULTING EDITOR:** DAN SWANSON  
**WEB EDITOR:** STEPHEN HEISER  
**TRAFFIC MANAGER:** EDWARD KIESSLING  
**TRAFFIC ADMINISTRATOR:** KEN HERNANDEZ  
**DIRECTOR OF PRODUCTION & DISTRIBUTION:** ROBERT BASS  
**MULTIMEDIA DESIGNER:** ELI CONNER  
**DTP COORDINATOR:** JANET A. MACDONALD

## EUROPE

**DEPUTY PUBLISHER:** MICHEL ZOGHOB  
**EUROPEAN EDITOR:** RICHARD MUMFORD  
**OFFICE MANAGER:** EUGENIE HARDY

## CORPORATE STAFF

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

## EDITORIAL REVIEW BOARD:

Dr. I.J. Bahl	Dr. S. Maas
D.K. Barton	Dr. R.J. Mailloux
Dr. E.F. Belohoubek	S. March
Dr. C.R. Boyd	Dr. G.L. Matthaei
N.R. Dietrich	Dr. D.N. McQuiddy
Dr. Z. Galani	Dr. J.M. Osepechuk
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
J.L. Heaton	F. Sullivan
Dr. G. Heiter	D. Swanson
N. Herscovici	Dr. R.J. Trew
Dr. W.E. Hord	G.D. Vendelin
Dr. T. Itoh	C. Wheatley
Dr. J. Lasker	Dr. J. Wiltse
Dr. L. Lewin	Prof. K. Wu
Dr. J.C. Lin	

## EXECUTIVE EDITORIAL OFFICE:

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

## EUROPEAN EDITORIAL OFFICE:

46 Gillingham Street, London SW1V 1HH, England  
 Tel: Editorial: +44 207 596 8730 Sales: +44 207 596 8740  
 FAX: +44 207 596 8749

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

Printed in the USA



# It's a matter of trust

Pilots trust their techs.  
Techs trust their systems.  
System developers trust Agilent.

## **LXI-based Link 16 Measurements**

*Agilent's synthetic-instrument Link 16 Measurement System offers the most complete solution available today for this very complex measurement challenge.*



[www.agilent.com/find/syntheticad](http://www.agilent.com/find/syntheticad)

When selecting a partner for an ATE program such as eCASS, you need to trust their reputation, their technology, and their word. When you choose Agilent, you can be confident you made the right choice.

In 1989, when known as Hewlett-Packard, Agilent was chosen as the premier partner for the RF portion of the CASS system. And, today, more than 17 years later, you can still find our RF equipment in the CASS rack, with support extended until 2015.

Every product within our LXI-based synthetic-instrument portfolio offers the highest performance available today—from digitizers and arbitrary waveform generators, to up- and down-converters. Along with Agilent's legendary quality and support, your customers can confidently take their test systems into deployment for the next 20 years, and beyond.

Above all, when Agilent commits to something, we do it. It's a matter of trust.



**Agilent Technologies**

**THE WORLD'S NO.1 CHOICE**  
**ADE MIXER**  
**SERIES**

50kHz - 4200MHz



0.27"x 0.31"

**\$1.99**  
 from 1 ea. (Qty.100)

With over 72 standard mixer models *IN STOCK*, and over 100 more available with optimized performance for specific requirements, the ADE series is the world's #1 choice of high-reliability, high-performance mixers from 50kHz to 4.2GHz. Whatever the application, ADE series mixers can meet your frequency conversion requirements. Models are available with a wide range of RF, LO, and IF ranges, and optimized for LO levels from +3 to +20dBm. ADE series mixers boast conversion loss of less than 6dB and outstanding LO-to-RF isolation of better than 50dB. They are designed to fit the tightest designs, supplied in surface-mount packages measuring just 0.27 x 0.31 in. and height as low as 0.080 in. (2mm).

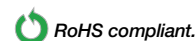


Full performance data and specifications are available for every model, making it simple to match a mixer to your specific requirements. ADE mixers are competitively priced for even the most demanding budgets. So don't waste time. If you need a mixer from 50kHz to 4200MHz, you'll find it in the ADE series, and you won't have to deal with long lead times or uncertain deliveries. Choose an ADE mixer today and we'll have it in your hands as early as tomorrow!

**Available from stock and only from Mini-Circuits!**

U.S. Patent #6,133,525

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



**Mini-Circuits®**  
 ISO 9001 ISO 14001 CERTIFIED

**ALL NEW**  
**minicircuits.com**

P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661 For detailed performance specs & shopping online see Mini-Circuits web site



The Design Engineers Search Engine Provides ACTUAL Data Instantly From MINI-CIRCUITS At: [www.minicircuits.com](http://www.minicircuits.com)

**RF/IF MICROWAVE COMPONENTS**

421 Rev Org.

Visit <http://mwj.hotims.com/11713-79> or use RS# 79 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)





## CALL FOR PAPERS

European Microwave Week (EuMW 2007)  
by February 25, 2007  
IEEE International Conference on  
Ultra-WideBand (ICUWB 2007)  
by March 4, 2007

## FEBRUARY

### SATELLITE 2007

February 19–22, 2007 • Washington, DC  
[www.satellite2007.com](http://www.satellite2007.com)

## MARCH

### MILITARY TECHNOLOGIES CONFERENCE

March 27–28, 2007 • Boston, MA  
[www.miltechconference.com](http://www.miltechconference.com)

### CTIA WIRELESS 2007

March 27–29, 2007 • Orlando, FL  
[www.ctiawireless.com](http://www.ctiawireless.com)

### RF & HYPER EUROPE 2007

March 27–29, 2007 • Paris, France  
[www.rfhyper.com](http://www.rfhyper.com)

### INTERNATIONAL WIRELESS COMMUNICATIONS EXPO (IWCE 2007)

March 28–30, 2007 • Las Vegas, NV  
[www.iwceexpo.com](http://www.iwceexpo.com)

## APRIL

### IEEE RADAR CONFERENCE 2007

April 17–20, 2007 • Waltham, MA  
[www.radar2007.org](http://www.radar2007.org)

## JUNE

### IEEE MTT-S INTERNATIONAL MICROWAVE SYMPOSIUM AND EXHIBITION

June 3–8, 2007 • Honolulu, HI  
[www.ims2007.org](http://www.ims2007.org)

### IEEE RADIO FREQUENCY INTEGRATED CIRCUITS SYMPOSIUM (RFIC 2007)

June 3–8, 2007 • Honolulu, HI  
[www.rfic2007.org](http://www.rfic2007.org)

### 69TH ARFTG CONFERENCE

June 7–8, 2007 • Honolulu, HI  
[www.arftg.org](http://www.arftg.org)

### WCA 2007

June 11–14, 2007 • Washington, DC  
[www.wcai.com/events.htm](http://www.wcai.com/events.htm)

### 4TH INTERNATIONAL WORKSHOP ON ADVANCED GROUND PENETRATING RADAR (IWAGPR 2007)

June 27–29, 2007 • Naples, Italy  
[www.irea.cnr.it/IWAGPR2007](http://www.irea.cnr.it/IWAGPR2007)

## JULY

### IEEE EMC SYMPOSIUM

July 8–13, 2007 • Honolulu, HI  
[www.emc2007.org](http://www.emc2007.org)

## SEPTEMBER

### IEEE INTERNATIONAL CONFERENCE ON ULTRA-WIDEBAND (ICUWB 2007)

September 24–26, 2007 • Singapore  
[www.icuwb2007.org](http://www.icuwb2007.org)

MICROWAVE JOURNAL ■ FEBRUARY 2007

## OCTOBER

### EUROPEAN MICROWAVE WEEK (EuMW 2007)

October 8–12, 2007 • Munich, Germany  
[www.eumweek.com](http://www.eumweek.com)

### ASSOCIATION OF OLD CROWS (AOC 2007)

October 28–31, 2007 • Orlando, FL  
[www.crows.org](http://www.crows.org)

### MILITARY COMMUNICATIONS CONFERENCE (MILCOM 2007)

October 29–31, 2007 • Orlando, FL  
[www.milcom.org](http://www.milcom.org)

## NOVEMBER

### ANTENNA MEASUREMENT TECHNIQUES ASSOCIATION (AMTA 2007)

November 4–9, 2007 • St. Louis, MO  
[www.amta.org](http://www.amta.org)

## DECEMBER

### ASIA-PACIFIC MICROWAVE CONFERENCE (APMC 2007)

December 11–14, 2007 • Bangkok, Thailand  
[www.apmc07.com](http://www.apmc07.com)

# MAXXED OUT?

## WiMax 802.16



## Passive RF Components Made for WiMax Applications

Are you maxxed out trying to stretch your old 2.5 GHz devices to work in higher frequency WiMax applications? EMC Technology and Florida RF Labs have released new components specified to work in WiMax applications for frequency requirements up to 5 GHz.

smiths

emct.com  
rflabs.com  
(800) 544-5594  
(772) 286-9300  
ISO 9001 and 14001 Certified

**EMC** **FLORIDA**  
Technology **RF**  
Labs

# AMPLIFIERS

for all applications

SUPER WIDE BAND 0.01 TO 20 GHz



- > Excellent gain flatness and noise figure
- > Uncompromised input and output VSWR
- > Very low power consumption
- > Miniature size and removable connectors
- > Drop-in package for MIC integration



MODEL	FREQ. RANGE (GHz)	MIN GAIN (dB)	MAX GAIN VARIATION (+/- dB)	MAX N.F. (dB)
AF0118193A AF0118273A AF0118353A	0.1 - 18	19 27 35	± 0.8 ± 1.2 ± 1.5	2.8 2.8 3.0
AF0120183A AF0120253A AF0120323A	0.1 - 20	18 25 32	± 0.8 ± 1.2 ± 1.6	2.8 2.8 3.0
AF00118173A AF00118253A AF00118333A	0.01 - 18	17 25 33	± 1.0 ± 1.4 ± 1.8	3.0 3.0 3.0
AF00120173A AF00120243A AF00120313A	0.01 - 20	17 24 31	± 1.0 ± 1.5 ± 2.0	3.0 3.0 3.0

\*VSWR 2 : 1 Max for all models  
 \* DC +5 V, 60 mA to 150 mA  
 \* Noise figure higher @ frequencies below 500 MHz

Custom Designs Available

Other Products: DETECTORS, COMB GENERATORS, LIMITERS, SWITCHES, IMPULSE GENERATORS, INTEGRATED SUBSYSTEMS

Please call for Detailed Brochures



155 BAYTECH DRIVE, SAN JOSE, CA.95134  
 PH: 408-941-8399 . FAX: 408-941-8388  
 E-Mail: info@herotek.com  
 Web Site: www.herotek.com  
 Visa/Master Card Accepted



## WORKSHOPS & COURSES

### SPACE-BASED RADAR

■ **Topics:** The Space-based Radar (SBR) course will explore theory, applications and orbital considerations for both synthetic aperture radar (SAR) and moving target indication (MTI) modes. SBR technology issues covered include electronically scanned antennas, waveforms, tracking and on-board processing. While it emphasizes radar sensor issues, the course will include top-level satellite prime power, structure, thermal and altitude control. For more information, visit [www.pe.gatech.edu](http://www.pe.gatech.edu).

■ **Site:** Atlanta, GA

■ **Dates:** March 5-9, 2007

■ **Contact:** Georgia Institute of Technology, Professional Education, PO Box 93686, Atlanta, GA 30377 (404) 385-3500.

### REVERBERATION CHAMBER THEORY AND EXPERIMENT SHORT COURSE

■ **Topics:** This course is designed for engineers who will be involved in radiated emission or immunity testing of commercial or military systems using reverberation chambers. The theory portion will cover the statistical nature of reverberation chamber testing, characterization of the EM test conditions, and the tradeoff between uncertainty in test results and test time. The experiments include typical measurement techniques, chamber calibration, immunity, emission and pulse testing in reverberation chambers.

■ **Site:** Stillwater, OK

■ **Dates:** April 30-May 4, 2007

■ **Contact:** For more information, visit <http://rc-course.okstate.edu>.

### MAKING ACCURATE LOW LEVEL ELECTRICAL MEASUREMENTS

■ **Topics:** This course provides users with a detailed understanding of how to make accurate low level electrical measurements. Users will learn what constitutes a low level measurement, the limitations of these measurements, sources of measurement error and techniques to eliminate these errors.

■ **Site:** Cleveland, OH

■ **Dates:** June 19-20, 2007

■ **Contact:** For more information, visit [www.keithley.com](http://www.keithley.com).

### PRACTICAL ANTENNA DESIGN

■ **Topics:** The course covers the important and timely issues involving modern antenna design and theory. Developed specifically for engineers and designers who work with radar and radio communications, this workshop will give participants the understanding of antenna theory and techniques, the skills to analyze, design and measure various antennas, and the knowledge of antenna measurements. For more information, visit [www.conted.ox.ac.uk](http://www.conted.ox.ac.uk).

■ **Site:** Summertown, Oxford, UK

■ **Dates:** June 20-21, 2007

■ **Contact:** University of Oxford Continuing Education, +44 (0) 1865 286958 or e-mail: [anthony.santiago@conted.ox.ac.uk](mailto:anthony.santiago@conted.ox.ac.uk).

### THE ENTREPRENEURIAL ENGINEER

■ **Topics:** This short course is an efficient and memorable introduction to the personal, interpersonal, business and organizational skills necessary to help engineers of applied science and mathematics perform at high levels in today's increasingly opportunistic organizations and enterprises. For more information, visit <http://online.engr.uiuc.edu/shortcourses/tee/index.html>.

■ **Site:** Archived on-line course.

■ **Dates:** Archived on-line for anytime viewing.

■ **Contact:** University of Illinois at Urbana-Champaign, 117 Transportation Bldg., 104 S. Mathews Avenue, Urbana, IL 61801 (217) 333-0897 or e-mail: [deg@uiuc.edu](mailto:deg@uiuc.edu).

### PCB DESIGN TECHNIQUES FOR EMC AND SIGNAL INTEGRITY

■ **Topics:** This course will assist practicing engineers who are responsible for PCB designs and system-level products. Disciplines include PCB layout, logic design, regulatory compliance and EMC. For more information, visit <http://epdwww.engr.wisc.edu>.

■ **Site:** For location information, please visit url.

■ **Dates:** For date information, please visit url.

■ **Contact:** University of Wisconsin, Department of Engineering Professional Development, 432 North Lake Street, Madison, WI 53706 (800) 462-0876.



# NOISE COM RISING ABOVE THE NOISE.



Sure, other companies talk about diodes, generators and components, but why work with an imitator when you can work with Noise Com? With 25+ years' experience and knowledge, only Noise Com can deliver total noise solutions. From custom components to complex instrumentation, you'll find the reliability and control you need, and the results you expect.

## COUNT ON THE NOISE LEADER. COUNT ON NOISE COM FOR:

- Custom designs
- Complete line of noise solutions
- Analog and digital noise
- Passion for innovation
- Proven expertise

# NOISE/COM

A WIRELESS TELECOM GROUP COMPANY

25 Eastmans Road, Parsippany, NJ 07054 • P: 973.386.9696 F: 973.386.9191 • [www.noisecom.com](http://www.noisecom.com)

Visit <http://mwj.hotims.com/11713-98> or use RS# 98 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)

Visit Us at Satellite 2007, Booth #493

**the power**

ELECTRONIC WARFARE

RADAR SYSTEMS

GROUND AND MOBILE  
COMMUNICATIONS

SATELLITE  
COMMUNICATION

COMMERCIAL  
AVIATION

SMART MUNITIONS  
AND MISSILES

HOMELAND SECURITY

SPACE SYSTEMS

SEARCH AND  
SURVEILLANCE

OVERHAUL AND  
REPAIR

# Cobham Defense Electronic Systems...



Positioners for RF &  
Microwave Applications



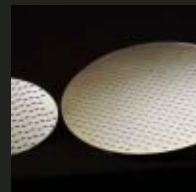
Positioning Systems  
for EO Applications



Ground Based  
Antennas



Platform and Soldier  
Combat Management  
Systems



Slotted Arrays



Waveguide  
Assemblies



# of integration

*the whole is far greater  
than the sum of its parts*

## **Cobham Defense Electronic Systems is...**

Atlantic Microwave, Atlantic Positioning Systems,  
Cobham Defense Communications Ltd., Continental Microwave,  
Kevlin, Nurad, REMEC Defense & Space, Sivers Lab AB



*The power of integration*



For more information, go to our Web site  
**[www.cobhamdes.com](http://www.cobhamdes.com)**

*A Cobham plc subsidiary*



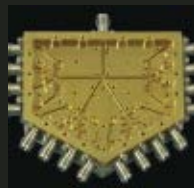
**Rotary Joints**



**Airborne Antennas**



**Filters**



**Control Components**



**Integrated Microwave  
Assemblies**



**MMIC**

Visit <http://mwj.hotims.com/11713-30> or use RS# 30 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)

COBHAM DEFENSE COMMUNICATIONS [www.cobhamdcweb.com](http://www.cobhamdcweb.com) +44 0 1254 292020 CONTINENTAL MICROWAVE [www.contmicro.com](http://www.contmicro.com) 603.775.5200  
REMEC DEFENSE & SPACE [www.remecrds.com](http://www.remecrds.com) 858.560.1301 SIVERS LAB AB [www.siverslab.se](http://www.siverslab.se) +46 8 477 6811



# RF MEMS: READY FOR PRIME TIME

**T**he promises and shortcomings of microelectromechanical systems (MEMS) switch technology have become almost legendary. Perhaps no other electronic component in history has been the source of so much hype—and the cause of so much disillusionment. So much so, that Internet sites advise engineers to steer clear of MEMS switch technology. Fortunately for those who have patiently followed this technology, the troubling early days are finally over and MEMS switches are rapidly fulfilling all of their earlier promise. This article takes a fresh look at lessons learned and where things stand today, along with prospects for a bright future.

## PAST

The first MEMS electrical switch was announced by IBM nearly 30 years ago.<sup>1</sup> Although the MEMS acronym was not coined for another decade,<sup>2</sup> this was one of the first practical microelectromechanical devices that used semiconductor fabrication techniques to build small mechanical structures in silicon that were moved or “actuated” electrically. It also showed that MEMS could create an entirely new class of switch technology that com-

bined the advantages of semiconductor manufacturing with the best features of electromechanical relays. In particular, it was predicted that MEMS switches would be small, have low power consumption and low loss—and, if properly manufactured in high volume, would be low cost and highly reliable.

The first part of this promise was realized by MEMS switch prototypes developed at leading US industrial research centers during the early 1990s.<sup>3</sup> Work at Hughes Research Labs, Raytheon/Texas Instruments and the Rockwell Science Center clearly demonstrated that MEMS switches could be small and high performance, and that they could deliver bandwidth and linearity equal to or better than the best electromechanical relays. The only problem that (seemingly) remained to be solved was lifetime reliability, and the race was on.

When reliable commercial devices failed to quickly come out of Hughes, Raytheon and Rockwell, the door opened for other companies

---

JOHN MCKILLOP  
*TeraVista Technologies Inc.*  
Austin, TX



# WHATEVER YOUR APPLICATION...



## RLC HAS THE POWER DIVIDER

For over 45 years RLC has been the Leader in Power Dividers with Standard and Custom Designs, Excellent Reliability, High Volume Production and Cost Effective Solutions... and RLC is ISO Certified.

RLC is your complete Microwave Component source... Switches, Filters, Power Dividers, Couplers, Terminations, Attenuators, DC Blocks, Hybrids, Bias Tees, Diplexers, Multiplexers, Equalizers & Detectors

- 2-32 way
- DC to 40 GHz
- Wide Bandwidth
- Low Insertion Loss & VSWR
- High Isolation
- Excellent Phase & Amplitude Balance
- Connectorized or Surface Mount
- SMA, N, BNC, TNC or Pins
- High Reliability
- Small Size
- 50 or 75 Ohms Impedance



**RLC ELECTRONICS, INC.**

83 Radio Circle, Mount Kisco, New York 10549

Telephone: 914-241-1334 • Fax: 914-241-1753

e-mail: [sales@rlcelectronics.com](mailto:sales@rlcelectronics.com) • [www.rlcelectronics.com](http://www.rlcelectronics.com)

Visit <http://mwj.hotims.com/11713-118> or use RS# 118 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)



to enter the race and the level of development activity exploded. By the end of the 1990s, more than 100 companies and research institutions throughout the world had started MEMS switch

development programs. Visible commercial activity peaked between 2000 and 2001 with product “pre-announcements” from a number of major manufacturers and the launch of multiple

startup companies.<sup>4</sup> Electrical performance was generally outstanding, but switch samples once again failed to meet customers’ expectations for quality and reliability.

### MEMS SWITCH CHALLENGES

Thinking that they were facing a “normal” set of technical challenges, MEMS switch developers consistently underestimated the difference between being able to sample a few prototype devices from a wafer and consistently manufacturing products that deliver high levels of quality and reliability. This created market expectations that are only now beginning to be met, and generated a considerable degree of skepticism concerning both MEMS companies and their products that still exists today. A number of technical issues contributed to this miscalculation, and to the difficulties in developing a reliable MEMS switch. Fortunately, hindsight allows us to highlight the most important of these issues and to identify the key solutions that were required to develop the first reliable RF MEMS switch products.

Unlike many other emerging technologies, MEMS switches must compete against established products based on very mature and stable technologies. Market entry products must have an initial defect rate of less than one percent and an operating life of at least 100 million cycles—10 times higher than a traditional electromechanical relay with otherwise comparable performance. This is a phenomenal expectation for an emerging technology product and a significant challenge in itself.

In parallel with this hurdle were two other serious technical issues that impacted nearly every MEMS switch development effort. The first was a subtle but important conflict between the market requirements for MEMS switches and stiction, the typical early failure mechanism of these devices (see **Figure A1**).

RF MEMS switch users need low loss devices that are capable of reliably handling a few watts of RF power in a frequency band from DC to 5 GHz. This demand can only be met by ohmic contact switches with very low contact resistance (insertion loss). The requirement for low contact resistance, in turn, favors the use of relatively soft con-

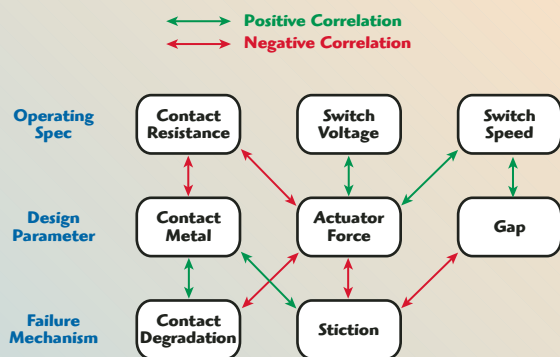
tact metals and/or high contact force, which makes the contacts stick together and fail (a phenomenon known in the MEMS community as stiction). Reliable low loss operation therefore requires stiff switch elements that provide enough return force to overcome stiction. High return force in turn requires a high enough operating voltage to generate enough closing force to overcome this stiffness and achieve an efficient contact. The correlation between design parameters and key failure mechanisms necessitates the use of high force actuator designs.

Low voltage actuator operation requires a compliant switch element (spring) that will necessarily have a limited return force. Thus, there is a fundamental conflict between the requirement for low switching voltage and the requirement for reliable, low loss operation. Although a variety of low voltage designs were investigated, all commercial solutions to date use “high force” actuator designs. This in turn requires high closing force, which can only be generated by high switch voltages.

Early MEMS switch designs were also plagued by the lack of hermetic packaging expertise within the MEMS industry. Contact degradation is one of two primary failure mechanisms for MEMS switches with ohmic contacts. This is primarily caused by contamination of the switch contacts and leads to steadily increasing values of switch resistance and insertion loss until the switch fails.

Long life MEMS switches thus require both high force actuation and manufacturing and packaging techniques that fabricate contaminant free switch contacts and keep them clean. This in turn requires cavity style packages that can protect the moving parts of the MEMS device from damage and contamination. A viable solution to this problem only emerged in the last several years as MEMS switch manufacturers adapted wafer bonding techniques to the fabrication of hermetic cavity packages. This advancement in packaging technology has shown the incredible sensitivity of MEMS switches to contamination. The crucial importance of hermetic packaging is highlighted by the fact that early MEMS switches attempted to get by with non-hermetic packaging technology. All failed to meet the 100 M cycle lifetime required for an entry-level product to compete with incumbent technologies. The MEMS switches manufactured by TeraVista and Radant MEMS use in-line chip scale hermetic packages that are sealed in a clean room. This approach helps eliminate contamination of the MEMS switch contact and is a key factor in achieving operating lifetimes in excess of 100 M cycles.

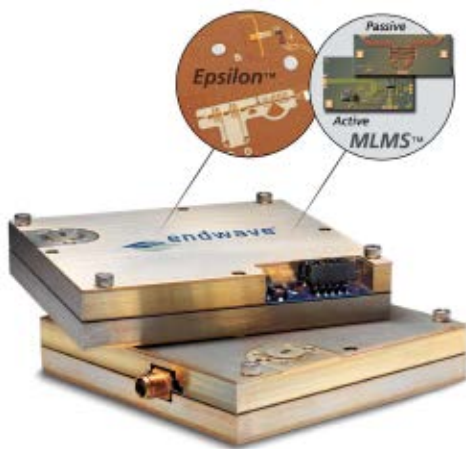
Looking back with perfect hindsight, it is now possible to see that two key achievements were required to develop a commercial MEMS switch. The first was the realization that high force actuation was essential. The second was that in-line chip scale hermetic packaging was equally important in delivering highly reliable MEMS switches. TeraVista and Radant MEMS have both solved the puzzle. ■



▲ Fig. A1 Diagram illustrating the cross-correlation between operation specifications, design parameters and failure mechanisms of RF MEMS switches.



# 100 GHz



#### Millimeter-wave Expertise

Active MLMS™ Flip-Chip Circuits

Passive MLMS™ Filters, Couplers

MMIC-based Assemblies

Discrete Hybrid Modules

Lightweight Epsilon™ Module Packaging

Automated Assembly/Test for Build-to-Print

## If you're ready to reach, we're ready to deliver.

When your applications have you reaching for higher frequencies, turn to Endwave. Our millimeter-wave products enable the "seeing and talking" behind broadband communications, high-resolution radars and advanced imaging systems.

You name it—E-Band T/R modules for gigabit radio links, a front-end to your Ka-Band seeker, or sensors for concealed weapons detection. If it's millimeter-waves, we have the team, experience and facilities you can lean on. With Endwave, nothing is out of reach.

Visit our Web site and learn more about our unique millimeter-wave experience on both commercial and defense related platforms.

**Endwave. Plug us in.**



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

Visit <http://mwj.hotims.com/11713-47> or use RS# 47 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)

The extensive wait of nearly 10 years for a viable MEMS switch product made customers wary of the difficulties involved in commercializing this technology. Although there were a number of good reasons for these failures (see *Inset*), the string of premature product announcements in 2000 and 2001 was the last straw. Customers became disillusioned by the hype surrounding MEMS switches and a cynical attitude toward the technology quietly settled

into the marketplace. Driven by this serious case of market overexposure and a realization that hard proof of reliable product performance was the only way to successfully win customers, MEMS switch development moved into "stealth" mode after 2001. While much of this activity remains out of the public eye to this day, MEMS switch development efforts continue at some of the most prestigious companies throughout the world.

A basic search of MEMS switch and related patents issued after 2000 illustrates the breadth and depth of MEMS development. As shown in **Figure 1**, nearly 200 US patents were issued for MEMS switch-related technology in the last seven years alone. In addition to the early pioneers in MEMS switching, patent assignees include major MEMS component manufacturers (Agilent, Analog Devices and Freescale) and other leaders in the semiconductor industry (Intel, IBM, Samsung and Toshiba).

Despite the massive deployment of resources and expertise by industry leaders, the first commercial MEMS switch was introduced by a relatively small company. Initial demonstration of what would become the first commercial MEMS switch was reported in the late 1990s by a team from Northeastern University working in collaboration with Analog Devices. This technology was ultimately licensed by Radant MEMS, a Stow, MA, company that is focused on the production of high reliability switches for government and military applications. Radant MEMS announced the first DC to 10 GHz single-pole single-throw (SPST) MEMS switch able to meet 100 M cycles (see **Figure 2**) in 2004. The company has since in-

## 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.

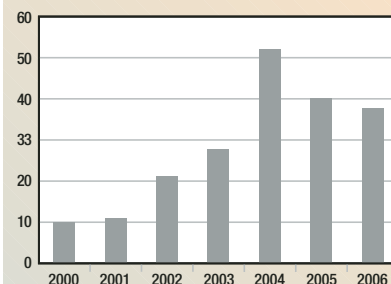
- \* Multi-function components
- \* RF front ends
- \* Switches & attenuators
- \* High level assemblies & modules
- \* Design capability up to 40 GHz
- \* Power handling to 1 MW+ peak
- \* Integral driver & associated electronics
- \* The industry's most extensive high power test facility

Communications & Power Industries  
Beverly Microwave Division

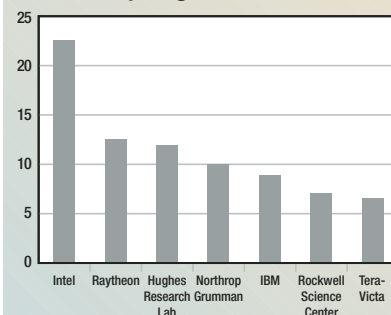
150 Sohler Road  
Beverly, MA 01915  
Phone: (978) 922-6000  
Fax: (978) 922-2736

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

**MEMS Switch Patents Issued (2000-2006)**



**MEMS Switch Patents (Top Assignees 2000-2006)**



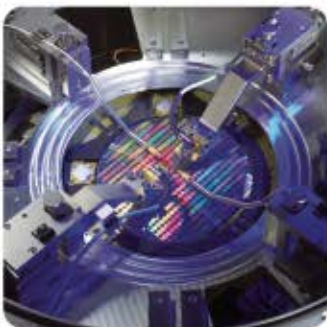
▲ Fig. 1 Results of a US patent search on MEMS switch technology.



# SUSS engineers go to the extreme for MEMS Testing



From temperatures of 4 K to over 200°C, pressures of 0.0000001 mbar to 50 bar and alien gas environments, wafer-level test of your MEMS devices at these extremes is possible at any place, but the surface of our planet. But before you start rocketing your devices into space, consider the fact that the leader in wafer-level MEMS test systems offers powerful solutions for testing in those extremes—right here on Earth.



- Test RF MEMS, accelerometers, microbolometers, gyrometers, pressure sensors, gas sensors, micromirrors, microphones, and much more
- Unique vacuum systems and patented cryo systems
- Pressure Probe Module adds differential pressure test capability to any SUSS probe system
- Full range of MEMS test accessories for a complete solution
- Ten years of experience testing MEMS using non-electrical methods

***At SUSS MicroTec, it's in our nature to take MEMS to a whole new level!***

## **SUSS. Our Solutions Set Standards**

For more information about MEMS Testing contact: [info@suss.com](mailto:info@suss.com)

**[www.suss.com/memstest](http://www.suss.com/memstest)**



Visit <http://mwj.hotims.com/11713-131> or use RS# 131 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)

roduced a single-pole double-throw (SPDT) switch that operates from DC to 20 GHz, and multi-contact series shunt switches that operate to 40 GHz.

The first commercially qualified MEMS switch was announced by TeraVista Technologies in 2005 and began shipping in early 2006. Based on the company's patented high force disk actuator (HFDA) technology (see **Figure 3**), the SPDT switch op-

erates from DC to 7 GHz. TeraVista led the industry by extending semiconductor qualification techniques to MEMS devices, and shipped the first-ever qualified commercial MEMS switch in early 2006. The company's RF MEMS switches have found their way into high volume commercial applications including automatic test equipment, instrumentation and wireless communications.

## PRESENT

While a number of companies have disclosed either development efforts or limited sampling of advanced prototypes, at present only Radant MEMS and TeraVista have MEMS switch products available in production quantities.<sup>5</sup> Radant MEMS markets its products almost exclusively to government and military customers in the United States, while TeraVista actively sells its products to commercial customers worldwide.

A discussion of the features of the TeraVista MEMS switch provides a useful illustration of current MEMS switch technology. This switch uses a "device on package" construction with the switch built directly on a ceramic (alumina) wafer with conductive metal vias (see **Figure 4**). Individual switch features are patterned using conventional high volume semiconductor fabrication techniques, including sputter deposition and etching processes, with bulk metal layers fabricated via electroplating.

## A world first: waterproof QMA connector

### Applications

- wireless communications
- portable radio systems
- cellular base stations

### Features

- IP 68 ingress protection rating
- intermateable with QMA according to QLF standard
- better environmental performance than standard QMA

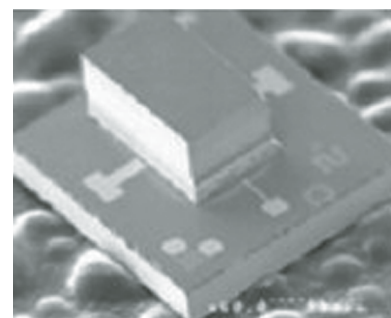


**HUBER+SUHNER**

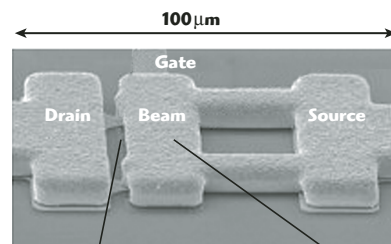
HUBER+SUHNER AG  
RF Communications  
CH-9100 Herisau, Switzerland  
Phone +41 (0)71 353 41 11  
Fax +41 (0)71 353 45 90  
www.hubersuhner.com



**Excellence in Connectivity Solutions**



(a)



(b)



(c)

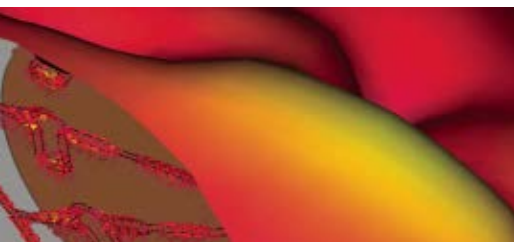
▲ Fig. 2 SEM photographs of the Radant MEMS switch package (a) the actuator (b) with detail of the contact area (c).





# So powerful. So experienced.

The evolution in 3D EM simulation software. CST MICROWAVE STUDIO® 2006.



► Do you have the flexibility to use the solver you need at the time you want, without having to change tool or even interface?

Discover the latest evolution in 3D EM simulation software and experience CST MICROWAVE STUDIO® [CST MWS]'s complete technology.

CST MWS is the first commercial HF3D EM code to offer the advantages of time and frequency domain, hexahedral and tetrahedral meshing, united in one interface.

Choose the technology best suited to your structure. Embedded in an advanced design environment, CST MWS can be coupled with all CST STUDIO SUITE™ solver technology including circuit and thermal simulation.

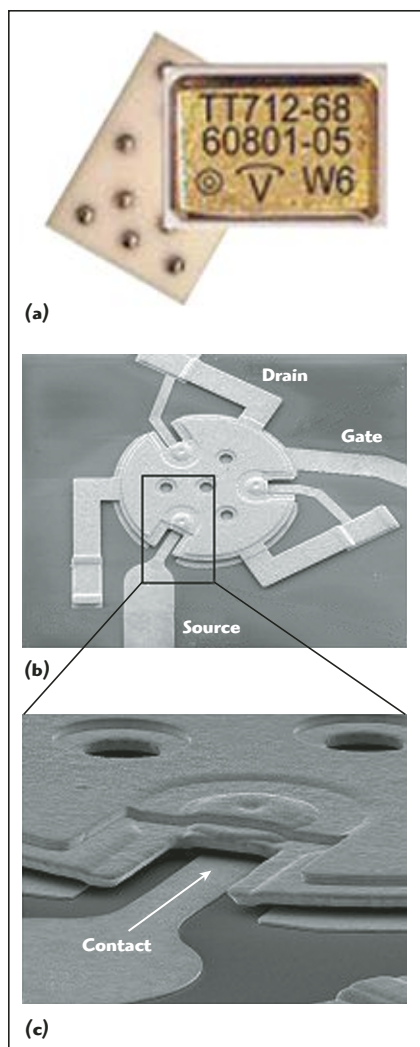
CST MICROWAVE STUDIO® is the powerful market leading time domain tool for 3D EM simulation. It has benefited from over 20 years experience in the area of numerical field calculation, and is used by industry market leaders worldwide.

► Change your outlook on simulation technology. Choose the outstanding advantages of complete technology with CST MICROWAVE STUDIO®.



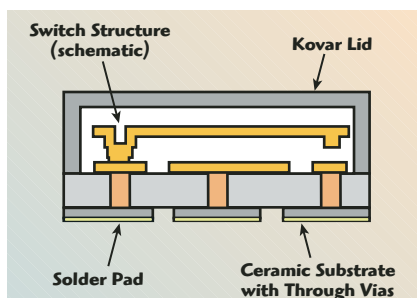
Visit <http://mwj.hotims.com/11713-35> or use RS# 35 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)

CHANGING THE STANDARDS

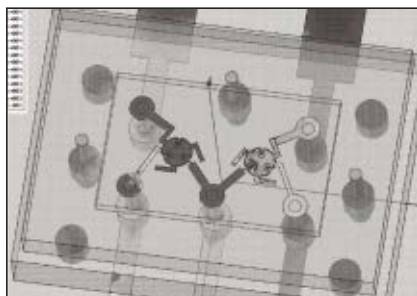


▲ Fig. 3 Photographs of the TeraVista TT712 MEMS package (a) and SEM photograph of the HFDA (b) with details of the switch contact area (c).

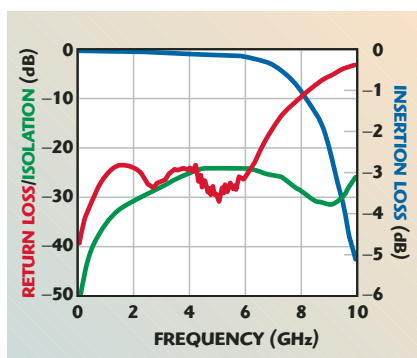
Device failures are minimized through the use of a proprietary high force disk actuator (HFDA), which provides substantial restoring force when the switch is in the closed position. This results in a very reliable operation, albeit at a relatively high switch voltage (68 V). Low voltage operation (3 to 5 V) is made possible through the use of a separate charge pump integrated circuit (IC). The package is completed by the attachment of a metal (Kovar) lid which provides a hermetic seal that eliminates the possibility of downstream contamination from backend manufacturing processes, and drastically reduces device failures due to contact contamination. The end result is a small ( $3.25 \times 4.5$  mm) surface-mountable micro-BGA ceramic package that provides a high efficiency, manu-



▲ Fig. 4 Cross-section representation of the basic TeraVista MEMS switch and chip-scale package.



▲ Fig. 5 Electromagnetic/solid model of an SPDT MEMS switch.



▲ Fig. 6 RF performance characteristics of the TeraVista DC to 7 GHz SPDT MEMS switch.

facturable electrical connection to the printed circuit board.

Switches with multiple contact configurations (SPDT, DPDT, etc.) can be constructed by connecting multiple HFDAs in a single package. This is illustrated by an RF electromagnetic/solid model of the basic DC to 7 GHz SPDT switch shown in **Figure 5**. The RF signal is conducted into the switch through a central terminal (RF common), which connects to two HFDAs on the device. Closing either HFDA results in an electrical connection to its respective output pin. Note that since the HFDAs can be independently actuated, it is possible to open (or close) both switch contacts at the same time or to arbitrarily control the opening and clos-

ing sequence of the switch contacts. Typical HFDA switches currently have a 70  $\mu$ s switching speed.

The HFDA technology used by TeraVista also provides resistance repeatability that is typically much better than 10 m $\Omega$ , which enables insertion loss reproducibility of better than 0.4 dB across the entire 7 GHz band. These switches are also rated for continuous operation at up to 15 W, with a peak power handling capability of at least 30 W.

By comparison, Radant MEMS uses a conventional silicon micromachining approach to produce a very high force cantilever switch structure, along with a wafer bonded hermetic package to insure hermeticity. Although the stiffness of this cantilever structure results in even higher operating voltages (90 V), switching times are reduced to 10  $\mu$ s. Electrical connection is provided by wire bonding from the top surface of the chip to either a chip carrier or directly to the printed circuit board.

The characteristic RF performance of the TeraVista DC to 7 GHz SPDT switch is shown in **Figure 6**. This MEMS switch delivers superior performance with insertion loss less than 0.1 dB at frequencies less than 1 GHz (0.4 dB at 7 GHz), with more than 20 dB of return loss and at least 25 dB of isolation. The simple construction of these switches also provides very low distortion for high power signals. Measured values of IP3 are typically in excess of 70 dBm, greater than the sensitivity of most measurement systems.

Although a number of MEMS switch developers have disclosed anecdotal results that show lifetimes of several billion cycles for individual switch samples, the perception of poor reliability still lingers in the marketplace. In response to this, TeraVista has published lifetime data based on statistically significant samples of production devices.<sup>6</sup> This data, reproduced in **Figure 7**, shows a Weibull plot of the failure distribution of current production devices. Included in the plot for comparison are representative failure distributions for competing electro-mechanical relays and reed relays. Additional data (green triangles) is included for devices that do not fail before 100 M cycles.

Device reliability in semiconductors and other electrical products is



# FREQUENCY SYNTHESIZER ULTRA HIGH SPEED DIRECT ANALOG 0.5 - 18.0 GHz



GSA Contract #GS24F0072M

Model: MW-15131HS-0.5-18-1Hz

## FEATURES

- Settling Time < 200 nsec.
- Low Spurious < -70 dBc
- Harmonics -50 dBc max.
- Resolution 1 Hz (0.1 Hz option)
- Ultra Wideband Frequency Coverage
- Phase-noise -105 dBc/Hz @ 1 KHz
- Noise Floor -140 dBc
- Phase and Frequency Coherent
- FM Modulations Built-in
- Front Panel Control
- Compact Size: (DxWxH) 19"x19"x3U

Elisra Microwave Division has over 35 years of proven experience in supplying best of class components and Multi-function integrated assemblies for a wide variety of RF and Microwave Applications up to 50 GHz.

- Multi-function Integrated Assemblies up to 50 GHz
- Solid State Amplifiers LNA & HP up to 18 GHz
- PIN Diode Control Devices
- IF and Video Signal Processing
- Frequency Sources 0.5-18 GHz
- Electronic Jammers against Bombs

**elisra** electronic  
systems ltd.  
Microwave Division

Visit <http://mwj.hotims.com/11713-42> or use RS# 42 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)

**Microwave Division:** 48 Mivtza Kadesh St. Bene Beraq, 51203 ISRAEL, Tel. 972(3)6175655, Fax. 972(3)6175299, Email: [trm1@elisra.com](mailto:trm1@elisra.com), [www.mw-elisra.com](http://www.mw-elisra.com)  
**Sales Office in USA:** Vanguard Engineering, Inc. 12905, Aiderlef Dr. Germanitown, MD 20874, Tel. (301)353-9113, Fax. (301)972-5669, Email: [vge1@erols.com](mailto:vge1@erols.com)

typically described in terms of mean time before failure or MTBF. The useful life of an RF MEMS switch is usually limited by the number of switch cycles, not by elapsed time, however, and their reliability is better described in terms of cycles before failure. Current MEMS switch products, manufactured by TeraVista, have a typical switch life or mean cycles before failure (MCBF) of approximately 200 million cycles, 20

times higher than the best electro-mechanical relays.

Like other small electromechanical switches, MEMS switch lifetimes are significantly de-rated in hot switching applications (opening or closing the switch with voltage present) at power levels above 0 dBm. Hot switching at 1 V/1 mA, for example, currently degrades the expected operating life by approximately a factor of 10.

MEMS switch prices are currently competitive with alternative switch technologies, and average sale prices will continue to decrease as volume manufacturing increases, making MEMS switches a viable option for some of the most price-sensitive consumer applications. Today, most commercial applications take advantage of one or more of the unique features of these devices: small size, low (repeatable) loss, high linearity and broad bandwidth. Leading applications include high speed digital channel switching in automated test equipment, antenna switching in wireless communications and filter bank switching in instrumentation, military and aerospace applications.

Finally, it should be noted that a number of MEMS switch development activities are still underway at leading companies and research institutions worldwide. Switch prototypes have recently been announced by Omron, Panasonic, WiSpry and XCom Wireless. Sampling to select customers is reportedly underway. As of this writing, only Radant MEMS and TeraVista have demonstrated the ability to deliver MEMS switches in production volume.<sup>5</sup>

## FUTURE

Three key trends will drive new applications for MEMS switches over the next three to five years: proliferation of a wide variety of new product configurations, substantial improvements in reliability, and significant reductions in switch size and cost.

The biggest change within the next year will be the emergence of a wide variety of new switch products. As an

## NETWORKS INTERNATIONAL CORPORATION

## CERAMIC FILTERS

**NIC's ceramic filters provide a cost-effective solution where High "Q" requirements are needed.**

## Features

- Bandpass & Bandreject
- Low Profile, Compact Design
- Packaging: Surface Mount (Hermetic + Non Hermetic), Connectorized, PIN
- Low to High Volume Production
- Custom Designs Available (3mm to 12mm resonators)

Frequency (MHz): 400 - 6000

3 dB%: 0.5% - 25%

# of Sections: 2-10

Impedance (Ohms): 50 or 75

Typical VSWR: 1.5: 1

Max Power (Watts): 10

Operating Temperature: -50° C ~ +100° C

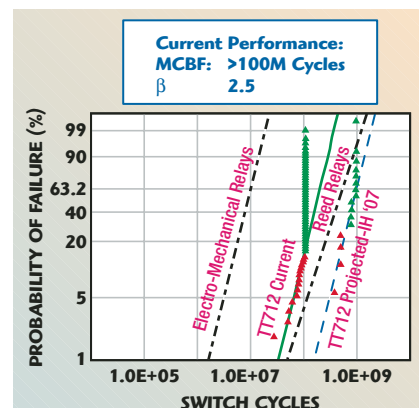


**NIC**

**913.685.3400**

**www.nickc.com**

**e-mail: sales@nickc.com**

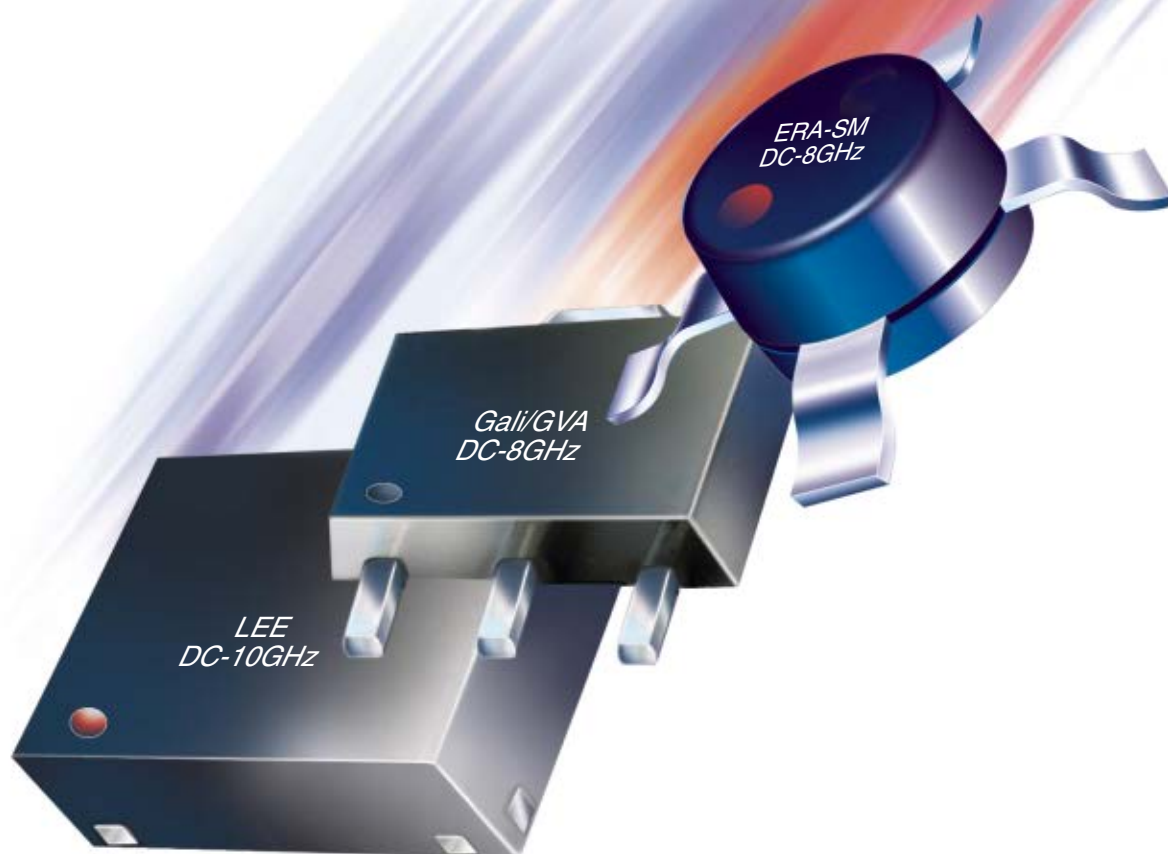


▲ Fig. 7 Weibull plot of life test data for the TT712 SPDT switches operated to 100M cycles over the 0° to 70°C operating range of the device.




# MMIC AMPLIFIERS

DC-10GHz as low as **99¢** ea. (qty. 30)



## Gain up to 26dB, Output power up to 21dBm, High IP3 up to 38dBm

MMIC amplifiers with just the right performance and size to fit your design, Mini-Circuits skinny Sigma LEE, Gali, ERA-SM and our new fixed voltage GVA. All MMIC's are transient protected against DC current surges and are available in a variety of over 50 models. These affordable compact amplifiers have low thermal resistance for high reliability. Available in three packages;

 Available as RoHS compliant.

**Leadless 3x3mm** Low Profile package

**SOT-89** for superior grounding and heat dissipation

**Plastic Micro-X** with surface mount leads, for easy configuration and assembly.

Complete performance specs, data and a wide selection of Amplifier Designer's Kits geared for your development needs are available on our web site.

All models protected under U.S. patent # 6,943,629.

 **Mini-Circuits®**  
ISO 9001 ISO 14001 CERTIFIED

**ALL NEW**  
**minicircuits.com**

P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661 For detailed performance specs & shopping online see Mini-Circuits web site



The Design Engineers Search Engine Provides ACTUAL Data Instantly From MINI-CIRCUITS At: [www.minicircuits.com](http://www.minicircuits.com)

**RF/IF MICROWAVE COMPONENTS**

376 Rev F

Visit <http://mwj.hotims.com/11713-80> or use RS# 80 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)

example, during 2007 TeraVista will deploy its proven HFDA technology in a variety of new high performance high reliability MEMS switches. This includes the introduction of a new high frequency switch line with products operating across the DC to 36 GHz band, and a range of new multi-pole multi-throw switch configurations within the existing 7 GHz product family.

In coming years, new MEMS switch companies and/or new prod-

uct features should also begin to emerge. Anticipated new product features include high isolation ( $> 45$  dB) switches, isolated gate (four-terminal) operation for relay replacement applications, as well as significant improvements in hot switching performance. Although current charge pump ICs can be used to drive independent banks of MEMS switches, in the future direct integration of high voltage drivers with

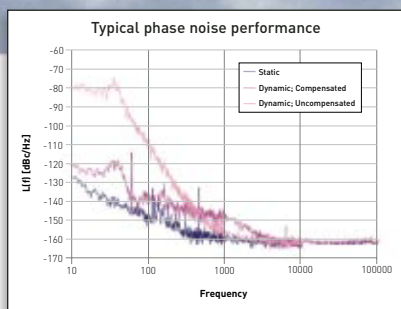
MEMS switches will enable the introduction of high reliability low voltage switches that eliminate the need for high voltage on the printed circuit board, a key feature for high volume consumer applications.

Substantial improvements in switch reliability will also occur over the next few years. The vast majority of field failures for MEMS switches today are caused by increases in contact resistance due to contamination of the switch contacts. Improvements in process cleanliness and package integrity, along with the elimination of contamination from other materials, will dramatically improve product lifetimes. Although a quantitative forecast of lifetime improvement is difficult, comparison with other emerging technologies can provide a qualitative guide. Similar requirements for process and materials improvement were faced by early developers of semiconductor diode lasers, for example. These researchers were able to consistently improve diode laser lifetime by a factor of 10 every 18 months (see **Figure 8**). A similar trend is likely for MEMS switches, with lifetimes of at least 10 B cycles and initial defect levels approaching 100 parts per million achieved over the next three to five years.

The most commercially significant trend over the next three to five years, however, will be reductions in switch size and cost. The substitution of lower cost materials, reductions in product size (proportional to cost) and higher fabrication utilization from increasing product sales will reduce product costs by a factor of 10 or more. Significant product size reductions will also occur, with packaged SPDT switches in form factors below  $1.5 \text{ mm}^2$  (a 90 percent size reduction).

## Low Phase Noise Under Vibration. Guaranteed.

**SYMMETRICOM'S SUITE  
OF LOW-G SENSITIVITY  
OCXOs OFFERS THE BEST  
PERFORMANCE FOR  
YOUR TACTICAL MILITARY  
ENVIRONMENT.**



**Y**ou're implementing more advanced communications, navigation and targeting systems. Precision oscillators that can withstand a wide range of operating environments is becoming more critical.

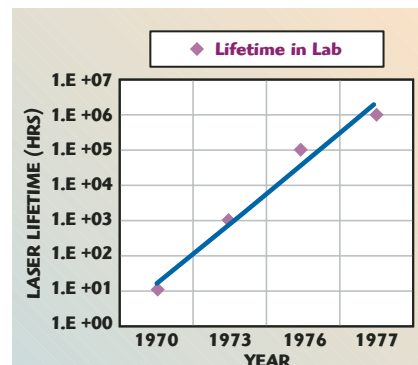
Discover how Symmetricom's family of low-g products, including the 9633, 9250 and 9210B meets the most demanding challenges for time and frequency, even under the most adverse environmental conditions.



Contact us at <http://www.symmsda.com/lp/mj>  
or call 978-232-1497 to learn more.

*Perfect Timing. It's Our Business.*

**Symmetricom**



▲ Fig. 8 Laboratory lifetime of early semiconductor lasers.



# "LEADERSHIP"

## *in* **HIGH POWER** *Design!!*



Celebrating our 37th Year Anniversary...UTE Microwave...

a pioneer in isolator and circulator design, continues to offer our customers "Ferrite Solutions" for Military and Commercial markets.

UTE Microwave has the experience to meet your low and HIGH POWER requirements (many off-the-shelf).

In Communications, Radar, TV, PCS, Satcom, Medical and Scientific Markets, UTE Microwave offers a broad line of products for your specific applications.

Contact us for your low loss, wide band requirements at:



"The Ferrite Solutions Company"

3500 Sunset Ave., Asbury Park, NJ 07712  
Tel: 732-922-1009 Fax: 732-922-1848  
E-mail: [info@utemicrowave.com](mailto:info@utemicrowave.com)

### **Our ferrite 'POWER-LINE'**

**includes:** Broadband Units • Common Band Devices • High Isolation Units • Multiport Devices • Drop-In Devices • Wireless/PCN Devices • High-Power Industrial/Medical Iso Adaptors • Waveguide Junctions High-Power TV Units • VHF and UHF Devices

### **Features:**

- 100 MHz to 20 GHz
- Power levels to 5 KW CW, 75 KW Pk.
- Low Intermod Units
- Low Loss Options
- Extended Octave Bandwidths
- Power Monitors and DC Blocks
- Iso Filter-Monitor Assemblies

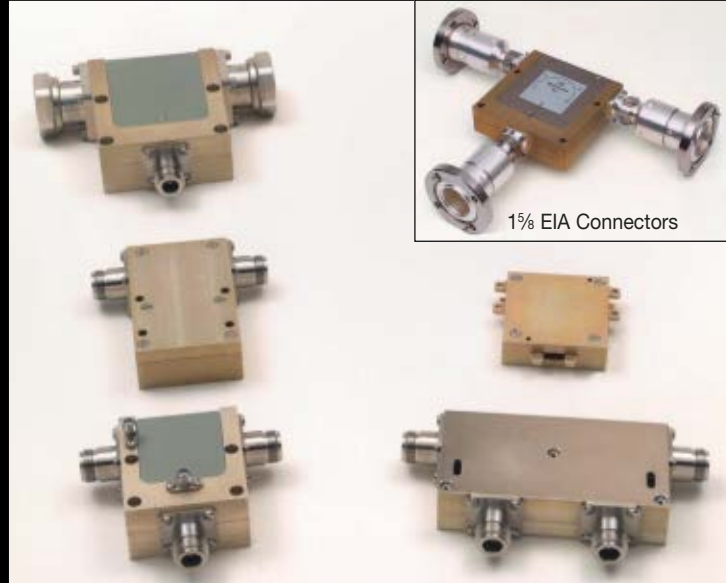
### **HIGH POWER CIRCULATORS Frequency Ranges from 100 MHz**

A broad line of low loss, High Power coaxial and stripline mounting circulators are available. Typical coax units handle 3 KW, CW, 10 KW peak at 120 MHz and 500 Watts CW, 2 KW peak in the 400-800 MHz TV bands, while 250 Watt stripline drop-in units are also available. In the .800-3.5 GHz spectrum, 0.15 dB loss stripline drop-in units operate at 200 Watts CW, 2 KW peak power levels.

Contact us for more information on our extensive product line and current catalog. We accept Visa, MC, Amex



Visit <http://mwj.hotims.com/11713-151> or use RS# 151 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)



**WWW.UTEMICROWAVE.COM**

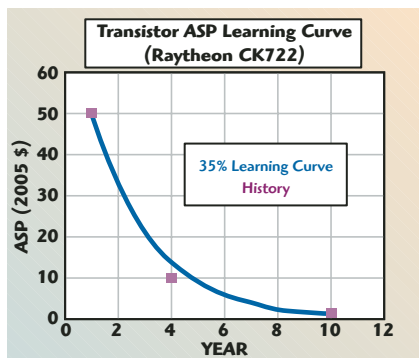


Fig. 9 Selling price "learning curve" for early transistors in constant 2005 dollars.

Although quantitative price forecasts are equally difficult, a review of historical price data from comparable technologies shows that most electronic devices experience a very uniform "learning curve," with a 35 percent reduction per year in the average selling price (ASP) of a given function (transistor, gate, or instructions executed per second). The learning curve for the

first high volume transistors, for example, is shown in **Figure 9** (with prices adjusted to constant 2005 dollars). Although prices declined uniformly at the same rate of 35 percent per year, this analysis shows that the first transistors actually entered the market with a comparative unit price of \$50. While there are reasons to suspect that limitations in size reduction will ultimately limit MEMS switch costs, price reductions of at least 35 percent per year are likely for the foreseeable future. Already, MEMS switches are price competitive with existing switching solutions.

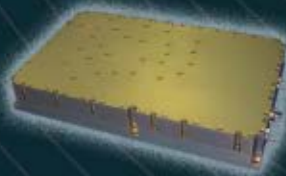
This fresh look at MEMS switch technology shows that despite lingering concerns about the reliability of this technology, a handful of MEMS switch manufacturers are finally delivering the first of a new family of high performance, high reliability switch products. These products are already finding high volume applications in automatic test equipment, instrumentation and communications. The list of applications is expected to explode as customers take advantage of all the benefits that MEMS switches have to offer. ■

## References

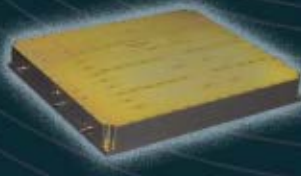
1. K.E. Petersen, "Micromechanical Membrane Switches on Silicon," *IBM Journal of Research and Development*, Vol. 23, 1979, pp. 376-85.
2. N. Maluf, *An Introduction to Microelectromechanical Systems Engineering*, Second Edition, Artech House, Norwood, MA, 2004.
3. G.M. Rebeiz, *RF MEMS: Theory, Design and Technology*, John Wiley & Sons Inc., Hoboken, NJ, 2003.
4. P. Chalmers, "Relay Races," *Mechanical Engineering-CIME*, 1/1/2001.
5. M. Potin, *MEMS4Mobile 2006*, Yole Développement, 2006.
6. J. McKillop, T. Fowler, D. Goins and R. Nelson, "Design, Performance and Qualification of a Commercially Available MEMS Switch," *Proceedings of the 2006 European Microwave Conference*.

**John McKillop** received his BA degree in chemistry from Rice University and his PhD degree in chemistry from Stanford University. He held senior engineering and business development positions in a number of public companies and was a member of the research staff at IBM's T.J. Watson Research Center. He has more than 20 years experience managing engineering, operations, business and technology development for companies focused on emerging technologies, particularly in the fields of MEMS, lasers and electro-optics. He has authored numerous publications, been invited to present on the applications for MEMS technology and taught multiple MEMS short courses. He is now vice president of product development and CTO at TeraVista Technologies Inc.

## EXCEPTIONAL BROADBAND POWER AMPLIFIERS FROM AETHERCOMM



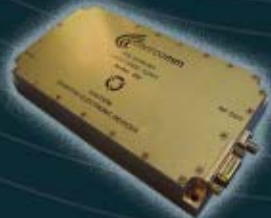
**SSPA 0.25-3.00-10**  
250 MHz - 3000 MHz  
10-20 Watt RF Amplifier



**SSPA 0.020-2.500-20**  
20 MHz - 2500 MHz  
20-40 Watt RF Amplifier



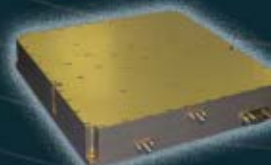
**SSPA 0.5-2.5-30**  
500 MHz - 2500 MHz  
30-40 Watt RF Amplifier



**SSPA 0.020-1.000-25**  
20 MHz - 1000 MHz  
25 Watt RF Amplifier



**SSPA 1.0-2.5-50**  
800 MHz - 2500 MHz  
50-80 Watt RF Amplifier



**SSPA 0.1-1.0-100**  
100 MHz - 1000 MHz  
100 Watt RF Amplifier

**We're Amped!** Aethercomm designs and manufactures quality broadband, high power RF amplifiers from 20 MHz to 40+ GHz. Aethercomm products are combat proven and are engineered to operate in the most stringent environments. We produce exceptional broadband amplifiers employing GaN, SiC, LDMOS and GaAs technologies for high volume, rapid delivery programs.

Visit our new interactive website at [www.aethercomm.com](http://www.aethercomm.com) !

Tel 760.598.4340

Fax 760.598.4342

[sales@aethercomm.com](mailto:sales@aethercomm.com)

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





# The #1 Synthesizer now comes with a full Two Year warranty!

Aeroflex is the #1 fast-switching synthesizer provider on the market today! We build the best synthesizers and even our most basic models are 30 times faster and 10 times cleaner than the closest competitor. Our synthesizers offer high speed, low noise and wide bandwidth all in one package.

We've built our synthesizer business reputation one installation at a time. Our installed base is the biggest in the world with more than 5,000 Aeroflex synthesizers installed to date.

## 2200 OEM Modular Frequency Synthesizer

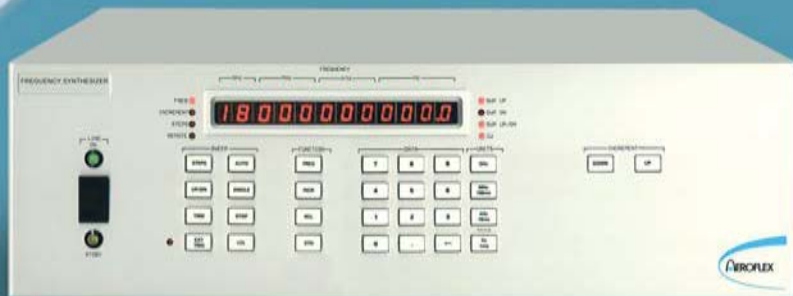
- Spans frequency range from 10 MHz to 18.4 GHz
- Standard resolution of 1.0 Hz
- Can switch from any frequency (F1), to any other frequency (F2), up or down, in 1  $\mu$ Sec

## 2500 Frequency Synthesizer

- Spans frequency range from 0.3 to 26.5 GHz
- Standard resolution of 1.0 MHz (0.5 MHz with range 0.3 to 13.5 GHz)
- Can switch frequency in <200 ns

Find out more about our world-class Synthesizers and receive the latest data sheets by visiting:

[www.aeroflex.com/twoyear](http://www.aeroflex.com/twoyear)



**AEROFLEX**  
A passion for performance.

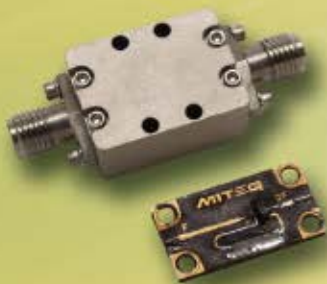
# Delivery From Stock!

## MIXERS



Model Number	RF/LO Frequency (GHz)	IF Frequency (GHz)	LO Power (dBm)	Conversion Loss (dB) Typ./Max.	LO-to-RF Isolation (dB) (Min.)
<b>DOUBLE-BALANCED VERSIONS</b>					
DM0052LA2	0.5 – 2	DC – 0.5	7 – 13	6.5/8.5	30
DM0104LA1	1 – 4	DC – 1	7 – 13	5.5/7.0	30
DM0208LW2	2 – 8	DC – 2	7 – 13	7.0/8.0	30
DM0416LW2	4 – 16	DC – 4	7 – 13	7.0/8.0	30
DB0218LW2	2 – 18	DC – 0.75	7 – 13	6.5/8.5	22
DB1826LW1	18 – 26	DC – 2	7 – 13	7.5/9.5	20
DB0226LA1	2 – 26	DC – 0.5	7 – 13	9.0/10	20
DB0440LW1	4 – 40	DC – 2	10 – 15	9.0/10	20
M1826W1	18 – 26	DC – 8	10 – 15	9.0/12	25
M2640W1	26 – 40	DC – 12	10 – 15	10/12	28
<b>TRIPLE-BALANCED VERSIONS</b>					
TB0218LW2	2 – 18	0.5 – 8	10 – 15	7.5/9.5	20
TB0426LW1	4 – 26	0.5 – 8	10 – 15	10/12	20
TB0440LW1	4 – 40	0.5 – 20	10 – 15	10/12	18

## PASSIVE DOUBLERS



Model Number	Input Frequency (GHz)	Input Power (dBm)	Output Frequency (GHz)	Conversion Loss (dB) Typ./Max.	Rejection (dBc, Typ.) Fund. Odd Harm.	
DROP-IN VERSIONS						
SXS01M	0.5 – 3	8 – 12	1 – 6	13/16	-20	-25
SXS04M	2 – 9	8 – 12	4 – 18	13/15	-20	-25
SXS07M	3 – 13	8 – 12	6 – 26	13/17	-18	-25
CONNECTORIZED VERSIONS						
SXS2M010060	0.5 – 3	8 – 12	1 – 6	13/16	-20	-25
SXS2M040180	2 – 9	8 – 12	4 – 18	13/15	-20	-25
SXS2M060260	3 – 13	8 – 12	6 – 26	13/17	-18	-25

Additional models available with 60 day lead time, please contact MITEQ.  
Above models also available with optional LO power ranges, please contact MITEQ.





# 30 Day Delivery!

## IMAGE REJECTION MIXERS



Model Number	RF/LO Frequency (GHz)	Conversion Loss (dB) Max.	Image Rejection (dB) Min.	LO-to-RF Isolation (dB) Min.
IMAGE REJECTION MIXERS				
IRM0204(*)C2(**)	2 – 4	7.5	18	20
IRM0408(*)C2(**)	4 – 8	8	18	20
IRM0812(*)C2(**)	8 – 12	8	18	20
IRM1218(*)C2(**)	12 – 18	10	18	20
IRM0208(*)C2(**)	2 – 8	9	18	18
IRM0618(*)C2(**)	6 – 18	10	18	18
IR1826NI7(**)	18 – 26	10.5	15	20
IR2640NI7(**)	26 – 40	10.5	15	15

Model Number	RF/LO Frequency (GHz)	Conversion Loss (dB) Max.	Balance Phase (±Deg.) Typ./Max.	Balance Amplitude (±dB) Typ./Max.	LO-to-RF Isolation (dB) Min.
I/Q DEMODULATORS					
IRM0204(*)C2Q	2 – 4	10.5	7.5/10	1.0/1.5	20
IRM0408(*)C2Q	4 – 8	11	7.5/10	1.0/1.5	20
IRM0812(*)C2Q	8 – 12	11	5/7.5	.75/1.0	20
IRM1218(*)C2Q	12 – 18	13	10/15	1.0/1.5	20
IRM0208(*)C2Q	2 – 8	12	7.5/10	1.0/1.5	18
IRM0618(*)C2Q	6 – 18	13	10/15	1.0/1.5	18
IR1826NI7Q	18 – 26	13.5	10/15	1.0/1.5	20
IR2640NI7Q	26 – 40	13.5	10/15	1.0/1.5	15

## SSB UPCONVERTERS OR I/Q MODULATORS



Model Number	RF Frequency (GHz)	Conversion Loss (dB) Max.	Carrier Suppression (dBc) Min.	Carrier Suppression Carrier - Fundamental IF (dBc) Min.
<b>IF DRIVEN MODULATORS</b>				
SSM0204(*)C2MD(**)	2 – 4	9	20	20
SSM0408(*)C2MD(**)	4 – 8	9	20	18
SSM0812(*)C2MD(**)	8 – 12	9	20	20
SSM1218(*)C2MD(**)	12 – 18	10	20	18
SSM0208(*)C2MD(**)	2 – 8	9	20	20
SSM0618(*)C2MD(**)	6 – 18	10	20	18

For full data sheets on the products shown, please visit [www.miteq.com/adinfo](http://www.miteq.com/adinfo)

For Carrier Driven Modulators, please contact MITEQ.

<b>MODEL NUMBER OPTION TABLE</b>				
(*) Add Letter	LO/IF Power Range	P1 dB C.P. (dBm) (Typ.)	(**) Add Letter	IF FREQUENCY OPTION (MHz)
L	10 – 13 dBm	+6	A	20 – 40
M	13 – 16 dBm	+10	B	40 – 80
H	17 – 20 dBm	+15	C	100 – 200
			Q	DC – 500 (I/Q)

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



100 Davids Drive, Hauppauge, NY 11788  
(631) 436-7400 FAX: (631) 436-7430

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



# RF Amplifiers and Sub-Assemblies for Every Application

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

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

ISO 9001:2000  
and AS9100B  
CERTIFIED



## OCTAVE BAND LOW NOISE AMPLIFIERS

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

## NARROW BAND LOW NOISE AND MEDIUM POWER AMPLIFIERS

CA01-2111	0.4 - 0.5	28	0.6 MAX, 0.4 TYP	+10 MIN	+20 dBm	2.0:1
CA01-2113	0.8 - 1.0	28	0.6 MAX, 0.4 TYP	+10 MIN	+20 dBm	2.0:1
CA12-3117	1.2 - 1.6	25	0.6 MAX, 0.4 TYP	+10 MIN	+20 dBm	2.0:1
CA23-3111	2.2 - 2.4	30	0.6 MAX, 0.45 TYP	+10 MIN	+20 dBm	2.0:1
CA23-3116	2.7 - 2.9	29	0.7 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA34-2110	3.7 - 4.2	28	1.0 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA56-3110	5.4 - 5.9	40	1.0 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA78-4110	7.25 - 7.75	32	1.2 MAX, 1.0 TYP	+10 MIN	+20 dBm	2.0:1
CA910-3110	9.0 - 10.6	25	1.4 MAX, 1.2 TYP	+10 MIN	+20 dBm	2.0:1
CA1315-3110	13.75 - 15.4	25	1.6 MAX, 1.4 TYP	+10 MIN	+20 dBm	2.0:1
CA12-3114	1.35 - 1.85	30	4.0 MAX, 3.0 TYP	+33 MIN	+41 dBm	2.0:1
CA34-6116	3.1 - 3.5	40	4.5 MAX, 3.5 TYP	+35 MIN	+43 dBm	2.0:1
CA56-5114	5.9 - 6.4	30	5.0 MAX, 4.0 TYP	+30 MIN	+40 dBm	2.0:1
CA812-6115	8.0 - 12.0	30	4.5 MAX, 3.5 TYP	+30 MIN	+40 dBm	2.0:1
CA812-6116	8.0 - 12.0	30	5.0 MAX, 4.0 TYP	+33 MIN	+41 dBm	2.0:1
CA1213-7110	12.2 - 13.25	28	6.0 MAX, 5.5 TYP	+33 MIN	+42 dBm	2.0:1
CA1415-7110	14.0 - 15.0	30	5.0 MAX, 4.0 TYP	+30 MIN	+40 dBm	2.0:1
CA1722-4110	17.0 - 22.0	25	3.5 MAX, 2.8 TYP	+21 MIN	+31 dBm	2.0:1

## ULTRA-BROADBAND & MULTI-OCTAVE BAND AMPLIFIERS

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

## LIMITING AMPLIFIERS

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

## AMPLIFIERS WITH INTEGRATED GAIN ATTENUATION

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

## LOW FREQUENCY AMPLIFIERS

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

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

Visit our web site at [www.ciaowireless.com](http://www.ciaowireless.com) for our complete product offering.

Visit <http://mwj.hotims.com/11713-29> or  
use RS# 29 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)

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

Tel (805) 389-3224 Fax (805) 389-3629 [sales@ciaowireless.com](mailto:sales@ciaowireless.com)







## **NetFires Successfully Completes Joint Critical Design Review**

Launch Unit. The Non Line-of-Sight-Launch System, which is one of the 18 Future Combat System's core systems, will operate as part of the Future Combat System Systems of Systems to meet the requirements of the Army's Future Brigade Combat Teams. It will provide increased capability for the Current Force's Modular Brigade Combat Teams.

Compared to systems with equivalent firepower (kill per combat load), the Non Line-of-Sight-Launch System provides a tailorable, modular, highly deployable and flexible precision fires capability to the US Army, US Navy and joint maneuver forces for a very low life-cycle system cost.

"This successful CDR was made possible by our dedicated government and industry personnel and I am pleased with the independent review team's assessment and approval of our success," said col. Doug Dever, Non Line-of-Sight-Launch System project manager. "There are not enough words to express my sincere thanks to the hundreds of people throughout the United States who made this major milestone a success. The team has demonstrated a design that meets all design and performance requirements for the Non Line-of-Sight-Launch System."

The successful completion of the Non Line-of-Sight-Launch System Critical Design Review represents a significant milestone in meeting the design and performance parameters of the Non Line-of-Sight-Launch System supporting Future Combat System Spin Out 1 and weaponization of the Navy Littoral Combat Ships.

"Joint procurement of this system by the Army and Navy will result in significant economy, better interoperability and the potential for mutual support between land and sea forces in the littorals. It is a win for both services," said Capt. Mikem Good, Navy program manager for Littoral Combat Ship Mission Modules, Program Executive Office Littoral and Mine Warfare. "The Non Line-of-Sight-Launch System is one of the key Littoral Combat Ship mission modules in a spiral development process to meet future requirements and improve our warfighting capability."

The Non Line-of-Sight-Launch System consists of Raytheon's Precision Attack Missile and a joint Lockheed Martin and Raytheon Container Launch Unit. In 2004, the Army decided to accelerate the Raytheon's Precision Attack Missile and the joint Lockheed Martin and Raytheon Container Launch Unit for incorporation into the Army's Evaluation Brigade combat Team, Spin Out 1.

**N**etFires LLC, a company composed of Raytheon Co. Missile Systems business and Lockheed Martin Missiles and Fire Control, successfully passed a joint critical design review (CDR) for the Non Line-of-Sight-Launch System Precision Attack Missile and Container

## **US Air Force Awards Northrop Grumman Contracts for Joint STARS Fleet Support**

sustainment and Joint STARS Extended Test Support (JETS) programs.

The \$140 M TSSR award is for a seventh year, through 2007, following an initial six-year \$810 M contract awarded in 2000, bringing the total cumulative value of the TSSR contract to \$950 M. The initial contract included options that could extend Northrop Grumman's participation on this program for more than two decades. Through this TRSS contract, the Air Force has reduced the cost of supporting the E-8C fleet by having the prime contractor, Northrop Grumman, partner with the Warner Robins Air Logistics Center. This cooperative business initiative has been a model for complete life cycle support.

The Air Logistics Center and Northrop Grumman use each other's best practices to provide economical Joint STARS support that fully meets the needs of the operational aircraft fleet. Northrop Grumman provides integrated management of all facets of depot maintenance, including some technology refreshment. The Air Force Logistics Center provided a dedicated management team in concert with software maintenance support, critical parts manufacture and repair of specific mission system items. Under this contract, most of the normal aircraft heavy depot maintenance repair and overhaul, including system upgrade modifications, will continue at the Lake Charles, LA Modification Center operated by Northrop Grumman. The contract also includes subcontract competition and small business participation.

The JETS II contract, worth \$114 M over four years, provides test support capability for the Joint STARS Improvement Program. JETS II is a continuation of the current \$64.8 M JETS program with similar objectives and provisions. The contract provides the critical skill infrastructure and the test assets necessary for the continued evolution and development of the Joint STARS system. The key mission objectives under the JETS II contract include: conducting government testing; providing training and proficiency flights for mission crew and primary aircrew; office facilities for the government Joint Test Force, engineering services; participation in system demonstrations and exercises; and installation, evaluation, demonstration and testing of potential system modifications and improvements. Both contracts are managed by the Air Force Material Command. The TSSR contract is managed through the Warner Robins Air Logistics Center at Robins Air Force Base, GA, and the JETS II contract is managed through the Electronic Systems Center at Hanscom Air Force Base, MA.

**T**he US Air Force has awarded Northrop Grumman Co. two contracts worth a total of \$254 M for the E-8C Joint Surveillance Target Attack Radar System (Joint STARS). The contracts cover work on the Joint STARS Total System Support Responsibility (TSSR)



## Harris Receives SCA-Certification for Falcon III AN/PRC-152(C)

**H**arris Corp., an international communications and information technology company, has announced that the Software Communications Architecture (SCA) of its Falcon® III AN/PRC-152(C) has been reviewed and tested by the Joint Program Executive Office

of the Joint Tactical Radio System Test and Evaluation Laboratory (JPEO JTEL) and certified with waivers by Dennis Bauman, the Joint Program Executive Officer of the Joint Technical Radio System (JPEO JTRS). All JTRS radios must use the SCA software operating environment as the basis to run the radio's waveforms. With over 3000 AN/PRC-152(C) multiband handheld radios in service today and over 17,000 expected to be in service by summer 2007, the AN/PRC-152(C) is the first widely fielded tactical radio to receive SCA certification. "We are very happy to see Falcon III radio now SCA- and NSA-certified," said Bauman. "I am committed to removing JTRS market entry barriers and creating a competitive environment within the JTRS family. Prod-

ucts like the reprogrammable, SCA-compliant Falcon III will permit faster and cheaper means to upgrade the radio capabilities and implement crypto modernization. Our goal is to provide our Joint Warfighters with a family of interoperable, secure, affordable software-defined radios. I welcome Harris into the JTRS family."

"Fielding JTRS technology this early is a great win for the JTRS program and the government, and shows the true power of JTRS standards," said Dana Mehnert, president, Harris RF Communications Division. "The AN/PRC-152(C) was internally developed by Harris and implements key JTRS requirements: the SCA operating environment, and type 1, software-programmable encryption. By leaving the doors open to competition, the government can significantly benefit from commercial technology and accelerate getting new capabilities to the warfighter faster." The AN/PRC-152(C) and its associated vehicular adapter amplifier, the AN/VRC-110, are examples of commercial technology providing new capabilities to the warfighter. In service today, the AN/VRC-110 fits into a standard SINGARS vehicular communications mount, but unlike the dedicated-use SINGARS radio, the multimode AN/VRC-110 supports multiple waveforms: SINGARS, Havequick I/II, VHF/UHF AM&FM and MIL-STD-188-181B. ■

## Circulators, Isolators, Attenuators



### for Military & Space Applications

REC engineering capabilities run the gamut of providing Circulators, Isolators and Attenuators with very low insertion loss all the way to low frequency devices requiring high continuous power operations.

Renaissance Electronics Corp. along with newly acquired P&H Laboratories has a strong heritage of providing quality products for a variety of military and space applications.

*Call our factory with your exact specifications*

ISO 9001 Certified

**RENAISSANCE**  
ELECTRONICS CORPORATION

Tel: 978 772-7774 Fax: 978 772-7775  
www.dropinisolator.com



4 kW CW

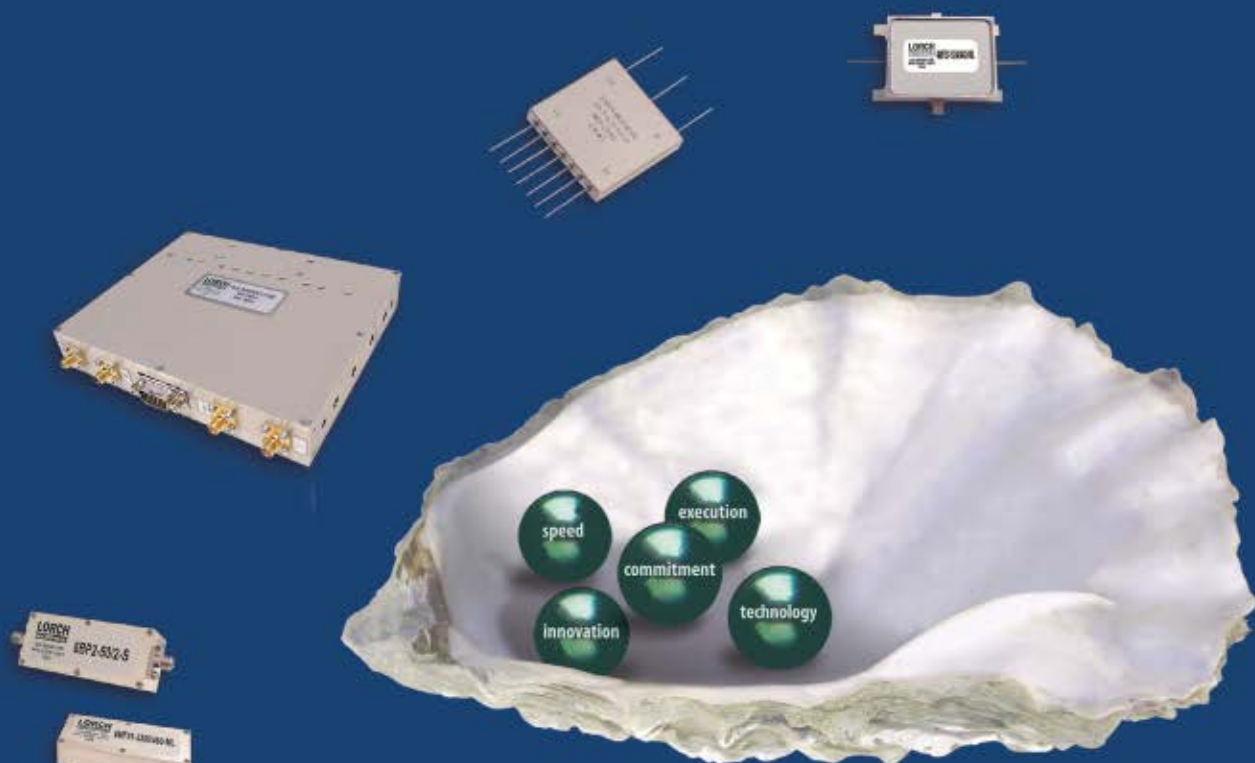


Fixed Attenuator



Low Insertion Loss





## a pearl is nature's gift knowledge and experience are ours

For more than 30 years Lorch Microwave has been a leading supplier of RF and Microwave components, delivering innovative solutions for even the most demanding applications. From high performance micro miniature filters to ceramics, cavity and integrated assemblies, the Lorch Microwave name is found on military and commercial products worldwide. Let us put our knowledge and experience to work for you.

**LORCH**  
**MICROWAVE**

Salisbury, MD 21802  
410.860.5100  
800.780.2169  
[www.lorch.com](http://www.lorch.com)

smiths

Visit <http://mwj.hotims.com/11713-70> or use RS# 70 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)

# Your Dream Our Design

## SURFACE MOUNT TECHNOLOGY

Take your engineering visions from dream to reality with Marki's surface mount components.

Performance and efficient circuit design are crucial considerations in today's product engineering. With Marki's rugged and versatile surface mount packaging, you can simplify your board assembly while achieving unmatched performance. Look to Marki for an expanding array of surface mount products:

- ▶ Double and triple balanced mixers up to 65 GHz
- ▶ Frequency doublers to 50 GHz
- ▶ Amplified doublers and triplers
- ▶ LO buffer amplifiers 1 to 26 GHz
- ▶ Bias Tees

To learn more, call Marki Microwave today and tell us your dreams.



Visit <http://mwj.hotims.com/11713-72> or use RS# 72 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)

215 Vineyard Court  
Morgan Hill, CA 95037 USA  
Ph +1.408.778.4200  
Fax +1.408.778.4300  
[info@markimicrowave.com](mailto:info@markimicrowave.com)  
[www.markimicrowave.com](http://www.markimicrowave.com)



ORDER SELECTED PARTS ONLINE.





## New Horizons for Surrey NanoSystems

Set to have a major impact on the semiconductor industry is Surrey NanoSystems, a new company resulting from leading UK technology venture company IP Group teaming up with scientists from the University of Surrey's Advanced Technology Institute (ATI) and CEVP Ltd., a leader in plasma tool manufacture. The new company's remit is to provide commercial tools for producing nanomaterials.

IP Group has financed the joint venture company in which ATI scientists are developing a 'NanoGrowth'™ machine in conjunction with specialists from CEVP. Using patented technologies and recipes developed by the university, the NanoGrowth machine represents the world's first commercial tool for low temperature growth of carbon nanotubes, which can provide high quality, high speed connections to the next generation of silicon chips. The low temperatures used permit the use of existing silicon semiconductor materials which are not able to withstand the high growth temperatures previously required for the formation of nanotubes.

The low temperature carbon nanotube growth process is expected to be of considerable use in both academic and commercial laboratories for the development of practical nanomaterial production techniques for high technology applications. Likely applications include low resistance nanowires in integrated circuits, semiconducting nanotubes for fabricating high performance transistors, micro-miniature heat sinks, ultra-tough polymer composites, gas sensors and light sources for flat panel displays.

Outlining the potential significance of the initiative, Ben Jensen, technical director for CEVP, said, "I am incredibly excited by the partnership mix between IP Group, the University of Surrey and Surrey NanoSystems. This will enable the company to break new ground in the manufacturing and use of carbon nanotubes and nanostructures within the CMOS process window."

## Thales Leads Development of First GMES Service

The European Commission has selected a consortium led by Thales to develop OSIRIS—Open architecture for Smart and Interoperable networks in Risk management based on In-situ Sensors, the first integrated service of the Global Monitoring for Environment and Security (GMES) programme. GMES will create an EU-wide capability to acquire, analyse, process and distribute information in support of European environment and security directives.

From 2008, GMES will provide services based on data from satellites and a range of in-situ sensors including

seismographs, water analysers and air analysers to improve Europe's environment and, in turn, the quality of life for its citizens. With a total budget of €11 M, the OSIRIS project calls for the definition, development and testing of an integrated real-time surveillance and crisis management system. The system will significantly enhance Europe's ability to monitor environmental crises and manage and coordinate related operations and emergency responses.

The proposed architecture is open and scalable to allow for easy integration of new data from satellites and other sources to further improve the quality of service.

The OSIRIS programme is a prime illustration of the integrated services concept underpinning the European GMES system, which will provide the secure information and communication system architecture needed to deliver functions ranging from earth observation to end user services.

## Diamond Set to be Semiconductors' Best Friend

Diamond Microwave Devices (DMD) is a new subsidiary set up by Element Six (E6), a world leader in the development of Chemical Vapour Deposition (CVD) diamond technology. The new company aims to develop novel diamond semiconductor materials and processing technology that will help create the next generation of high power, high temperature semiconductor devices for use in microwave power amplifiers and transmitters.

Element Six has also signed a collaboration agreement with Filtronic plc to work with DMD to develop this new technology. Filtronic and E6 will use their complementary high technology strengths in materials, semiconductor device processing and circuits to expedite the development of this new microwave technology that has the potential of revolutionising microwave power electronics.

E6 has been involved with major research and industrial programmes such as the UK's Department of Trade and Industry sponsored Carbon Power Electronics (CAPE) programme aimed at overcoming the technical challenges of developing diamond-based electronics components. For high power electronics, CVD diamond offers unique properties such as high breakdown voltage and high temperature operation. If a practical semiconductor device can be demonstrated, it could have the potential to provide superior microwave power and higher operating temperatures than existing semiconductor devices and technologies.

Dr. Richard Lang, general manager of DMD, said, "Whilst the technical challenges are high, a diamond MESFET could revolutionise the design of future microwave power modules. There is much work to be done in order to realise a practical device, and we are excited by the opportunity to explore the boundaries of this emerging technology."



### Enterprising Tactics for EADS in Ireland

**E**ADS and Enterprise Ireland have signed a strategic partnership agreement for aerospace research, technology development and procurement. The Memorandum of Understanding between the two parties forms the basis for co-operation until 2012 by which time the aim is to

increase annual sales by Irish companies to EADS to a value of €35 M.

The primary aim of the agreement is to increase the level of procurement by EADS from Enterprise Ireland's client companies. Furthermore, the agreement aims to optimise opportunities for co-operation in technology research and development between EADS, Enterprise Ireland client companies and Science Foundation Ireland. It will also help maximise the benefits of the involvement of EADS, Enterprise Ireland and Science Foundations Ireland in the European Framework Program 7, a European Union programme for funding scientific research.

A significant part of the agreement is research and technology collaboration between EADS and The Centre for Telecommunications Value-Chain Research at Trinity College Dublin (TCD) and NUI Maynooth. The company

will also fund a number of PhD programmes in key research areas of aerospace and security, with the first programme commencing at TCD.

### Ericsson Strengthens Swedish-Chinese Relations

**E**ricsson and the Stockholm School of Economics have agreed to create a programme aimed at generating in-depth knowledge of Chinese business and economics and China's impact on global trade patterns. The programme began on 1 January 2007 and comprises several compo-

nents designed to support the capacity of Sweden to follow developments in China, strengthen Swedish-Chinese relations in economics, business and research and its impact on the world economy.

The programme will be based at the Stockholm School of Economics in close cooperation with the China Centre for Economical Research at Peking University.

Carl-Henric Svanberg, president and CEO of Ericsson, commented, "This new initiative creates the base for a competence centre in Sweden with the aim of strengthening Ericsson's and Sweden's relations with China." ■



## 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](mailto:sales@shp-seals.com) - website: [www.shp-seals.com](http://www.shp-seals.com)



# VERY HIGH IP3...to +36dBm

# MIXERS

## 2 to 2500MHz



- Very Wide Band, 2-2500MHz
  - Very High Isolation, up to 52dB
  - Very High 1dB Compression, up to +23dBm
  - Very Low Conversion Loss, from 6.3dB
- It's an industry first...only from Mini-Circuits!**

Mini-Circuits shielded RoHS LAVI frequency mixers deliver the breakthrough combination of very high IP3 up to +36dBm, ultra-wideband operation, and outstanding electrical performance.

From **\$13<sup>95</sup>** **IN STOCK**  
ea. Qty. (100)

By combining our advanced ceramic, core & wire, and semi-conductor technologies, we've created these evolutionary broadband mixers that are specially designed to help improve overall dynamic range so you can realize lower distortion and combat interference in today's crowded spectrum. They're the very best, very low in cost, and immediately available off-the-shelf from the world leader in mixer technology, **Mini-Circuits!**

#### TYPICAL SPECIFICATIONS

Model No.	RF	Frequency (MHz) LO	IF	LO Pwr. (dBm)	IP3 (dBm)	1dB Comp. (dBm)	Conv.Loss (dB)	Isolation (dB) L-R L-I	Price \$ea. Qty.(1-9)
LAVI-9VH+	820-870	990-1040	120-220	+19	+36	+23	7.2	46 46	15.95
LAVI-10VH+	300-1000	525-1175	60-875	+21	+33	+20	6.3	50 45	22.95
LAVI-17VH+	470-1730	600-1800	70-1000	+21	+32	+20	6.8	52 50	22.95
LAVI-22VH+	425-2200	525-2400	100-700	+21	+31	+20	7.7	50 45	24.95
LAVI-2VH+	2-1100	2-1100	2-1000	+23	+34	+23	7.5	48 47	24.95
LAVI-25VH+	400-2500	650-2800	70-1500	+23	+32	+20	7.5	50 45	24.95

U.S. Patent Number 6,807,407



**Mini-Circuits®**  
ISO 9001 ISO 14001 CERTIFIED

**ALL NEW**  
**minicircuits.com**

P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661 For detailed performance specs & shopping online see Mini-Circuits web site



The Design Engineers Search Engine Provides ACTUAL Data Instantly From MINI-CIRCUITS At: [www.minicircuits.com](http://www.minicircuits.com)

**RF/IF MICROWAVE COMPONENTS**

412 RevB

Visit <http://mwj.hotims.com/11713-81> or use RS# 81 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)

# WORLD'S SMALLEST 2WAY-0° SPLITTERS

5 to 2500MHz... Immediate Delivery



**\$1.69**

from each (qty. 1000)

Measuring only 0.15" square, Mini-Circuits tiny SBTC power splitters are also the **world's lowest priced** 2way-0° splitters operating within the 5 to 2500MHz band. But that's not all! Patented technology provides outstanding performance features including **low insertion loss** down to 0.3dB typical, excellent 0.2dB amplitude and 1 degree phase unbalance (typ), and **superior temperature stability**.

Pads are solder plated, and connections are assembly welded for high temperature reflow reliability. As demand for smaller gets bigger, blow away the competition with Mini-Circuits space saving, **money saving** SBTC power splitters.

*CUSTOM PRODUCT NEEDS... Let Our Experience Work For You.*



Model	Freq. (MHz)	Z	Price \$ea. (Qty. 25)
SBTC-2-10+	5-1000	50Ω	2.49
SBTC-2-20+	200-2000	50Ω	3.49
SBTC-2-25+	1000-2500	50Ω	3.49
SBTC-2-10-75+	10-1000	75Ω	3.49
SBTC-2-15-75+	500-1500	75Ω	3.49
SBTC-2-10-5075+	50-1000	50/75Ω	3.49
SBTC-2-10-7550+	5-1000	50/75Ω	3.49

U.S. Patent No. 6,963,255

**Mini-Circuits®**  
ISO 9001 ISO 14001 CERTIFIED

**ALL NEW**  
**minicircuits.com**

P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661 For detailed performance specs & shopping online see Mini-Circuits web site



The Design Engineers Search Engine Provides ACTUAL Data Instantly From MINI-CIRCUITS At: [www.minicircuits.com](http://www.minicircuits.com)

**RF/IF MICROWAVE COMPONENTS**

354 Rev F

Visit <http://mwj.hotims.com/11713-82> or use RS# 82 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)





### **Global In-building Wireless Systems to Show 20 Percent Annual Growth Rate**

**C**ustomer's dependence on wireless communications and their adoption of high bandwidth 3G cellular services are the primary drivers of the global growth for in-building wireless systems that extend and create wireless coverage indoors. According to a new study from

ABI Research, deployments of these systems are expected to result in revenues in excess of \$3.6 B by 2011.

Says ABI Research analyst Dan Shey, "People spend a significant amount of time indoors and, not surprisingly, they also expect indoor access from their outdoor wireless service. But indoor coverage does not just satisfy a need for service convenience; it is also used to improve business productivity." As a result, commercial buildings will be a major focus of the in-building wireless systems industry, affecting carriers, businesses, building owners, equipment manufacturers and solution providers.

Deployments and revenues of in-building wireless systems will be dominated by distributed antenna systems, commanding over 60 percent of the deployments and over 75 percent of the equipment revenues. These systems are most economical for buildings larger than 100,000 square feet, a size where coverage and signal level capacity from outdoor networks into buildings begin to fall significantly.

For buildings smaller than 100,000 square feet, repeaters are the primary solution; however, repeater shipment growth will slow, due to replacement by picocells and femtocells. According to Shey, "Repeaters are a cost-effective way to provide coverage inside buildings but they do not add capacity, which will be needed as 3G services usage increases. New picocells and femtocells, which can be backhauled via an IP connection are a cost-effective way to add capacity and coverage."

ABI Research's study, "In-Building Wireless Systems: Worldwide Deployment Scenarios for Active, Passive and Distributed Antenna Systems, Repeaters, Picocells and Femtocells," provides a comprehensive view of the global in-building wireless systems industry. It examines in-building wireless systems based on the value chain, building size and type; and system type, component, cost and functional capabilities. The analysis is complemented by worldwide forecasts for in-building wireless deployments, revenues, penetration and unit shipments for five global regions: North America, Europe, Asia-Pacific, Latin America and Rest of World. The study forms part of the firm's Wireless Infrastructure Research Service, which includes Research Reports, Research Briefs, Market Data, On-line Data Bases, ABI Insights, the ABI Vendor Matrix and analyst inquiry support.

Founded in 1990 and headquartered in New York, ABI Research maintains global operations supporting annual research programs, intelligence services and market reports in broadband and multimedia, RFID and contactless, M2M, wireless connectivity, mobile wireless, transportation and emerging technologies.

### **A New Industry Study on Active Electronically Scanned Arrays**

**T**he AESAs report details an extensive new study of Active Electronically-Scanned Arrays (AESA), which has just been released by Engalco.

AESAs have been already well proven in many new and upcoming radar systems and are increasingly being adopted for vari-

ous platforms—with airborne installations (including UAVs) always forming the major segment.

According to Engalco's research, the overall "free world" market value for AESAs will grow from approximately \$2.8 B in 2006 to more than \$10 B in 2013. Engalco also estimates that the total value of the required transceiver modules will increase from \$1.3 B in 2006 to \$6 B in 2013 and therefore the requirements for the embedded semiconductors (being mainly X-band MMICs) will exhibit similar strong growth. Power amplifiers, required for every transceiver module, will always lead the market for these specialized semiconductors and GaN-based devices will take over in this application after 2010.

AESAs have a very large growth potential, notably for military end-users. With just one AESA, very high speed, multi-target radar tracking is possible, simultaneously with microwave communications and EW—all available using the same system. In addition, these systems intrinsically exhibit graceful degradation, which results in substantially reduced down times and maintenance costs, compared to traditional radars.

The systems identified and the quantitative data provided in the report are segmented operationally by airborne, land-based and ship-borne installations and geographically by Europe, North America and the "Rest of the World." Space-based AESAs are also considered. In every respect, North America always strongly leads in all markets and for sources of development and production. Markets for all segments are shown in detail within the report, with forecasts extending to 2014. A substantial number of mainly market-data charts are provided as well as more data tables. Transceiver unit prices (ASP) and shipment forecasts are also provided in most instances.

Forthcoming platforms having built-in AESAs are included, as well as AESA-upgrades for existing platforms.

In the report, 14 AESA OEM companies are profiled, with more extensive profiles provided for the major companies that own some of these OEMs.

Engalco is a tech-sector consultancy, industry analysis, market forecasting and publishing concern. With strong experience in all relevant commercial and defense segments, the firm specializes mainly in the RF/microwave, wireless, fiber-optics, photonics and related electronics sectors. The firm has been responsible for several published market reports and the completion of a number of private client projects in these sectors. Engalco's mission is to continue providing a range of vital types of analysis, research and publishing services, in addition to customized consultancy based upon the firm's specialist capabilities.



For further information, contact Engalco at +44 (0) 1262 424 249 (GMT) or e-mail: [enquiries@engalco-research.com](mailto:enquiries@engalco-research.com).

## India Expected to Become a Semiconductor Manufacturing Player

India, with growing semiconductor consumption and acceleration in electronics manufacturing activities and with the setting-up of EMS shops, is destined to emerge as an important semiconductor manufacturing location, reports In-Stat. India is one of the fastest growing semiconductor-consuming markets in the world, the high-tech market research firm says. The rise of the middle class is driving the consumer market in India at an astounding pace.

"The semiconductor ecosystem, which is currently dominated by design services and embedded software, will be in place by 2010 with the setting-up of planned semiconductor manufacturing facilities," says Mayank Jain, In-Stat analyst. "Thus, by 2010, India will have the entire semiconductor industry in place, and will be in the reckoning among other Asia semiconductor manufacturing countries."

*Recent research by In-Stat found the following:*

- The market for semiconductors in India was valued at \$1.18 B in 2005 and is forecast to reach \$3.09 B by 2010.

- Television sets lead semiconductor consumption in the consumer segment.

- By 2010, communications is anticipated to be the major contributor to semiconductor consumption.

The research, "Indian Semiconductor Market Update: Consumption, Manufacturing and Future Development," gives a five-year forecast for semiconductor consumption in India and points out consumption trends across different segments.

It highlights the drivers in each segment and gives the breakdown of semiconductor products like microprocessors, microcontrollers, memory and DSP across each segment. The major players in various semiconductor segments are discussed to provide an overview of the market's direction. The report also analyzes the semiconductor manufacturing scenario in India.

This report is part of In-Stat's Asia Semiconductor and Manufacturing Service, which tracks semiconductor consumption by applications and by country.

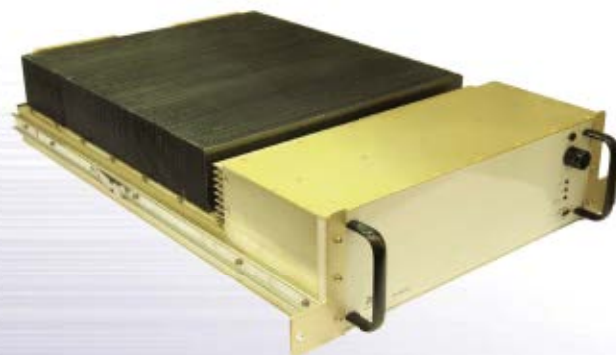
This service forecasts application segments in crucial Asian markets, including China, India, Japan, Korea and Taiwan. Semiconductor manufacturing is also addressed by country and an additional step in identifying the largest markets for semiconductor consumption is presented with a look at CEM and assembly capacity by country. This research is an invaluable tool in identifying business opportunities in the increasingly important Asian marketplace. ■

# UBS

Unique Broadband Systems Ltd.

## LDMOS based Linear High Power Amplifier

- **High Linearity PA for Broadcast of COFDM waveforms**
- **Enhanced Heat Sink Design**
- **Optimized Thermal Distribution**
- **Designed for Outdoor Operation**



Model	Frequency (GHz)	Output Power	Power Gain	Output Emissions IN-BAND	SHOULDERS	RF Input VSWR	RF Output VSWR
DHPA - 1500	1.450 - 1.500	300 W	54 dB (typ.)	- 25 dB	- 30 dB	1.50 : 1	1.20 : 1
DHPA - 1670	1.670 - 1.675	250 W	53 dB (typ.)	- 30 dB	- 35 dB	1.50 : 1	1.20 : 1
DHPA - 2200	2.170 - 2.200	280 W	54 dB (typ.)	- 27 dB	- 32 dB	1.50 : 1	1.20 : 1
DHPA - 2330	2.305 - 2.360	280 W	55 dB (typ.)	- 25 dB	- 30 dB	1.50 : 1	1.20 : 1
DHPA - 2600	2.500 - 2.700	250 W	54 dB (typ.)	- 27 dB	- 32 dB	1.50 : 1	1.20 : 1

**Please contact our Sales Team for more information on this line of Amplifier products:**

North America Toll Free: 1 877 669 8533

Fax: 905 669 8516

Email: [sales@uniquesys.com](mailto:sales@uniquesys.com)

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

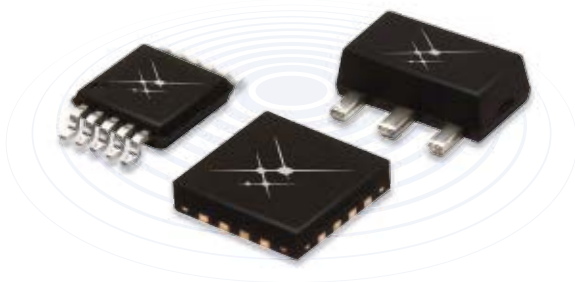




# Enabling Mobile Connectivity

## The Skyworks Advantage

- Solutions for all air interface standards, including CDMA2000, GSM/GPRS/EDGE, WCDMA and WLAN
- Analog, RF and mixed signal design capabilities
- Key process technologies: GaAs HBT, PHEMT, BiCMOS, SiGe, CMOS and RF CMOS
- World-class manufacturing capabilities and scale



Power Amplifiers • Switches • Transceivers • Front End Modules • RF Subsystems

Single Package Radios • Mixers • Synthesizers • Switches • Attenuators • Diodes • Technical Ceramics

USA: 781-376-3000 • Asia: 886-2-2735 0399 Ext. 990 • Europe: 33 (0)1 41443660

Email: [sales@skyworksinc.com](mailto:sales@skyworksinc.com) • [www.skyworksinc.com](http://www.skyworksinc.com)

Visit <http://mwj.hotims.com/11713-127> or use RS# 127 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)



# DID YOU KNOW?

**FACT #1:** ALTHOUGH MUCH FOLKLORE SURROUNDS THE EAGLE, STORIES CELEBRATING ITS GREAT EYESIGHT ARE TRUE: EAGLES SEE AT LEAST FOUR TIMES BETTER THAN HUMANS AND CAN SPOT SMALL PREY A MILE AWAY.

**FACT #2:** TRIQUINT HAS ITS EYE FIXED ON THE WIRELESS MARKET WITH MODULE PRODUCTS TO INTEGRATE THE RF FRONT-END, OFFERING DIVERSE SOLUTIONS FOR THE EVOLVING COMMUNICATIONS WORLD.

Long a symbol of pride and majesty, the eagle remains supreme as 'king of birds.' Although much myth surrounds the eagle – loyalty, legendary eyesight and majestic flying skills are factual. Eagles are truly remarkable.

Like the sharp-eyed eagle, TriQuint Semiconductor has fixed its gaze and resources on the wireless market, using a highly integrated technology portfolio to create advanced products including PA / Tx / Rx modules, filter banks and pHEMT switch modules – a diverse solution for wireless handsets, network radios and broadband.

Few industries turn as fast as wireless. So like the free-wheeling eagle that soars overhead, TriQuint is pushing new limits, offering highly integrated products that merge our legendary GaAs expertise with the latest SAW and BAW filter technology. Like the eagle that depends on speed, vision and adaptability, TriQuint's speed, visionary engineering and quick-turn reflexes help us deliver new Tx & Rx modules, PAs, PAMs, switches and filters.

- Our QUANTUM Tx Module™ family of GSM / GPRS, EDGE and WEDGE products including the TQM6M4028: a new dual-band transmit (Tx) module with full ESD protection for entry-level GSM / GPRS handsets; alongside our TQM6M5001: a quad-band GSM / GPRS / EDGE - Linear Tx module already shipping world-wide.

- Our HADRON PA Module™ family of EDGE - Linear and Polar products including TQM7M5008: a new EDGE - Polar PA module optimized to the industry's leading 3G multi-mode transceiver design – built on the technology of our successful TQM7M5003.

- Our TRITIUM PA-Duplexer Module™ family of WCDMA and CDMA power products, including TQM676001 for WCDMA IMT2100 and TQM663017 for CDMA PCS – both now shipping in volume.

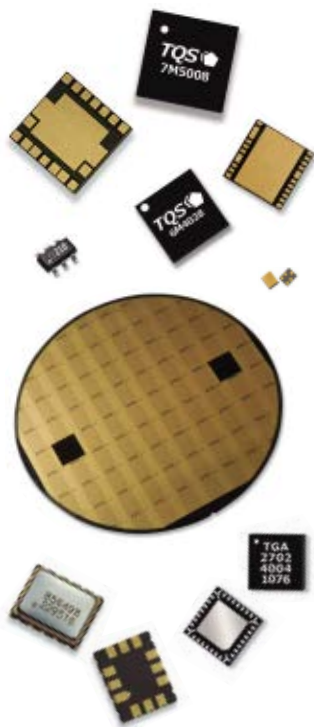
- CDMA FEMs: TriQuint Semiconductor offers a comprehensive CDMA product portfolio including PA modules, filters and our complete TRITIUM PA-Duplexer Module™ family of products that include a wide selection of devices offering enhanced, low-power efficiency, a revolutionary biasing circuit – all optimized to leading transceiver reference designs and for superior operation at extremely low idle current levels.

- Multi-Function Circuits: A new product line available in packages or as die for 18 and 23 GHz point-to-point radios.

- Bluetooth GaAs PA: The TQP770001 Class 1 PA is designed for greater efficiency, high data rate and is ideal for both network and mobile device applications.

- New high-power PAs: Products for millimeter wave radio covering 17-35 GHz, available packaged and as MMIC; new enhanced performance Ku-band amplifiers.





TriQuint Semiconductor is a global telecommunications supplier focused on media interface applications for both RF and optical systems. TriQuint continually strives to lower customers' costs by speeding manufacturing and improving system performance through advanced engineering expertise, dedicated service and forward-looking design. Our unique RF front-end module solutions free-up PC board space for new multimedia applications in wireless handsets.

TriQuint researches, designs and manufactures its products in advanced facilities staffed by some of the world's most creative engineering and service professionals. Design and manufacturing takes place in Oregon, Texas and Florida, with additional design facilities in New England, North Carolina and Germany. Our international locations include production and assembly operations in Costa Rica with sales and applications support in China, Korea and Taiwan. We connect the digital world to the global network as a premier supplier of advanced products based on gallium arsenide (GaAs), SAW and BAW technologies.

**WIRELESS HANDSET:** TriQuint is the supplier of choice for state-of-the-art RF front-end solutions including every critical module and component for GSM / EDGE, CDMA and WCDMA / HSDPA phones. We offer highly integrated module solutions for the handset RF front-end as well as discrete products including PA modules, pHEMT switches, LNAs, duplexers, triplexers and SAW filters.

**BLUETOOTH & BROADBAND:** TriQuint is a leading supplier of high-power and low-noise GaAs amplifiers for WLAN manufacturers as well as a wide variety of SAW filters for WLAN, WiFi, CATV / STB and Bluetooth systems, plus GPS and emerging WiMAX chipsets.

## and Did You Know TriQuint is a Leader in Value and Innovation?



**BASE STATION:** TriQuint is a long-established supplier of base station products and leads the world in mobile network SAW filters. Our GaAs devices for communications networks, back-haul (digital) radios as well as custom Foundry designs are also leaders. TriQuint offers customers a full portfolio of general purpose ICs, GaAs MesFET, pHEMT and HFET power transistors (packaged or bare die).

**MILITARY & AEROSPACE:** TriQuint Semiconductor is proud of its military and aerospace heritage. Today we serve the needs of Defense Department offices and major contractors by providing basic research, modules, components and MMICs for a number of on-going programs. TriQuint parts are built into the newest generations of phased-array radar as well as numerous other communications and counter-measure systems that leverage our BAW, SAW and oscillator expertise. Our specialized GaAs 100mm Foundry services play a vital role in TriQuint military programs, with components appearing in applications as close as terrestrial battlefields, up to the 'middle ground' of orbiting payloads and all the way to far-flung worlds, including the latest generation of Mars rovers: 'Spirit' and 'Opportunity' where TriQuint amplifiers are still at work.

**FOUNDRY SERVICES:** TriQuint created many of the GaAs processes used to build today's most popular 'standard' microwave products – you can depend on the company that created the process for all your custom circuit needs. TriQuint has expanded its capacity for low-noise, power and logic applications (DC-80 GHz), offering the industry's widest GaAs process selection: HBT, pHEMT, E/D pHEMT, MesFET, PIN, HFET and mHEMT. For value, innovation, security and guaranteed supply, look to TriQuint Semiconductor.

**TriQuint Semiconductor...**

**Connecting the Digital World to the Global Network.™**

Phone: +1-503-615-9000 | Fax: +1-503-615-8900 | E-mail: [info-sales@tqs.com](mailto:info-sales@tqs.com) | Website: [www.triquint.com](http://www.triquint.com)

Visit <http://mwj.hotims.com/11713-146> or use RS# 146 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)

**TriQuint**   
SEMICONDUCTOR



## INDUSTRY NEWS

■ **RF Micro Devices Inc.** (RFMD) announced it has signed an agreement to sell the majority of its Bluetooth® assets to **QUALCOMM** for \$39 M. The pending transaction is expected to provide QUALCOMM access to next-generation Bluetooth technology. RFMD anticipates the transaction will enable it to increase its focus on its highest growth wireless business opportunities. Under the agreement, QUALCOMM will acquire the majority of RFMD's Bluetooth assets, including intellectual property, related to RFMD's next-generation SiW1722 and RF4000 series.

■ **Laird Technologies**, a designer and manufacturer of antenna solutions, electromagnetic interference (EMI) shielding products, telematics and thermal management solutions, announced the acquisition of **Steward Inc.** and its subsidiaries for \$52.5 M. Steward is a provider of ferrite-based products that are used to remove unwanted EMI "noise" and other signals at unwanted frequencies from conductors. Steward revenues in its fiscal year ending September 30, 2006, were \$50 M.

■ **CoorsTek Inc.**, a large technical ceramics supplier and manufacturer of critical components for high technology markets, announced the acquisition of **Gaiser Tool Co.**, a ceramic precision tooling manufacturer based in Ventura, CA with operations in Tokyo, Japan. CoorsTek plans to retain the Gaiser brand while infusing technical and material innovations to further enhance the company's high quality market position. With precision ceramic tools capable of part dimensions as small as 2 µm, CoorsTek also expects to expand its micro-component capabilities for a variety of markets.

■ **Comarco Wireless Test Solutions**, a supplier of wireless test systems for field applications, and **Ascom**, a specialist in wireless onsite communication solutions, announced that the two companies have formed a cooperative alliance to develop and market 3G and 4G wireless network Quality of Service, optimization and test measurement systems. This alliance will create a global leader by positioning the two companies to capitalize on the increasing interest of wireless carriers in improved Quality of Service, as well as the expected deployment of more advanced, high capacity next-generation broadband wireless networks.

■ **Response Microwave Inc.**, a global specialist in providing RF/microwave customer solutions, announced that it has moved into a new, larger facility in Devens, MA. The new facility includes office and meeting space for administrative tasks, as well as a complete microwave test and engineering lab for electrical measurements and simulations. The complete offering of passive control components and Compel connectivity solutions are also stocked within this space, which provides enhancements to existing Framingham and Leominster office areas. The facility is located at 94 Jackson Road, Suite 110, Devens, MA 01434, and all existing contact numbers for the company remain valid.

## AROUND THE CIRCUIT

■ **2Wire**, a provider of broadband service delivery platforms, is expanding operations into the state of Texas, beginning with a new facility in San Antonio. Headquartered in Silicon Valley, 2Wire is rapidly growing to meet the needs of major telecom broadband providers, and plans to hire hundreds of employees to staff the new facility. The San Antonio facility includes a 38,000 square foot call center staffed by more than 500 technical support agents.

■ The **ZigBee™ Alliance**, a global ecosystem of companies creating wireless solutions for use in residential, commercial and industrial applications, announced the first group of ZigBee Certified Products, marking a major milestone in the Alliance's ultimate vision of creating an open, global, wireless sensor and control networking solution. Member companies earning ZigBee Certified Product status include MaxStream, NEC Engineering, S3C and Software Technologies Group.

■ **Provigent**, a provider of system-on-a-chip (SoC) solutions for the broadband wireless transmission market, announced that the company has been shipping lead free components for the past two years. Provigent SoC components are in compliance with the European Union's Restriction of Hazardous Substances (RoHS) legislation.

## CONTRACTS

■ **Merrimac Industries Inc.** announced that it has received a contract that could reach a maximum value of \$4.3 M over its five-year term from **ITT Corp.** to continue to provide a sophisticated Multi-Mix® multilayer filter assembly for use in an Airborne Electronic Countermeasures (ECM) application. The initial order placed on this contract is valued at \$708,000 and is scheduled to be recognized during 2007. Under the terms of this contract, ITT will be able to order varying numbers of filter assemblies to support its Department of Defense contract managed by ITT's Electronic Systems Division.

■ **Triton Services Inc.**, Electron Technology Division, Easton, PA, has been awarded a contract for the development of a new Traveling Wave Tube Amplifier (TWTA) for a shipboard tracking radar. The value of the contract awarded by a European defense contractor exceeds \$1 M for the development and the first pre-production lot.

■ **Goodrich Corp.** has been awarded a contract from the US Air Force Unmanned Aerial Vehicle Battlelab (UAVB) at Nellis Air Force Base (Nevada) to develop and fabricate a short-wave infrared (IR) sensor for the Spectre-Finder initiative. The purpose of the initiative is to rapidly demonstrate the potential of a small, air launched and recoverable Unmanned Aircraft System (UAS) to provide off-board sensing in support of future Air Force Special Operations Command concepts of operation. Under the terms of the contract, Goodrich's SUI team, headquartered in Princeton, NJ, will develop a SWIR camera payload assembly.

■ **M2 Global Technology Ltd.**, a San Antonio, TX-based engineering and contract manufacturer of satellite,



# Ultra

# WIDE BANDWIDTH



# Voltage Controlled Oscillators

Model	Frequency (MHz)	Tuning Voltage (VDC) *	DC Bias VDC @ I (Max)	Typical PhaseNoise @ 10 kHz (dBc/Hz)
DCMO514-5	50 - 140	0.5 - 24	+5 @ 30 mA	-105
DCMO616-5	65 - 160	0.5 - 24	+5 @ 35 mA	-108
DCMO1027	100 - 270	0 - 24	+5 to 12 @ 35 mA	-112
DCMO1129	110 - 290	0.5 - 24	+5 to +12 @ 35 mA	-105
DCMO1545	150 - 450	0.5 - 24	+5 to 12 @ 35 mA	-108
DCMO1857	180 - 570	0.5 - 24	+5 to 12 @ 30 mA	-108
DCMO2260-5	220 - 600	0.5 - 24	+5 @ 35 mA	-108
DCMO2476	240 - 760	0.5 - 24	+5 to 12 @ 35 mA	-108
DCMO3288-5	320 - 880	0.5 - 24	+5 @ 35 mA	-109
DCFO35105-5	350 - 1050	0 - 25	+5 @ 40 mA	-112
DCMO50120-5	500 - 1200	0.5 - 24	+5 @ 40 mA	-118
DCMO50120-12	500 - 1200	0.5 - 24	+12 @ 35 mA	-103
DCMO60170-5	600 - 1700	0 - 25	+5 @ 35 mA	-99
DCMO80210-5	800 - 2100	0.5 - 24	+5 @ 35 mA	-96
DCMO80210-10	800 - 2100	0.5 - 24	+10 @ 35 mA	-100
DCMO90220-5	900 - 2200	0.5 - 24	+5 @ 35 mA	-98
DCMO90220-12	900 - 2200	0.5 - 25	+12 @ 35 mA	-99
DCMO100200-12	1000 - 2000	0.5 - 24	+12 @ 35 mA	-105
DCMO100230-12	1000 - 2300	0.5 - 24	+12 @ 35 mA	-101
DCMO100230-5	1000 - 2300	0.5 - 24	+5 @ 35 mA	-98
DCMO110250-5	1100 - 2500	0.5 - 28	+5 @ 35 mA	-100
DCMO135270-8	1350 - 2700	0.5 - 20	+8 @ 35 mA	-93
DCMO150318-5	1500 - 3200	0.5 - 20	+5 @ 30 mA	-93
DCMO150320-5	1500 - 3200	0.5 - 18	+5 @ 60 mA	-92
DCMO172332-5	1720 - 3320	0.5 - 24	+5 @ 30 mA	-94
DCMO190410-5	1900 - 4100	0.5 - 16	+5 @ 50 mA	-90
DCMO250512-5	2500 - 5125	0.5 - 24	+5 @ 50 mA	-78

\* Guaranteed sub bands with lower tuning voltages. See specification sheet for details.



## Features:

- Ultra Wide Bandwidth
- High Immunity to Phase Hits
- Exceptional Phase Noise
- Very Low Post Thermal Drift
- Small Size Surface Mount
- Lead Free - RoHS Compliant
- Patent Pending
- REL-PRO® Technology



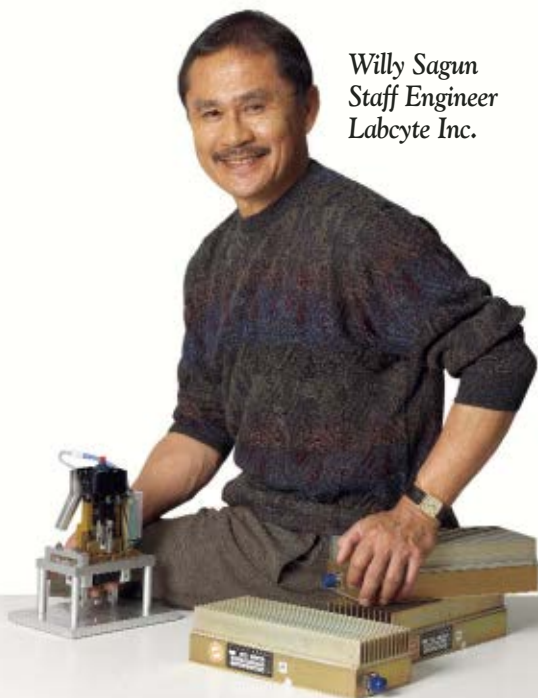
Visit <http://mwj.hotims.com/11713-134> or use RS# 134 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)

For additional information, contact Synergy's sales and application team.  
 Phone: (973) 881-8800 Fax: (973) 881-8361 E-mail: [sales@synergymwave.com](mailto:sales@synergymwave.com)

Visit Our Web Site At [WWW.SYNERGYMWAVE.COM](http://WWW.SYNERGYMWAVE.COM)

*"Other amplifier companies acted like we weren't worth the trouble. AR treated us like we were the only customer that mattered."*

Willy Sagun  
Staff Engineer  
Labcyte Inc.



*We develop liquid handling equipment for the pharmaceutical market. We don't use a lot of amplifiers, but we needed something special – a smaller version of the AR amps we'd been using.*

*Of course, we called AR Modular RF. But we also got a competitive bid. What a difference! From the start, AR was so much more responsive. They sent a group of technical people out to see us and determine our needs.*

*The other company acted like we weren't worth the trouble. AR developed a working prototype in about 1 1/2 months. The other company took an additional 3 months; and their cost was double! Even when our specs changed along the way, the AR team never missed a beat. Everyone talks about service and value, but AR really delivered. This is what they mean when they talk about giving their customers a 'competitive edge.'*

*To learn more visit [ar-worldwide.com](http://ar-worldwide.com) or call 425-485-9000.*



Other AR divisions: rf/microwave instrumentation • receiver systems • ar europe  
Copyright© 2007 AR. The orange stripe on AR products is Reg. U.S. Pat. & TM. Off.

## AROUND THE CIRCUIT

microwave, TV broadcast and radio subsystems, has been awarded a US Air Force (USAF) contract to develop an advanced Personal Locator Beacon (PLB). The new PLB will replace the aging AN/URT-33, which is a part of the survival equipment issued to USAF aircrew. The beacon will provide search and rescue satellite-aided tracking capabilities as well as multiple homing signals to assist in the location and rescue of downed aircrew.

■ **Mtel** (formerly known as Mobitel EAD), a wireless operator in Bulgaria, has selected and implemented **Andrew Corp.**'s Odyssey™ cellular radio planning software system to replace a market-leading radio planning tool. Odyssey, used by operators worldwide and backed by Andrew's global customer support services, provides radio frequency design for the complete network lifecycle and is an accurate radio prediction solution. It significantly enhances a wireless operator's ability to save network planning time and infrastructure costs.

■ **Agilent Technologies Inc.** has won a European-wide bid to supply the German Federal Armed Forces with more than 1500 digital storage oscilloscopes (DSO). The 6000 series oscilloscopes will be used by engineers and technicians to test electrical equipment at the maintenance and repair facilities of the German Air Force, Navy and Army.

■ **XCOM Wireless Inc.**, a developer of radio frequency (RF) products, has selected **Innovative Micro Technology (IMT)**, a microelectromechanical systems (MEMS) contract manufacturer, to manufacture die for the company's RF MEMS relay product. XCOM and IMT have implemented an effective wafer manufacturing process to produce RF relay die with exceptional performance, reliability and environmental ruggedness.

## FINANCIAL NEWS

■ **Plexus Corp.** reports sales of \$396.9 M for the fourth quarter of fiscal 2006 ended September 30, 2006, compared to \$322.2 M for the same period in 2005. Net income for the quarter was \$42.6 M (\$0.91/per diluted share), compared to a net income of \$10.5 M (\$0.24/per diluted share) for the fourth quarter of last year.

■ **Credence Systems Corp.**, a provider of test solutions from design-to-production for the worldwide semiconductor industry, announced that it has entered into separate privately negotiated agreements with certain holders of its outstanding 1.50 percent Convertible Subordinated Notes due 2008 (the "Outstanding Notes") under which such holders have agreed to exchange \$72.5 M aggregate principal amount of Outstanding Notes for an equivalent principal amount of a new series of 3.50 percent Convertible Senior Subordinated Notes due 2010 and to purchase an additional \$50 M aggregate principal amount of the new series of 3.50 percent Convertible Senior Subordinated Notes due 2010 (together, the "New Notes").

■ **Tower Semiconductor Ltd.** reports sales of \$51.5 M for the third quarter ended September 30, 2006, compared to





# Truly high-end

## R&S®ZVA network analyzer – the culmination of our expertise

When Rohde & Schwarz introduces a new line of high-end products, you can expect the utmost in performance and innovation. The R&S®ZVA is a good example. This family of instruments incorporates the culmination of everything that's possible in network analysis today. Each instrument offers superior RF performance paired with maximum speed, yet it's easy and intuitive to operate. The R&S®ZVA makes amplifier and mixer measurements quick and easy – including with pulsed signals, of course. Intelligent measurement wizards turn the task of making complex settings into a quick and clear-cut process, saving you time and reducing operator errors to a minimum. Let the R&S®ZVA show you just how convenient state-of-the-art network analysis can be!

- ◆ Choose from our two-port and four-port models up to 8 GHz, 24 GHz, or 40 GHz (overrange up to 43.5 GHz)
- ◆ Complex measurements such as required on high-blocking filters are straightforward owing to exceptional dynamic range and output power
- ◆ Two internal signal sources (four-port model) mean fast inter-modulation measurements and mixer characterization without an additional signal generator
- ◆ High measurement speed, optimized data transfer times, and truly parallel measurements maximize throughput in production
- ◆ And, for the first time, a new method enables you to perform pulse profile measurements of very short pulses at high dynamic range and resolution easily and cost-efficiently



# ROHDE & SCHWARZ

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

Visit <http://mwj.hotims.com/11713-120> or use RS# 120 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)

## AROUND THE CIRCUIT

\$20.6 M for the same period in 2005. Net income for the quarter was \$39.5 M (\$0.46/per share), compared to a net loss of \$55.4 M (\$0.83/per share) for the third quarter of last year.

■ **Alereon Inc.**, an ultra-wideband (UWB) technology leader for mobile WiMedia and Wireless USB solutions, announced it has received a \$4 M investment from **Samsung Ven-**

**tures'** strategic technologies investment fund.

## PERSONNEL

■ **Lord Bach of Lutterworth** has been named chairman of Selex Sensors and Airborne Systems. Lord Bach, who was UK Minister for Defence Procurement from 2001 to 2005, will bring his deep understanding and experience of the defence environment in the UK and internationally, to support the Group's growth strategy. The company has two main operating subsidiaries,

Galileo Avionica S.p.A. (Italy) and Selex Sensors and Airborne Systems Ltd. (UK), with over 4000 employees in the UK. The company also announced the appointment of **Giancarlo Grasso** as chief executive officer, with operational responsibility for the business.

■ **Xceive® Corp.**, a developer of fully integrated multi-standard RF-to-baseband transceiver ICs for TVs, announced that **Rich Beyer**, CEO and director of Intersil Corp., has joined Xceive's board of directors. Following Intersil's acquisition of Elantec Semiconductor Inc. in 2002, Beyer held the position of president in addition to his two current titles. In early 2006, Beyer shifted rolls at Intersil and took his current position as CEO and director. Beyer also serves as director of Credence Systems Corp. and is currently on the board of directors of the Semiconductor Industry Association.

■ **Amphenol Corp.** announced that it has promoted **R. Adam Norwitt** to the newly created position of president and chief operating officer. Norwitt will focus on enhancing the company's growth in new technologies and new markets. Norwitt will also be assuming an active role in the further strengthening and expansion of the company's existing business, particularly in international markets. Norwitt has held a variety of management, business development and operating positions in Amphenol operations in Asia and the United States since joining Amphenol in 1998. Most recently, he served as senior vice president of the company and group general manager of Amphenol's worldwide RF and microwave products operations.




▲ Mike Edwards

■ **Antenova** has strengthened its management team with the appointment of **Mike Edwards** as vice president of worldwide sales and marketing and the promotion



▲ CL Lim

of **CL Lim** to vice president and general manager of Asia. Edwards' role is to drive the company's global sales activities. He has extensive applica-




# All Standard Products

**Standard Products From Stock (2 Weeks)**


	GAIN	NF	P-1
SG02-2015	25	3.0	15
SG08-2015	25	2.5	15
SG18-B2012	25	3.5	12
SG12-2015	25	3.0	15
SG18-2012	25	3.5	12
SG26-2010	25	4.0	10
SG40-2010	25	8.0	10

Let Phase One Microwave support all your project needs. With over 100 man-years of microwave product experience, we are sure to meet or exceed your expectations. Contact us today for an immediate quotation.

**1840 GHz +27 dBm Psat**

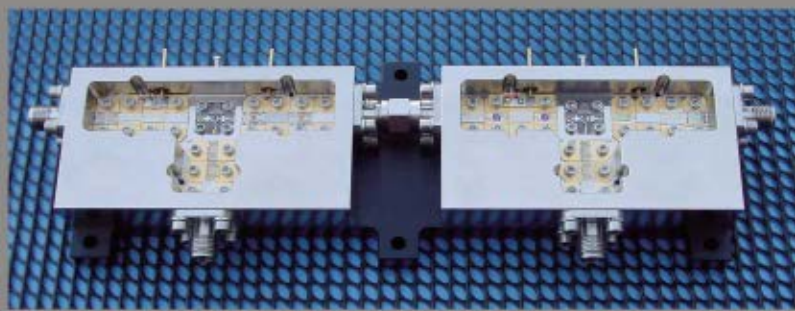


**2-18 GHz +31.5 dBm**




### Broadband Solutions

- Integrated Power Combining
- Integrated Multi Function Capability
- Frequency Up/Down Conversion
- Customer Form Fit Options



**Frequency Up/Down Conversion**

- 2 -18 GHz IN / OUT
- X2 LO Multiplier
- 25 dB Gain



**Phase One Microwave Inc.**  
[www.phase1microwave.com](http://www.phase1microwave.com)  
 Ph (916) 784-9072 Fx (916) 784-9074





# CABLES



DC to 18GHz from **\$68<sup>95</sup>** **IN STOCK** ea. (qty.1-9)

Strength, ruggedness, and reliability...*supercharged!* That's what you get when you choose Mini-Circuits ultra-flexible precision test cables. Engineered to be a workhorse for your day-to-day test operations, these triple shielded cable assemblies are qualified to at least 20,000 bends, employ an advanced strain relief system, and are equipped with passivated stainless steel connectors, so you can rely on them to **flex, connect and disconnect over and over and over again!** They're so rugged, each test cable is backed by our 6 month guarantee\*! With low insertion loss and very good return loss, you can also rely on getting good performance over the wide DC-18GHz band. Need them right away? Overnight shipment is available. So make Mini-Circuits your test cable connection! *Mini-Circuits...we're redefining what VALUE is all about!*

Custom sizes available,  
consult factory.



SMA  
Female

SMA  
Male

N-Type  
Male



Frequency Range: DC-18GHz, Impedance: 50 ohms

Models	Connector Type	Length (Ft.)	Ins. Loss (dB) Midband Typ.	Return Loss (dB) Midband Typ.	Price \$ ea. Qty.(1-9)
<b>Male to Male</b>					
CBL-1.5FT-SMSM+	SMA	1.5	0.7	27	68.95
CBL-2FT-SMSM+	SMA	2	1.1	27	69.95
CBL-3FT-SMSM+	SMA	3	1.5	27	72.95
CBL-4FT-SMSM+	SMA	4	1.6	27	75.95
CBL-6FT-SMSM+	SMA	6	3.0	27	79.95
CBL-10FT-SMSM+	SMA	10	4.8	27	87.95
CBL-12FT-SMSM+	SMA	12	5.9	27	91.95
CBL-15FT-SMSM+	SMA	15	7.3	27	100.95
CBL-2FT-SMNM+	SMA to N-Type	2	1.1	27	99.95
CBL-3FT-SMNM+	SMA to N-Type	3	1.5	27	104.95
CBL-4FT-SMNM+	SMA to N-Type	4	1.6	27	112.95
CBL-6FT-SMNM+	SMA to N-Type	6	3.0	27	114.95
CBL-15FT-SMNM+	SMA to N-Type	15	7.3	27	156.95
CBL-2FT-NMNM+	N-Type	2	1.1	27	102.95
CBL-3FT-NMNM+	N-Type	3	1.5	27	105.95
CBL-6FT-NMNM+	N-Type	6	3.0	27	112.95
CBL-15FT-NMNM+	N-Type	15	7.3	27	164.95
CBL-20FT-NMNM+	N-Type	20	9.4	27	178.95
CBL-25FT-NMNM+	N-Type	25	11.7	27	199.95
<b>Female to Male</b>					
CBL-3FT-SFSM+	SMA-F to SMA-M	3	1.5	27	93.95
CBL-2FT-SFNM+	SMA-F to N-M	2	1.1	27	119.95
CBL-3FT-SFNM+	SMA-F to N-M	3	1.5	27	124.95
CBL-6FT-SFNM+	SMA-F to N-M	6	3.0	27	146.95

**6mo. GUARANTEE** \*Mini-Circuits will repair or replace your test cable at its option if the connector attachment fails within **six** months of shipment. This guarantee excludes cable or connector interface damage from misuse or abuse.

**Mini-Circuits®**  
ISO 9001 ISO 14001 CERTIFIED

**ALL NEW**  
**minicircuits.com**

P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661 For detailed performance specs & shopping online see Mini-Circuits web site



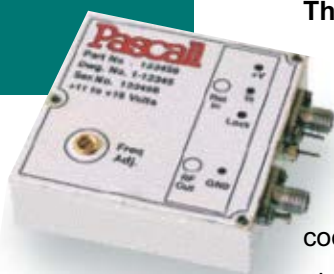
The Design Engineers Search Engine Provides ACTUAL Data Instantly From MINI-CIRCUITS At: [www.minicircuits.com](http://www.minicircuits.com)

**RF/IF MICROWAVE COMPONENTS**

403 Rev H

Visit <http://mwj.hotims.com/11713-83> or use RS# 83 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)

# Pascall oscillators hit new lows



**The Phase Locked Dielectric Resonator Oscillator series** has low power consumption and stays cool whilst delivering low phase noise, low microphony, high stability and reliability at low cost.

**The OCXO Series** has been designed to meet the increasing demand for high performance reference oscillators.

Oven-controlled crystals are used for temperature stability and low phase noise.



**Contact us for more information or to discuss your specific requirements.**

OTHER PRODUCTS FROM PASCALL:

- Digital Phase Detector
- Limiting Amplifiers
- Logarithmic Amplifiers
- Frequency Discriminators
- I & Q Demodulators
- Sub-Systems

**Pascall**

[www.pascall.co.uk](http://www.pascall.co.uk)



Pascall Electronics Limited  
Ryde, Isle of Wight PO33 1QT, UK

Tel +44(0) 1983 817300 Fax +44(0)1983 564708  
e-mail [enquiries@pascall.co.uk](mailto:enquiries@pascall.co.uk)

A Subsidiary of Emrise Electronics

## AROUND THE CIRCUIT

tions-oriented product marketing experience in the wireless device, telecoms, computer and telematics market sectors, from start-up firms to large multi-national corporations. Lim is to lead manufacturing and operations in Asia. He has more than 26 years experience in international sales, business development and technical operations and management in the wireless and telecommunication industry, which includes senior roles at Motorola and Sanmina.



▲ David Smith

■ Roke Manor Research Ltd. has appointed **David Smith** as managing director. Smith takes responsibility for a company employing more than 450 employees, a turnover of £40 M and a reputation for world-class research and development in both the defense and commercial sectors. He joined Roke in 2000 and became the head of the company's wireless business in 2001, building up the division on the strength of

its expertise in cellular technology and defense communications.

■ Kulicke & Soffa Industries Inc. announced the appointment of **Richard Boulanger** as general manager of its die bonder operations located in Berg, Switzerland. Boulanger will be responsible for overall manufacturing, R&D, product development and business operations for the facility, including the development of a next-generation die bonder platform and expansion into new markets throughout the world. Boulanger has extensive experience in semiconductor assembly. Most recently, he served as vice president of the Advanced Semiconductor Assembly Division of Universal Instruments Corp., a business unit that provided full solutions for the precision placement of flip chips and bare die.



▲ Paul J. Leo

■ CobhamDES Corp. announced the addition of **Paul J. Leo** as director, business development for the Cobham Microwave Group. Leo will oversee the domestic and international sales channels and the development of CobhamDES's strategic product integration. Leo brings more than 25 years of experience in domestic and international business development to the industry.

■ RFMW Ltd. announced **Carolyn Evans** as the company's regional sales engineer covering Pennsylvania and southern New Jersey. Evans previous experience includes eight years as a field sales engineer at California Eastern Labs, as well as stints with M/A-COM, Amplifonix and Merrimac.

## REP APPOINTMENTS

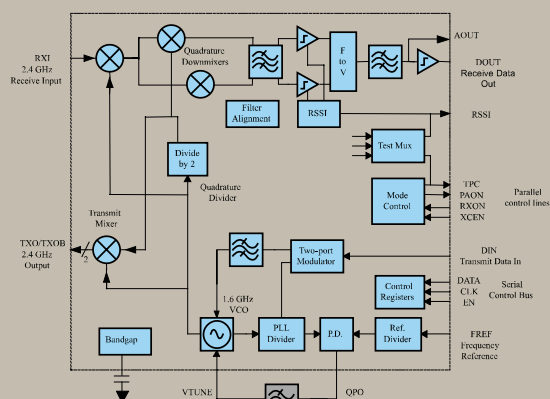
■ **Digi-Key Corp.** and **Nihon Dempa Kogyo Co. Ltd.** (NDK) announced the signing of a global distribution agreement. One of the fastest growing distributors of electronic components, Digi-Key Corp. ships products to



# New from Sirenza!

## Complete ISM Transceiver Solutions...

...all on a single Chip.



- Easy to use
- No production tuning/calibration
- 1.5Mbps – the highest data rate in its class
- Can be used with Sirenza LNA and/or PA products for improved performance
- Ideal for wireless audio or video applications
- Interfaces to many different basebands
- Transverter also available to upband existing 2.4GHz products to 5.8GHz



**Sirenza's new Transceivers feature best-in-class 1.5 Mbps data rate—ideal for streaming wireless audio and video applications.**

These fully integrated, 2FSK ISM-band transceivers include complete receiver, transmitter and synthesizer on a single chip. They are designed for simple ease-of-use with a minimum of external components and no tuning/alignment. To help customers get started quickly, Sirenza also offers a starter kit that demonstrates a working wireless link using a low-cost microcontroller and simple packet protocol.

Visit us at either [www.sirenza.com](http://www.sirenza.com) or [www.microlinear.com](http://www.microlinear.com) for more information about our new ISM transceiver and networking solutions.



RoHS and WEEE  
compliant parts  
are also available.

Visit <http://mwj.hotims.com/11713-126> or use RS# 126 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)

## Model 3100 Modular HF Receiver

Sets new performance standards with:

- Phase Coherence
- No Local Oscillators
- 10 kHz to 30 MHz coverage
- -130 dBm to +10 dBm input level
- 400 Mbps Firewire Output Connection



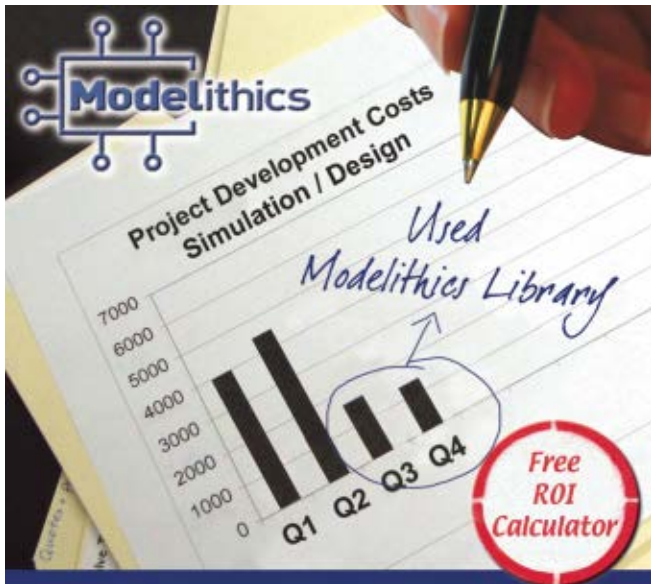
For more information on Interad surveillance, intercept, aviation, communications, and cellular products go to [www.interadlimited.com](http://www.interadlimited.com) call us at 757-787-7610, or Fax 757-787-7740



**Interad Ltd.**

Accomack Airport Industrial Park  
Melfa, VA 23410  
Email: [sales@interadlimited.com](mailto:sales@interadlimited.com)

Visit <http://mwj.hotims.com/11713-59>



**Lower Your Design Cost  
Accelerate Your Design Success**

Find out how at  
[www.modelithics.com/ROI](http://www.modelithics.com/ROI)  
or at  
[DesignerInfo@modelithics.com](mailto:DesignerInfo@modelithics.com)

Precision Measurements and Models You Trust

more than 140 countries from its single facility in Minnesota (US). The NDK surface-mount crystals and oscillators stocked by Digi-Key will be featured in both Digi-Key's print and on-line catalogs with this new distribution agreement enabling Digi-Key to fulfill both the design and production needs of its diverse customer base.

■ **Unity Wireless Corp.** announced that it has successfully signed a distribution agreement with Russia's largest wireless equipment distribution company. This agreement now gives Unity much needed relationships and access to Russia's tier-1 wireless network operators for the outdoor and new indoor repeater line of products.

■ **Auriga Measurement Systems LLC** announced the signing of four new representatives for its custom test, characterization, and modeling systems and services. **ProTEQ Solutions Inc.** will be the company's exclusive representative in five New England states while **Jay Stone Associates (JSA)**, San Jose, CA, will cover northern California and northern Nevada. Existing representative **CWI Technical Sales** has expanded its territory to the entire east coast beyond New England. **Sematron UK Ltd.** has signed on as exclusive distributor for the UK and Ireland while **Testforce Systems Inc.** will exclusively cover Canada.

■ **MITEQ Inc.** announced the appointment of **SpanTech Microwave Technology S.A.** as the company's exclusive sales representative in Spain and Portugal. SpanTech Microwave 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 multifunction assemblies and fiber optic products. SpanTech Microwave can be contacted at +34-95-241-7024 or e-mail: [sales@spantech.es](mailto:sales@spantech.es).

■ **Temex** has concluded a representative agreement with **Nearzenith Technologies** to promote and sell the company's range of components, which includes SAW filters, VCOs, PLL synthesizers, crystal resonators and crystal oscillators, in China. Nearzenith Technologies is based in Shenzhen, Guangdong Province, China, and has branches in Hong Kong, Shanghai and Nanjing. The company has 21 employees, annual revenue of \$6 M and clients in South, East, Central, Southwest and Northwest China.

■ **W.L. Gore & Associates**, a provider of aerospace wire and high data rate cable, announced **A.E. Petsche Co.** as the exclusive North America distributor of GORE™ Bulk Wire and Cable. This agreement enables Gore to continue to provide its key customers with excellent service and sales support.

■ **Zilker Labs Inc.** announced that it has signed **TLG Electronics Ltd.** as a distribution partner in China. TLG will complement the efforts of Zilker Labs' Asian subsidiary, Hong Kong-based Zilker Labs Asia Ltd., to expand Zilker Labs' Chinese business. Specifically, TLG will focus on forging new customer relationships and providing applications support to developing programs.



# Broadband Amplifiers by AML Communications

To Order Call: (805)388-1345 ext. 203

Model	Frequency (GHz)	Gain (dB)	Flatness (dB) max	NF (dB) max	P1dB (dBm) min	VSWR (In/Out)	DC Current @ +12/+15VDC
<b>Broadband Low Noise Amplifiers</b>							
AML016L2802	0.1 – 6.0	28	±1.25	1.3*	+7	2.0:1	190
AML48L3001	4.0 – 8.0	30	±1.0	1.2	+10	1.8:1	150
AML412L3002	4.0 – 12.0	30	±1.5	1.5	+10	1.8:1	150
AML218L0901	2.0 – 18.0	9	±1.0	2.2	+5	2.5:1	60
AML0518L1601-LN	0.5 – 18.0	16	±1.0	2.7	+8	2.2:1	100
AML0126L2202	0.1 – 26.5	22	±2.25	3.5*	+8	2.2:1	170
AML1226L3301	12.0 – 26.5	33	±2.0	2.8	+8	2.5:1	200

## Broadband Medium Power Amplifiers

AML0016P2001	0.01 – 6.0	21	±1.25	3.2*	+23*	2.0:1	480
AML26P3001-2W	2.0 – 6.0	28	±2.5	6	+33	1.8:1	1500
AML28P3002-2W	2.0 – 8.0	30	±2.0	5.5	+33	2.0:1	2000
AML218P3203	2.0 – 18.0	32	±2.5	4	+25	2.0:1	450
AML618P3502-2W	6.0 – 18.0	35	±2.5	4	+33	2.0:1	1850

## Narrow Band Low Noise Amplifiers

AML23L2801	2.8 – 3.1	28	±0.75	0.7	+10	1.8:1	150
AML1414L2401	14.0 – 14.5	24	±0.75	1.5	+10	1.5:1	130
AML1718L2401	17.0 – 18.0	24	±0.75	1.6	+10	1.8:1	150

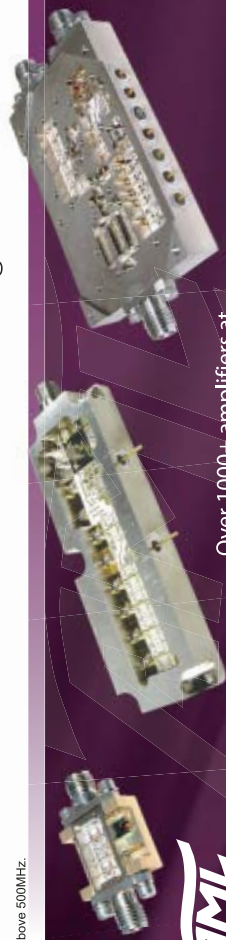
## Low Phase Noise Amplifiers

Part Number	Frequency (GHz)	Gain (dB)	Output Power (dBm)	100Hz	1KHz	10KHz	100KHz
<b>Phase noise (dBc/Hz) at offset</b>							
AML811PN0908	8.5 – 11.0	9	17	-154	-159	-167	-170
AML811PN1808	8.5 – 11.0	18	18	-152.5	-157.5	-165.5	-168
AML811PN1508	8.5 – 11.0	15	28	-145.5	-153.5	-158.5	-164.5
AML26PN0904	2.0 – 6.0	9	20	-150	-165	-165	-178
AML26PN1201	2.0 – 6.0	11	15	-155	-160	-160	-175

## High Dynamic Range Amplifiers

Part Number	Frequency (MHz)	Gain (dB)	P1dB (dBm)	OIP3 (dBm)	DC
AR01003251X	2 – 32	21	32	52	+28V @ 470mA
AFL30040125	50 – 500	23	28	53	+28V @ 700mA
BP60070024X	20 – 2000	32	30	43	+15V @ 1100mA

\*Above 500MHz.



Communications

Camarillo, CA (805)388-1345 ext. 203

Visit <http://mwj.hotims.com/11713-18> or use RS# 18 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)

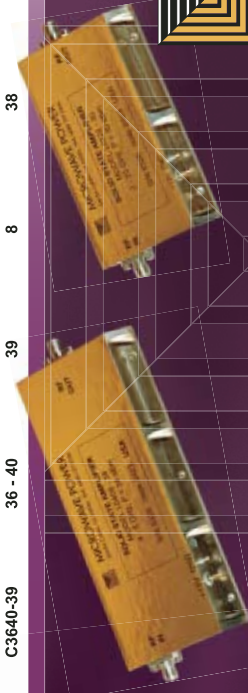
Over 1000+ amplifiers at

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

# Power Amplifiers by Microwave Power

To Order Call: (408)727-6666 ext. 42

Model	Frequency (GHz)	Psat (dBm)	Psat (W)	P1dB (dBm)	Gain (dB)	DC Current(A) @ +12V or +15V
<b>Broadband Microwave Power Amplifiers</b>						
L0104-43	1 - 4	42.5	17.8	41.5	45	14
L0204-44	2 - 4	44	25	42.5	45	14
L0206-40	2 - 6	40	10	38.5	40	8.5
L0208-41	2 - 8	41	12	40	40	17
L0218-32	2 - 18	32	1.4	31	35	5
L0408-43	4 - 8	43	20	41.5	45	17
L0618-43	6 - 18	43	20	41.5	45	22
L0812-46	8 - 12	46	40	45	45	28
<b>Millimeter-Wave Power Amplifiers</b>						
L1826-34	18 - 26	34	2.5	33	35	4
L1840-27	18 - 40	27	0.5	26	30	2
L2240-28	22 - 40	28.5	0.7	27	30	3
L2630-39	26 - 30	39	8.0	38	40	15
L2632-37	26 - 32	37	5.0	36	38	10
L2640-31	26 - 40	31	1.2	30	30	5
L3040-33	30 - 40	33	2.0	32	33	9
L3337-36	33 - 37	36	4.0	35	40	12
L3640-36	36 - 40	36	4.0	35	40	10
<b>High-Power Rack Mount Amplifiers</b>						
Model	Frequency (GHz)	Psat (dBm)	Psat (W)	P1dB (dBm)	Pac (kW)	Height (in)
C071077-52	7.1 - 7.7	52.5	170	51.5	1.8	10.25
C090105-50	9 - 10.5	50	100	49	1	8.75
C140145-50	14 - 14.5	50.5	110	49.5	2	10.25
C1416-46	14 - 16	46	40	45	0.35	5.25
C1820-43	18 - 20	43	20	41.5	0.25	5.25
C2326-40	23 - 26	40	10	39	0.25	5.25
C2630-45	26 - 30	45	30	44	0.45	5.25
C3236-40	32 - 36	40	10	39	0.25	5.25
C3640-39	36 - 40	39	8	38	0.24	5.25



Microwave Power

An AML Communications Company

Santa Clara, CA (408)727-6666 ext. 42

Look for some serious power at

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





## RF Distribution Unit

Planar Electronics Technology's new configurable system platform, the PET-VI is user configurable and is easily adaptable to meet many military and commercial requirements. The PET-VI features a 6" color LCD touch screen display which allows easy system control and configuration. This platform consists of three plug and play, field replaceable modules, namely the power supply module, computer module, and the RF module.



### Possible Applications:

- Airborne RF Distribution Units
- Broadband Switch Matrices
- RF Attenuation featuring internal computer controlled linearization and touch screen attenuation selection.
- State-of-the-Art Up/Down Converters with integrated options such as linearized attenuation features and many others.
- High Speed Frequency Synthesizers
- Log Amplifiers featuring touch screen log slope selection.
- Multiple RF functions. The PET-VI RF Module can be populated to meet your desired system functions.

### Features:

- Airborne Ruggedized 19" Rack Mount Chassis, 6U Height, 18" Deep
- 6" Color LCD Touch Screen Display
- Arcom SBC-GX533 400MHz Single Board Computer featuring AMD Geode GX Processor
- Linux or Windows CE Operating System
- Compact Flash contains all boot up and operation software. Can be removed for security purposes.
- Compatible with RS-232-C, RS-422, RS-485, PECL, TTL, and Ethernet protocols.
- Current monitoring of every internal RF component. Failures are displayed on the front panel display.
- Cooling Fan speed monitoring. Fan failures are displayed on the front panel display.
- RF module internal temp. monitoring. Over temp. conditions are displayed on the front panel display.
- Plug & Play, Modular design allowing in-the-field repairs & flexibility for custom configs. (3 Modules)
  - Power Supply Module can contain any required power supply.
  - Computer Module can be switched out in minutes.
  - RF Module can contain any set of RF components required.
- Up to 320 individual control lines can be accommodated.

**Planar Electronics Technology & Planar Filter Company - (A division of Planar Electronics Technology, Inc.)**

Phone: 1.877.PLANAR1 • 301.662.5019 • FAX: 301.662.1731

5715 Industry Lane, Unit 11, Frederick, MD 21704 USA

Email: [PET-SALES@planarelec.com](mailto:PET-SALES@planarelec.com) • Web: [www.planarelec.com/02](http://www.planarelec.com/02)

FREE on-line order tracking system updated daily.

Track your order on-line at <http://www.planarelec.com/OrderStatus/>



# Don't Miss the Opportunity...

## ...for these Incredible Savings!



### RF / Microwave Amplifiers on SALE for only \$495 each

New amplifiers listed at  
[www.planarelec.com/02](http://www.planarelec.com/02) are now on  
sale for only \$495 each

All narrow band to Ultra-Broadband amplifiers covering the frequency range of 30 MHz to 20 GHz with 30 dB of gain or less are now offered for a low fixed price of \$495 each when 10 or more pieces are ordered.



New listings offering hundreds of new models.

All LCA Series (Low-Cost - From Stock) models that are priced over \$495 are included in this sale when 10 or more pieces are ordered.



Terms and Conditions: This sale applies only to amplifiers that are ordered between January 1, 2007 and March 31, 2007. The sale is only for amplifiers listed on the present PET web site. The sales price is for any listed amplifier that has 30 dB of gain or less and has a maximum operating frequency of 20 GHz. The ten piece minimum order requirement must be met. Up to three different models totaling ten pieces may be ordered and will still be considered to meet the minimum order requirement. The specifications shown are typical. If a specific guaranteed specification is required please specify this requirement at the time of ordering and additional charges may apply. PET reserves the right to change the contents of its web site and/or model availability at anytime without notice. Specifications are subject to change without notice.

Visit <http://mwj.hotims.com/11713-104> or use RS# 104 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)

# A CMOS FREQUENCY SYNTHESIZER WITH SELF-BIASING CURRENT SOURCE FOR A 5 GHz WIRELESS LAN RECEIVER

*This article describes a fully integrated 3.2 GHz synthesizer with a self-biasing current source for a 5 GHz wireless LAN receiver in the lower UNII band from 5.15 to 5.35 GHz. The circuit has been designed using a 0.18  $\mu\text{m}$  one-poly six-metal CMOS technology of UMC. OFDM is considered one of the most attractive transmission techniques for future wireless multimedia communications in frequency selective channels. However, it also has the disadvantage of an increased sensitivity to phase noise generated by the local oscillators inside a communication transceiver. In order to achieve a high performance device, therefore, the simulation tool Simusyn has been implemented to predict the phase noise, spurious emissions and lock time of the synthesizer before its fabrication. The synthesizer consumes 53 mW with a power supply of 3.3 V. Furthermore, it has a bandwidth of 20 kHz and a phase noise of  $-118$  dBc/Hz at 1 MHz offset frequency resulting in a total integrated phase noise over the channel bandwidth less than  $-32$  dBc. Finally, the spurious sidebands at the center of adjacent channels do not exceed  $-64$  dBc. These results made the circuit suitable inside a UNII band 5 GHz wireless LAN receiver.*

In the past several years, the wireless local area network (WLAN) market has grown significantly due to the great demand for high speed wireless connectivity. Furthermore, there is a constant desire to keep power consumption, cost and size of the communication devices to a minimum. This has been possible thanks to continuing advances in integrated circuit (IC) technology allowing the development of devices capable of operating at multiple gigahertz carrier frequencies with data rates competitive with established wired alternatives.<sup>1,2</sup> In 1999, the IEEE ratified two

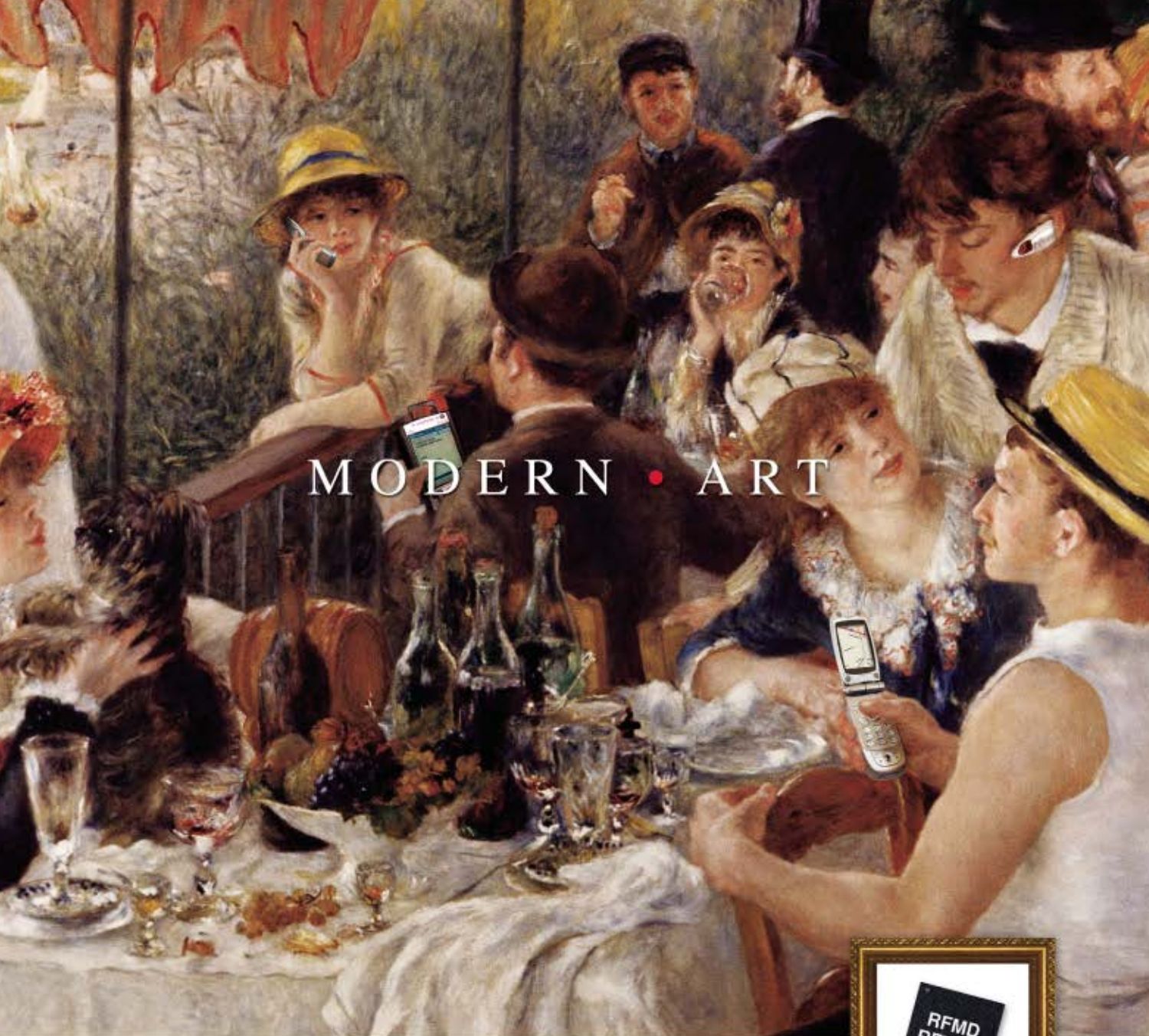
wireless networking communications standards named 802.11a and b. The 802.11b standard operates in the 2.4 GHz industrial-

---

C. QUEMADA, H. SOLAR AND G. BISTUÉ  
*Centro de Estudios e Investigaciones  
Técnicas de Gipuzkoa (CEIT)  
San Sebastián, Spain*

J. DE NO AND I. SANCHO  
*Escuela Superior de Ingenieros Industriales de  
San Sebastián (Universidad de Navarra)  
Spain*





## MODERN • ART



With innovation, integration and performance, RFMD® keeps the conversation going long after the competition has lost the energy to keep pace. Utilizing our leading **PowerStar®** power amplifier technology with integrated power control, pHEMT switch technology and integrated transmit filtering, the RF7115 transmit module features quad-band transmit capability and four receive ports, enabling use in all geographic combinations of GSM/GPRS handset configurations. Thus, not only can we bring people together from all corners of the globe, we can keep them connected well into the midnight hours. RFMD. We're discovering **what's next in RF.**

### RF7115

<ul style="list-style-type: none"> <li>• <b>PowerStar®</b> power amplifier with integrated power control, antenna switch, current limiter and harmonic filtering</li> </ul>	<ul style="list-style-type: none"> <li>• GSM 850/900 system efficiency &gt;40%, equivalent to &gt;50% PA PAE</li> </ul>
<ul style="list-style-type: none"> <li>• Laminate package technology in 7x8x1.2mm form factor</li> </ul>	<ul style="list-style-type: none"> <li>• DCS / PCS system efficiency &gt;38%, equivalent to &gt;48% PA PAE</li> </ul>
<ul style="list-style-type: none"> <li>• +33.5 dBm GSM <math>P_{OUT}</math> at 3.5V</li> </ul>	<ul style="list-style-type: none"> <li>• 2-6 dBm drive level, &gt;50 dB of dynamic range</li> </ul>
<ul style="list-style-type: none"> <li>• +31.0 dBm DCS <math>P_{OUT}</math> at 3.5V</li> </ul>	<ul style="list-style-type: none"> <li>• Controlled harmonic levels &lt;-35 dBm across all power levels</li> </ul>
	<ul style="list-style-type: none"> <li>• Low Insertion loss in receive path</li> </ul>

**RFMD** 

rfmd.com

[Invention is the art of science.]

scientific-medical (ISM) band, using direct-sequence spread-spectrum (DSSS) modulation, while the 802.11a standard operates in the 5 GHz unlicensed national information infrastructure (UNII) band. On the other hand, 802.11a employs orthogonal frequency division multiplexing (OFDM) in order to compete more effectively with the peculiarities of indoor propagation.<sup>1</sup> The UNII frequency band provides 300 MHz of spectrum at 5 GHz (see **Figure 1**). Those 300 MHz are divided into two frequency segments: a contiguous 200 MHz portion from 5.15 to 5.35 GHz and a separate 100 MHz segment from 5.725 to 5.825 GHz. Furthermore, depending on the allowed maximum level of transmitted powers, these frequency assignments are split into three equal domains. The bottom 100 MHz domain is limited to a maximum transmitted power of 50 mW, the next 100 MHz to 250 mW and the top 100 MHz to a maximum of 1 W (outdoor communications).<sup>3</sup> OFDM modulation subdivides a carrier into several individually modulated orthogonal subcarriers, all of which are subsequently transmitted in parallel. This technique mitigates the effect of multi-path. In the 802.11a standard, each OFDM channel consists of 52 subcarriers in a 16.6 MHz bandwidth (channel spacing of 20 MHz); 48 subcarriers are for data, the rest are for error correction (pilot signals).<sup>2,3</sup> Thanks to this

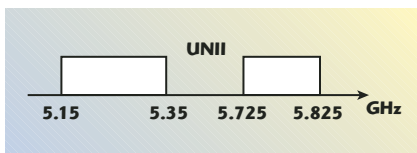
subdivision, a variety of data rates with different modulations are possible, permitting different levels of service. Therefore, the data can be modulated with BPSK, QPSK, 16QAM, or 64QAM with data rates of 6 Mb/s, 12 Mb/s, 24 Mb/s and 54 Mb/s, respectively. The medium access control (MAC) protocol used to give multiple users access to a shared environment is the carrier sense multiple access with collision avoidance (CSMA/CA).<sup>3</sup>

The aim of this article is to implement a frequency synthesizer design flow. This design flow achieves two important improvements: prediction of the synthesizer specifications before its fabrication and reduction in the number of fabrication runs, minimizing the overall manufacturing cost and development time. The new generation systems that utilize OFDM modulation are extremely sensitive to phase noise, which is present in the up- and down-conversion synthesizers. Therefore, a proper prediction is essential to design a high performance device. A design flow has been implemented thanks to the development of a Matlab simulation tool that predicts the phase noise, spurious emissions and lock time of a frequency synthesizer with great accuracy before its fabrication. This procedure has been applied to the design of a frequency synthesizer for the IEEE 802.11a standard UNII band from 5.15 to 5.35 GHz. This synthesizer is part of a greater development, focused on the implementation of a heterodyne receiver built in a standard 0.18  $\mu\text{m}$  CMOS technology. This choice is based on the continuing advances made in CMOS technology, which make high volume, low

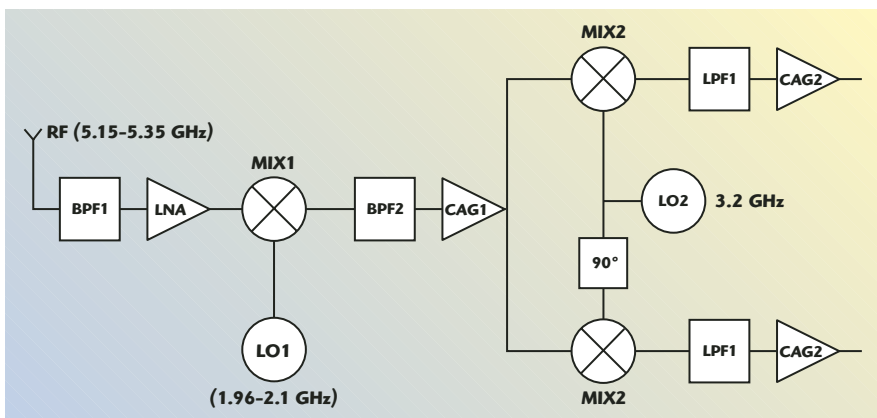
cost and high frequency solutions possible. Finally, since the 802.11a and HIPERLAN2 standards share many performance requirements for the RF signal processing blocks, this synthesizer will also be suitable for HIPERLAN2.<sup>1</sup>

## PERFORMANCE REQUIREMENTS

A rigorous choice of the performance requirements for the synthesizer is fundamental in order to achieve a competitive device within the WLAN market. The most important performance requirements are the operating frequency, frequency stability, crystal reference frequency, phase noise, spurious emissions and lock time. The requirements have been obtained from the IEEE 802.11a and HIPERLAN2 standards, and considering the fact that in a system with OFDM multiplexing, the synthesizer phase noise introduces intercarrier interference (ICI) and leads to a degradation in the signal-to-noise ratio (SNR). The operating frequency of the synthesizer depends on the receiver architecture chosen, which is a heterodyne receiver with the second downconversion in quadrature, as shown in **Figure 2**. The main focus of this article is the implementation of the second local oscillator (LO2), which works at 3.2 GHz. An external 20 MHz crystal oscillator is used, matching up with the channel spacing for the IEEE 802.11a standard. Furthermore, this standard requires a maximum crystal frequency tolerance of  $\pm 20$  ppm. Therefore, a crystal frequency tolerance less than that value is acceptable.<sup>3</sup> OFDM systems exhibit a sensitivity to phase noise higher than single carrier modulations. Because of this, the phase-noise specification is a key point in the synthesizer design. For that reason, two phase-noise specifications have been considered: VCO phase noise at 1 MHz offset and synthesizer total integrated phase noise over the channel bandwidth (20 MHz). The phase-noise requirements at 1 MHz offset come from two considerations: interferer strength and sensitivity of the OFDM scheme to phase impairments. With respect of the first consideration, for the highest data rate of 54 Mb/s, the receiver sensitivity is  $-65$  dBm, and allowing for an adjacent interferer 40 dB stronger than



▲ Fig. 1 The UNII frequency band.



▲ Fig. 2 Receiver architecture.



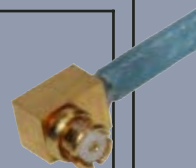
# SOLUTIONS

**RF, microwave and millimeter wave connectors, adapters, cable assemblies and resistive components for military and test/instrumentation applications.**

Solve your RF interconnect problem today. If the right product isn't already in stock at SV Microwave, our exceptional engineering staff will design your solution and our lean manufacturing will deliver. For over 40 years we've been reliably supplying all types of solutions to the world's most discerning OEMs.



- All popular coaxial connector interfaces
- Blindmates, push-ons and ZMAs
- Space-qualified Hi-Rel
- QPL and DSCC approved
- Precision and high frequency
- Cable assemblies
- Resistive components



## SV MICROWAVE®

RF Connectors & Components  
an Amphenol Company

***The performance you need. The quality you demand.***

**[www.svmicrowave.com](http://www.svmicrowave.com) | 561.840.1800**

Visit <http://mwj.hotims.com/11713-132> or use RS# 132 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)

the desired channel, the VCO phase noise needs to be lower than  $-132$  dBc/Hz at 17.3 MHz offset. This result has been obtained by integrating the phase noise over the adjacent channel (20 MHz) and assuming a pre-detection SNR of 19 dB for a BER of  $10^{-6}$  in a 64-QAM system. Since the VCO phase-noise spectrum decreases 20 dB per decade, its value will be  $-107$  dBc/Hz at 1 MHz offset. Furthermore, the degradation added

by the second consideration must be included. The phase noise in the OFDM system introduces intercarrier interference (ICI) and leads to a degradation in SNR. For an SNR degradation less than 0.1 dB, the phase-noise specification at 1 MHz offset should be at least  $-110$  dBc/Hz, assuming a 64QAM modulation with subcarrier spacing of 312.5 kHz and pre-detection SNR of 19 dB.<sup>4</sup> Therefore, in order to meet the require-

ments for the IEEE 802.11a standard, the VCO should have a phase-noise performance of at least  $-110$  dBc/Hz at 1 MHz offset.

What is left to be determined is the total integrated phase noise, which is related to the synthesizer bandwidth. The influence of this requirement in OFDM-WLAN systems is well explained by Côme, et al.<sup>5</sup> According to this reference, a total integrated phase noise of  $-32$  dBc results in low BER degradation for 64QAM modulation. Therefore, with the aim of fulfilling the requirements for the IEEE 802.11a standard, the total integrated phase noise must be at least  $-32$  dBc. The spurious emissions also play an important role in the new generation of OFDM-WLAN systems. In an integer frequency synthesizer, the dominant spurious emissions appear at multiples of the reference frequency, matching up in this case with the crystal oscillator frequency. Using the first consideration made previously for the phase noise, the spurious emissions level should be at least  $-59$  dBc.<sup>4</sup> Finally, the maximum setting time to switch from one channel to another is 1 ms.<sup>3</sup>

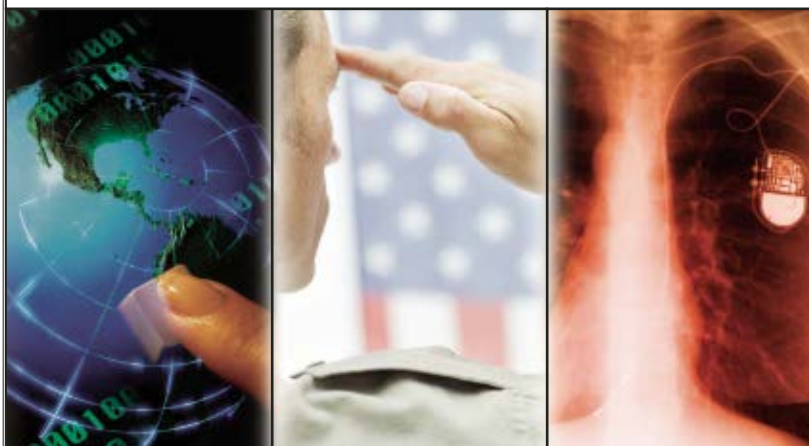
### ACCURATE PREDICTION IN PHASE-LOCKED LOOPS

Some aspects of the synthesizers, such as phase noise, spurious emissions and lock time ( $T_L$ ), can be key issues in a communications system design.<sup>6</sup> As previously presented, the present-day systems that utilize OFDM modulation are extremely sensitive to phase noise. Additionally, the reference spurs have a notable influence on the adjacent channel interferer. A high performance design requires an accurate prediction of the phase noise, spurs and lock time. Therefore, a simulation tool has been developed using Matlab to solve this problem. This simulation tool analyzes the influence of different synthesizer parameters, such as the output frequency ( $f_{out}$ ), reference frequency ( $f_{ref}$ ), VCO gain ( $K_{vco}$ ), charge pump current ( $K_\phi$ ), loop bandwidth ( $\omega_p$ ), spurs attenuation (ATTEN) and the division ratio ( $N$ ), in the phase noise, spurs and lock time.<sup>7</sup>

### Phase-locked Loop (PLL)

A phase-locked loop (PLL) is a feedback system that operates on the

## Aerospace, Defense, Medical ... state of the art resistors



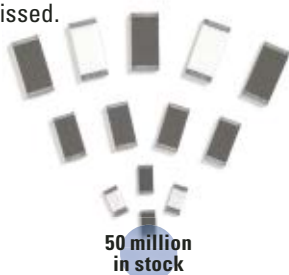
When a window of opportunity can't be missed.

When being on target saves lives.

When a life depends on it.

You need State of the Art resistors.

Superior quality... established reliability.



**USA made, technology you can't resist.**



**State of the Art, Inc.**

**RESISTIVE PRODUCTS**

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

2470 Fox Hill Road, State College, PA 16803-1797  
Phone: 800-458-3401 or 814-355-8004  
Fax: 814-355-2714, E-mail: [sales@resistor.com](mailto:sales@resistor.com)

#### QUALIFICATIONS

ISO9001 & AS9100  
MIL-PRF-55342  
MIL-PRF-32159  
MIL-PRF-914



# Replace your SRD

## with Low Phase Noise NLTL-based Comb Generators!

### Picosecond NLTL Comb

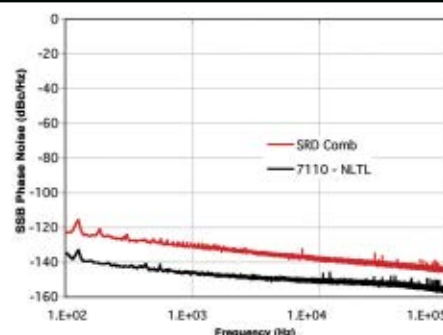
- ✓ Phase noise =  $20\text{LogN!}$
- ✓ Low input power of 20dBm
- ✓ Variable inputs
- ✓ Freq harmonics to 50GHz!

NLTL comb generators  
beat ~~SRD's~~ across the board!

### ~~SRD Combs~~

- Noisy
- 27dBm required
- Fixed input only
- Roll-off at >20GHz

### ULTRA-LOW Phase Noise



Model 7110 and SRD residual phase noise comparison. 200MHz, 19dBm input. Measured at 2GHz or 10th harmonic.

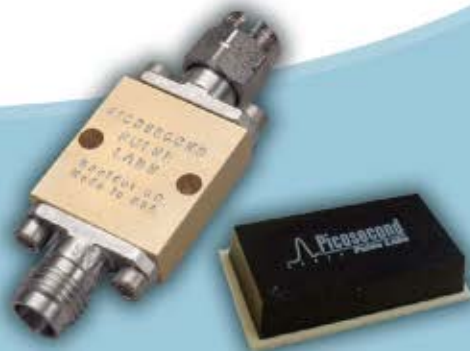
### ► LOW PHASE NOISE COMB GENERATOR FEATURES:

- **20LogN multiplication** with the cleanest sources!
- New design possibilities with **Variable Input Power and Frequency**
- Flexible system design with **Lower Input Power**

Model	Typical Input Power	Min Input Frequency	Max Output Frequency	High Output Harmonic
7100	20-24 dBm	100 MHz	400 MHz	20 GHz
7102	20-24 dBm	300 MHz	700 MHz	20 GHz
7103	20-24 dBm	500 MHz	1.2 GHz	30 GHz
7110	25-29 dBm	100 MHz	300 MHz	20 GHz
7112	25-29 dBm	300 MHz	700 MHz	20 GHz
7113	25-29 dBm	500 MHz	1.2 GHz	30 GHz
7123	25-29 dBm	800 MHz	1.4 GHz	50 GHz
7124	25-29 dBm	1.6 GHz	2.4 GHz	50 GHz

\*Choose the right model for your application\*

### ► ALSO AVAILABLE IN SURFACE MOUNT



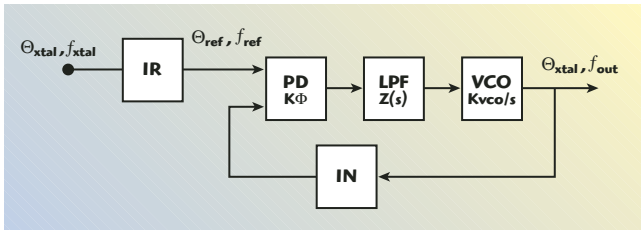
The Technology Leader in  
High-Speed Analog Signals

**Picosecond**  
Pulse Labs

2500 55th Street, Boulder, CO 80301 • Tel: (303) 209 8100 • Fax: (303) 447 2236

Contact a knowledgeable Sales Representative at 303-209-8100 for more information  
or go to [www.picosecond.com/comb](http://www.picosecond.com/comb)

Visit <http://mwj.hotims.com/11713-103> or use RS# 103 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)



▲ Fig. 3 Phase-locked loop.

excess phase of nominally periodic signals. A PLL consists of a phase detector (PD), a low pass filter (LPF), a volt-

age-controlled oscillator (VCO) and two frequency dividers whose division ratios are N and R (see **Figure 3**). The filter impedance  $Z(s)$  is calculated as the ratio of the output voltage to the input current. The units of  $K_{vco}$  and  $K_\phi$  are Hz/V and A, respectively.

### Spurs Level

The reference spurs, which appear at multiples of the reference frequency, can be classified into two kinds of spurious emissions: spurs based on leakage currents (leakage spurs) (Equation 1) and spurs based on charge pump mismatches (pulse spurs) (Equation 2)<sup>7</sup>

$$\text{leakage\_spurs} = \text{base\_leakage\_spur}$$

$$+20 \log \left| \frac{\text{leakage}}{K_\phi} \right| + \text{spur\_gain} \quad (1)$$

$$\text{pulse\_spurs} = \text{base\_pulse\_spur}$$

$$+40 \log \left| \frac{f_{ref}}{1\text{Hz}} \right| + \text{spur\_gain} \quad (2)$$

where base\_leakage\_spur is equal to 16 dBc and base\_pulse\_spur depends on charge pump mismatches, unequal transistor turn-on times and dead-zone elimination circuitry. Leakage is the parasitic leakage current through the charge pump, VCO and loop filter capacitors when the charge pump is in the tri-state state that is ideally high impedance. Finally, spur\_gain can be calculated with Equation 3 and the total spur level is obtained by means of the sum of leakage\_spurs and pulse\_spurs

$$\text{spur\_gain} =$$

$$20 \log \left| \frac{K_{vco} K_\phi Z(s)}{s} \right|_{s=j2\pi f_{ref}} \quad (3)$$

For older PLLs, where the leakage currents were in the microamp range, it is customary to model the reference spurs based entirely on leakage currents. However, modern PLLs typically have leakage currents of 1 nA or less, and therefore the pulse\_spurs tend to be dominant, except at very low reference frequencies.

### Phase Noise

The main PLL noise sources usually considered include: phase detector, VCO, crystal reference, frequency divider and loop filter. Equations 4 to 8 allow calculating the contribution to the total phase noise of each noise sources, respectively<sup>7</sup>

## Mission-capable microwave assemblies

Aerospace and defense to sat launch and commercial applications, Herley integrated microwave assemblies simplify vertical integration, function with power levels of up to 2 kW, and cover 0.5 to 40 GHz. Herley microwave assemblies add capability and performance on land, sea, and in the air.

With a strong technical base and a commitment to on-going R&D, Herley remains a leader in satisfying the challenges for more capable and more intelligent microwave assemblies.

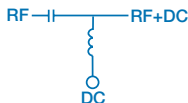
To find out more, call us or visit us on the web at [www.herley.com](http://www.herley.com).

- Amplifiers
- Attenuators
- Phase Shifters
- Limiting Amplifiers
- Synthesizers
- Limiters
- Delay Lines
- Analog and Digital Circuits
- Switches
- Filters
- Mixers
- Oscillators
- Hybrid Circuits
- Equalizers
- Couplers

**HERLEY** Industries, Inc. **Proven Microwave Performance**  
[www.herley.com](http://www.herley.com)

Herley New England, 10 Sonar Dr., Woburn, MA 01801 • Telephone: 781-729-9450  
 FAX: 781-729-9547 • [www.herley.com](http://www.herley.com) • E-Mail: [sales@herleynewengland.com](mailto:sales@herleynewengland.com)





# BIAS-TEES

Now up to 500mA DC current 100 kHz-12 GHz

Mini-Circuits is your complete source for Bias-Tees, covering from 100 kHz to 12 GHz and handling up to 500mA DC in a variety of coaxial, plug-in, and surface mount packages. All of our Bias-Tees boast low insertion loss and VSWR. Our patented TCBT LTCC ceramic designs are the smallest in the world and are ready for your projects where very low price, space limitation, and temperature stability are a must. Our ultra-wideband ZX85 Bias-Tees use our patented Unibody construction to give you small size and high repeatability. Whether your applications call for biasing amplifiers, laser diodes, or active antennas, DC blocking, DC return, satellite communications, test, or if you have custom requirements, just contact Mini-Circuits and let us fit your needs to a "TEE"!



ZX85+ ZNBT ZFBT-FT ZFBT JEFT PBTC TCBT  
\* LTCC TECHNOLOGY  
ZX85+ RoHS compliant.

**\$395\*** IN STOCK  
from ea. Qty. 1000

## TYPICAL SPECIFICATIONS

Model	Freq (MHz)	Insertion Loss (dB)	Isolation (dB)	VSWR (1:1)	Price \$ea. Qty:10
TCBT-2R5G	20-2500	0.35	44	1.10	6.95*
TCBT-6G	50-6000	0.7	28	1.20	9.95
TCBT: LTCC, Actual Size .15"x.15", U.S. Patent 7,012,486.					
					Qty:1-9
JEFT-4R2G	10-4200	0.6	40	1.10	39.95
JEFT-4R2GW	0.1-4200	0.6	40	1.10	59.95
PBTC-1G	10-1000	0.3	33	1.10	25.95
PBTC-3G	10-3000	0.3	30	1.13	35.95
PBTC-1GW	0.1-1000	0.3	33	1.10	35.95
PBTC-3GW	0.1-3000	0.3	30	1.13	46.95
ZFBT-4R2G	10-4200	0.6	40	1.13	59.95
ZFBT-6G	10-6000	0.6	40	1.13	79.95
ZFBT-4R2GW	0.1-4200	0.6	40	1.13	79.95
ZFBT-6GW	0.1-6000	0.6	40	1.13	89.95
ZFBT-4R2G-FT	10-4200	0.6	N/A	1.13	59.95
ZFBT-6G-FT	10-6000	0.6	N/A	1.13	79.95
ZFBT-4R2GW-FT	0.1-4200	0.6	N/A	1.13	79.95
ZFBT-6GW-FT	0.1-6000	0.6	N/A	1.13	89.95
ZNBT-60-1W	2.5-6000	0.6	45	1.10	82.95
ZX85-12G+ <b>NEW</b>	0.2-12000	0.6	N/A	1.20	99.95
ZX85: U.S. Patent 6,790,049.					

Note: Isolation dB applies to DC to (RF) and DC to (RF+DC) ports.

**Mini-Circuits®**  
ISO 9001 ISO 14001 CERTIFIED

**ALL NEW**  
**minicircuits.com**

P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661 For detailed performance specs & shopping online see Mini-Circuits web site



The Design Engineers Search Engine Provides ACTUAL Data Instantly From MINI-CIRCUITS At: [www.minicircuits.com](http://www.minicircuits.com)

**RF/IF & MICROWAVE COMPONENTS**

395 Rev F

Visit <http://mwj.hotims.com/11713-84> or use RS# 84 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)

$$L_{PD}(f) = L_{1Hz} f_{ref} \left| \frac{G(s)N}{1+G(s)} \right|_{s=j2\pi f}^2 \quad (4)$$

$$L_{VCO}(f) = \ell_{vco} \left| \frac{1}{1+G(s)} \right|_{s=j2\pi f}^2 \quad (5)$$

$$L_{XTAL}(f) =$$

$$\ell_{txo} f_{ref} \left| \frac{G(s)N}{R(1+G(s))} \right|_{s=j2\pi f}^2 \quad (6)$$

$$L_{DIV}(f) = \ell_{div} \left| \frac{G(s)N}{1+G(s)} \right|_{s=j2\pi f}^2 \quad (7)$$

$$L_{term}(f) = \frac{2kTRK_{vco}^2 TR}{f^2} \quad (8)$$

$L_{1Hz}$  = 1 Hz normalized phase detector noise floor

$\ell_{vco}$  = VCO phase noises

$\ell_{txo}$  = crystal reference phase noises

$\ell_{div}$  = frequency divider phase noises

TR = transfer function to calculate the noise voltage at the filter output

f = frequency offset

G(s) = Equation 9

$$G(s) = \frac{K_{vco} K_{\phi} Z(s)}{N_s} \quad (9)$$

The normalized phase detector noise floor,  $L_{1Hz}$ , is the phase detector noise floor when the reference frequency is 1 Hz and the filter noise,  $L_{term}$ , is the thermal noise of any loop filter resistor. The transfer functions that multiply each noise source are obtained through the block diagram. The PLL total output phase noise can be calculated adding the contributions of each noise source given by Equations 4 to 8. At frequency offsets much lower than the loop bandwidth, the phase detector noise is dominant, although the crystal and divider noises can also be considerable. On the other hand, at frequency offsets greater than the loop bandwidth, the VCO phase noise is dominant. Depending on the VCO gain and the resistor values of the loop filter, the thermal noise will be comparable with the VCO noise.

### Transient Response

The lock time that a PLL takes to switch from one channel to another is strongly dependent on the loop filter used. For example, the lock time to switch from frequency  $f_1$  to frequency  $f_2$ , for a passive third-order loop filter, is given by Equation 10<sup>7</sup>

$$T_L = \frac{-\ln \left( \frac{\text{tol}}{f_2 - f_1} \frac{\sqrt{1 - \xi^2}}{1 - 2R2C2\xi\omega_n + (R2C2\omega_n)^2} \right)}{\xi\omega_n} \quad (10)$$

where

$\omega_n$  = PLL natural frequency

$\xi$  = PLL damping factor

tol = PLL frequency tolerance

### Simulation Tool

The phase noise, spurs and lock time prediction play a decisive role in the frequency synthesizers design. Furthermore, OFDM systems are highly sensitive to phase noise, which is present in the up- and down-con-

## GET THE PERFORMANCE YOU NEED ULTRA BROADBAND ATTENUATORS



- Digitally Controlled
- Voltage Controlled
- Current Controlled
- Linearized Voltage Controlled
- Phase Invariant
- Digital Switched Pad

### OPTIONS

- Optimized Narrowband Models
- Resolution to 12 Bits
- Switching Speed to 350 nsec
- High Power Models
- Up to 120 dB Attenuation

### Electrical Specifications

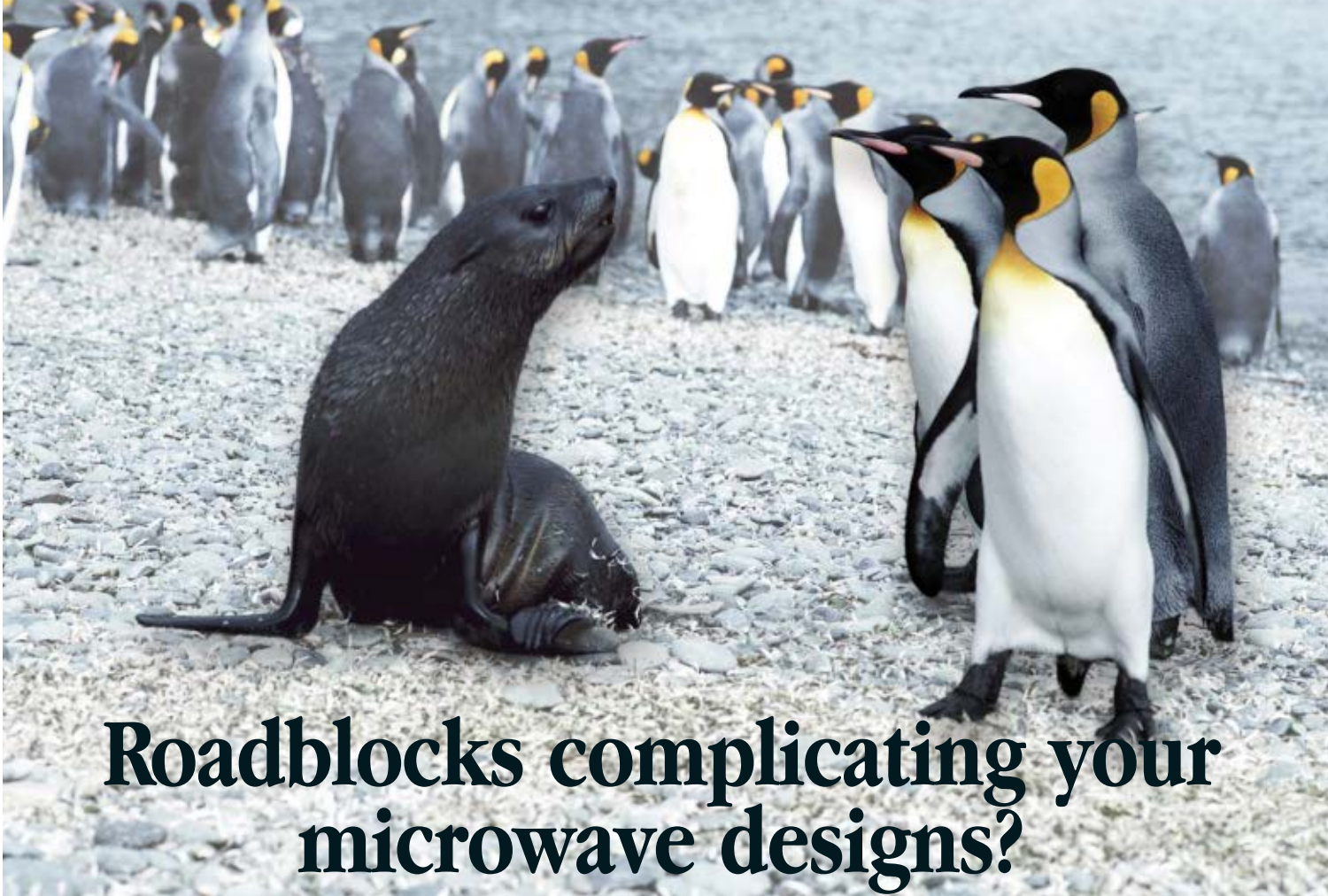
FREQUENCY GHz	FLATNESS & ACCURACY VS FREQUENCY	INSERTION LOSS MAX	V.S.W.R. MAX
0.5 - 2.0	±3.00	2.5 dB	1.8:1
6.0 - 18.0	±2.50	3.25 dB	1.9:1
2.0 - 18.0	±4.50	4.5 dB	2.1:1

• 64 dB Attenuation • 1 psec Switching



2 Emery Avenue  
Randolph, NJ 07869 USA  
973-361-5700 Fax: 973-361-5722  
www.gtmicrowave.com  
e-mail: gtmicrowav@aol.com





# Roadblocks complicating your microwave designs?

Teledyne Microwave can remove the roadblocks to your microwave designs. We have over 40 years experience as a worldwide leader in the design, development and manufacture of microwave components and integrated assemblies for the **communications, aerospace, defense, aviation** and **instrumentation** markets.



- ☐ **Synthesizer Subsystems**
- ☐ **Integrated Microwave Assemblies**
- ☐ **Transceiver Subsystems**
- ☐ **Power and Low-Noise Amplifiers**
- ☐ **BAW Delay Lines**
- ☐ **Isolators and Circulators**
- ☐ **Filters: Lumped Element, Compline, High Power**
- ☐ **Switched Filters**
- ☐ **YIG Oscillators and Filters**
- ☐ **Frequency Synthesizers**

**Let our team help solve your microwave questions.** Whether you need component-level or a complete subassembly Teledyne Microwave has the experience and know-how to find the right solution to meet your needs and budget.



Go on-line to order your copy of the new Teledyne Microwave 140-page catalog or CD

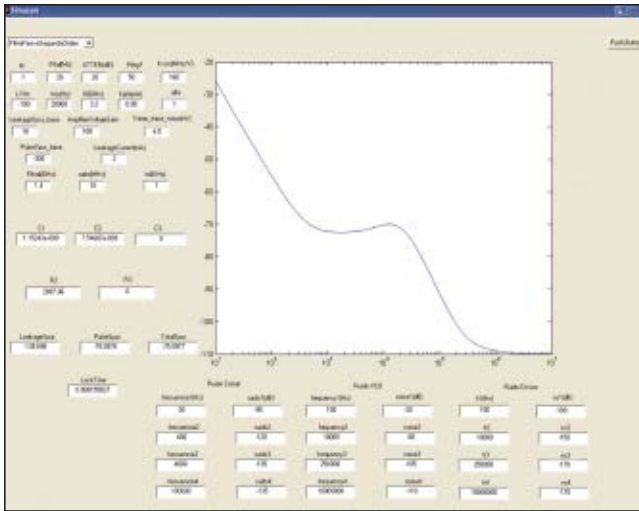


A Teledyne Technologies Company

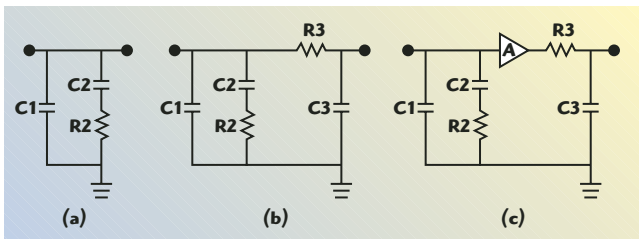
1274 Terra Bella Avenue, Mountain View, CA 94043, Phone: +1-650-962-6944, Fax: +1-650-962-6845

[www.teledynemicrowave.com](http://www.teledynemicrowave.com) e-mail: [microwave@teledyne.com](mailto:microwave@teledyne.com)

Visit <http://mwj.hotims.com/11713-139> or use RS# 139 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)

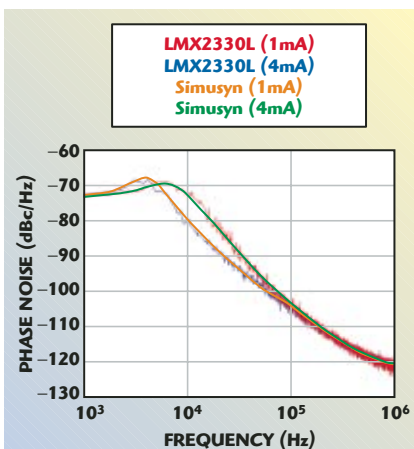


▲ Fig. 4 Simusyn display.

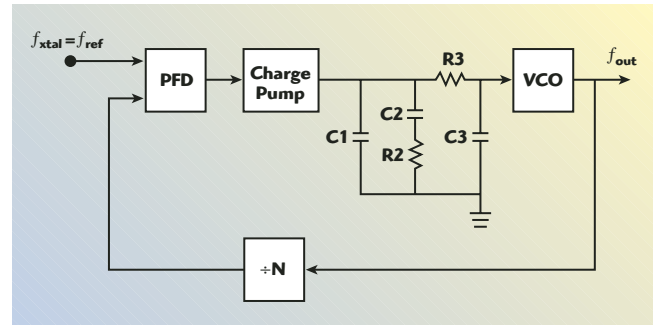


▲ Fig. 5 Loop filters: (a) second-order passive; (b) third-order passive; and (c) third-order active.

version synthesizers. Consequently, a rigorous design requires an effective prediction to estimate accurately the phase noise, spurs and lock time. A simulation tool named Simusyn has been implemented using Matlab (see **Figure 4**). This software predicts the phase noise, spurs and lock time, and calculates the loop filter components for the following inputs: reference divider, crystal frequency, spurs attenuation, VCO gain, phase margin,  $L_{1\text{Hz}}$ , loop bandwidth, output frequency, charge pump current, base\_leakage\_



▲ Fig. 6 LMX2330L phase noise for charge pump currents of 1 and 4 mA.



▲ Fig. 7 Synthesizer architecture.

spur, base\_pulse\_spur, leakage current, frequency step and tolerance for lock time and divider, VCO and crystal reference phase noise. In addition, Simusyn allows using three kinds of loop filters: passive second-order, passive third-order and active third-order loop filters (see **Figure 5**).

If the active loop filter is used, it is necessary to know the amplifier voltage gain ( $A$ ) and its input noise voltage. The last step before starting the synthesizer design involves verifying the Simusyn results with the measured National Semiconductor's LMX2330L commercial synthesizer. Phase noise, spurs and lock time have been verified for different synthesizer parameters. For example, in **Figure 6**, the phase noise for charge pump currents of 1 and 4 mA are presented. The rest of the basic parameters include: output frequency of 1.408 GHz, reference frequency of 1 MHz, spurs attenuation of 20 dB, loop bandwidth of 10 kHz and VCO gain of 60 MHz/V. The Simusyn software bases its results on the theoretical expressions shown in this section.<sup>7</sup> Finally, the LMX2330L synthesizers have been controlled using Visual Basic software through the PC parallel port.

## DETERMINATION AND PREDICTION OF THE SYNTHESIZER SPECIFICATIONS

It is essential to determine with great precision all the Simusyn inputs to achieve a high performance prediction. For that reason, the synthe-

sizer architecture is chosen and the specifications of each block now must be deduced. Furthermore, this determination tries to be a rigorous design guide that can be used for other devices.

The proposed architecture is an integer- $N$  frequency synthesizer with self-biasing current source and without a reference divider (see **Figure 7**). Furthermore, a passive third-order filter is employed to achieve additional filtering of the reference spurs. The frequency synthesizer consists of a phase-frequency detector (PFD), a high performance charge pump, an integer frequency divider and a VCO with self-biasing current source. The output signal of the VCO is divided by 160 and then is compared with a reference frequency of 20 MHz. Once the synthesizer architecture has been chosen, it is necessary to determine the general specifications of each block.

## Voltage-controlled Oscillator

The voltage-controlled oscillator (VCO) is the core of the frequency synthesizer. A proper synthesizer design depends strongly on the VCO performance. The basic VCO specifications include: output frequency, frequency range, gain, output power and phase noise at 1 MHz offset. The output frequency has been established previously as 3.2 GHz.

The frequency range has been calculated considering the capacitive (four percent) and inductive (one percent) tank tolerances of the CMOS fabrication process with a safety margin of three percent. If the output frequencies were variable, the variation range would have to be included. The tank tolerances are obtained from the research team experience in the design of integrated inductors and varactors.



## Test, Simulation, RF Distribution Subsystems... Smart Solutions at Work!



**Attenuation Matrices &  
Multi-Channel Subsystems**



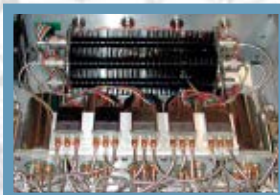
**RF Distribution Networks**



**Switch Matrices**



**RF/Microwave Frequency  
Translators**



**Cellular & Wireless Subsystems  
with Low IM Performance**



**Mobile Unit (Radio & WLAN)  
Fading Simulators**



**Cable Modem Redundant  
Switches & Test Systems**

Aeroflex / Weinschel offers smart solutions to challenging test, simulation and RF distribution requirements by offering subsystem products that are either off-the-shelf or designed to customer specifications. Our subsystems feature:

- Standard communication interfaces (IEEE-488, RS-232, Ethernet) with proprietary SmartStep® Technology;
- Flexible, high-density mechanical layout & packaging;
- 50 & 75  $\Omega$  configurations.

Our subsystems are employed in telecommunications, radar and CNI, satellite and ground communication systems, base station and mobile unit software conformance verification, signal analysis, cable modem and VoIP testing, production test systems and precision microwave related test instruments.

Aeroflex / Weinschel, Inc.  
800-638-2048  
301-846-9222  
[www.aeroflex-weinschel.com](http://www.aeroflex-weinschel.com)  
[sales@eroflex-weinschel.com](mailto:sales@eroflex-weinschel.com)

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

**AEROFLEX**  
A passion for performance.

The frequency range limits are  $f_{\text{HIGH}}$  (3383 MHz) and  $f_{\text{LOW}}$  (3031 MHz) and are given by Equations 11 and 12, where  $L$ ,  $C$  and  $f_{\text{osc}}$  are the inductor value, the varactor value and the VCO oscillation frequency, respectively

$$f_{\text{HIGH}} = \frac{1}{2\pi\sqrt{L0.99 C0.96}} \frac{1}{0.97} = 1.057f_{\text{osc}} \quad (11)$$

$$f_{\text{LOW}} = \frac{1}{2\pi\sqrt{L1.01 C1.04}} \frac{1}{1.03} = 0.947f_{\text{osc}} \quad (12)$$

The VCO gain is deduced from the frequency range and tuning voltage. If the tuning voltage is varied from 0.5 to 2.8 V, since the mismatch of the sink and source currents of the charge pump is very high at the power supply rails, the VCO gain is 153 MHz/V.

The phase noise requirement was determined as  $-110$  dBc/Hz at 1 MHz offset. Before designing the VCO, it is essential to verify that this requirement can be fulfilled. For this reason, the quality factor ( $Q$ ) of the tank required to achieve the required phase noise has been estimated by means of Equation 13, which calculates the necessary quality factor to obtain a certain value of phase noise ( $\mathcal{L}$ )<sup>8,9</sup>

$$Q = \frac{2kT(1+A)\omega_0}{LV_A^2 C \Delta\omega^2} \quad (13)$$

where

$V_A$  = differential output amplitude

$C$  = varactor capacitor

$A$  = excess noise factor of the amplifier

$\omega_0$  = oscillation frequency

$T$  = temperature

$k$  = Boltzmann constant

$\Delta\omega$  = frequency offset from the carrier

Since the minimum differential input amplitude of the mixer employed in the frequency down-conversion is 0.5 V, a quality factor of 6.3 is necessary to obtain a phase noise of  $-110$  dBc/Hz at 1 MHz offset, for a varactor capacitance of 0.8 pF and an excess noise factor of 2.<sup>13</sup> This quality factor can be achieved using the inductors and varactors provided by the foundry libraries. For example, in these libraries, there are inductors with a quality factor of 10 at 3.2 GHz and varactors whose quality factor is greater than 40 at 3.2 GHz.<sup>10</sup> Lastly, the output power depends on the mixer employed in the downconversion. In this case, the mixer is passive and needs a minimum input power of  $-3$  dBm.

### Charge Pump

The principal specification of this block is the charge pump current. Its value has been established to minimize the power consumption and taking into account that the capacitor in the loop filter next to the VCO is at least three times the VCO input capacitance.<sup>7</sup> Thus, the charge pump current is set to 50  $\mu$ A.

### Loop Filter and Phase-frequency Detector

There are several specifications related to the filter design. First, it is

**The Total Microwave Solution**

- > DC — 50 GHz
- > Custom Designs
- > Multifunction RF Modules
- > Components
  - Filters • Amplifiers
  - Switches • Multipliers
  - T/R Modules • Oscillators
- > MMICs
- > Low-Cost Manufacturing

**One company...  
multiple technologies...  
optimum solutions.**

**REMEC Defense & Space**

858.560.1301 | sales@remecrds.com | www.cheltonmicrowave.com

**COBHAM**  
Defense Electronic Systems





Teledyne Switch Matrices incorporate our extensive selection of highly reliable and repeatable coaxial switches.



*Custom Matrices*



*SP3T to SP6T Latching & N.O.*



*Transfer Switch Failsafe & Latching*



*2P3T Failsafe & Latching*



*SPDT Failsafe & Latching*

# Think inside the box.

- Over 40 years of expertise
- Modular design
- 50Ω, 75Ω impedance
- Standard rack enclosures
- Designed to minimize losses
- Long life, high cycle rate
- High-power capabilities
- Multiple connector options
- Universal power supply



**TELEDYNE**  
**COAX SWITCHES**

(800) 351-7368 • [www.teledynecoax.com](http://www.teledynecoax.com)

Visit <http://mwj.hotims.com/11713-140> or use RS# 140 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)

necessary to choose the order of the loop filter and its gain (passive or active). It will be shown later that the VCO frequency range can be obtained with a passive filter, avoiding the amplifier noise. In addition, a third-order filter is selected to obtain an additional filtering of the reference spurs. There are two specifications related to the loop filter that are quite difficult to predict:  $\mathcal{L}_{1\text{Hz}}$  and  $\text{base\_pulse\_spur}$ .

The 1 Hz normalized phase detector noise floor has a considerable importance in the total integrated phase noise over the channel bandwidth. A priori, it is not possible to predict  $\mathcal{L}_{1\text{Hz}}$ , but two methods have been used to estimate its value. The first is based on Equation 14, which calculates  $\mathcal{L}_{1\text{Hz}}$  according to the charge pump current,  $V_{\text{GS}} - V_{\text{T}}$  of the charge pump current source transistors, Boltzmann constant (K), temperature

(T) and the time period during which the charge pump is active ( $t_{\text{qp}}$ )<sup>8</sup>

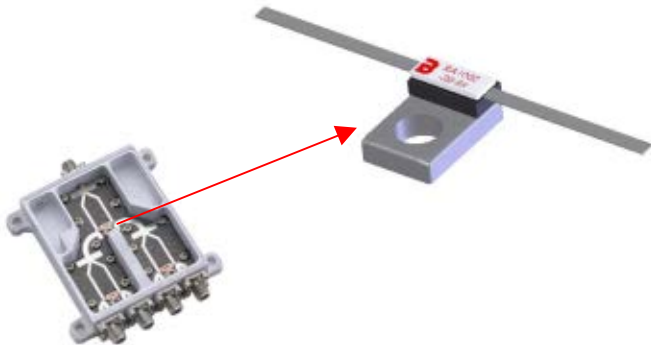
$$\mathcal{L}_{1\text{Hz}} = \frac{32\pi^2 t_{\text{qp}} K T}{K_{\phi} (V_{\text{GS}} - V_{\text{T}})} \quad (14)$$

This method is too optimistic, since using typical values of  $t_{\text{qp}}$  (5 ns) and  $V_{\text{GS}} - V_{\text{T}}$  (0.5 V),  $\mathcal{L}_{1\text{Hz}}$  achieves the value of -216 dBc/Hz. Therefore, the second method will have to be applied. It involves utilizing the worst  $\mathcal{L}_{1\text{Hz}}$  of the bibliographic revision done by Banerjee<sup>7</sup> about the 1 Hz normalized phase detector noise floor of different commercial synthesizers. Consequently, a 1 Hz normalized noise floor of -200 dBc/Hz is chosen. In addition, this value determines the loop bandwidth. By means of Simusyn and considering the VCO phase noise and the synthesizer total integrated phase-noise specifications, a loop bandwidth of 20 kHz is obtained. Finally, the  $\text{base\_pulse\_spur}$  is the last one to complete all Simusyn inputs. This specification is the most difficult to estimate because it depends principally on the charge pump mismatches, unequal transistor turn on times and dead-zone elimination circuitry. There are some expressions given,<sup>7</sup> but they are not very useful in practice. The only solution entails selecting the worst  $\text{base\_pulse\_spur}$  (-292 dBc) of Banerjee's bibliographic revision about the spur levels of different commercial synthesizers. In the following section, with the use of CADENCE,  $\text{base\_pulse\_spur}$  and  $\mathcal{L}_{1\text{Hz}}$  will be estimated with greater accuracy.

The values of the filter components are calculated using Simusyn by means of the well-known Application Note AN1001,<sup>15</sup> with the following warnings: the phase margin must be chosen between 40° and 70°; the added spurs attenuation is chosen to fulfill the total spur requirements; and the capacitor in the loop filter next to the VCO is at least three times the VCO input capacitance. Therefore, using Simusyn, the values of the filter components are  $C1 = 701.88 \text{ pF}$ ,  $C2 = 3.06 \text{ nF}$ ,  $C3 = 70.18 \text{ pF}$ ,  $R2 = 4.39 \text{ k}\Omega$  and  $R3 = 340.13 \Omega$  for the following input parameters: crystal reference frequency of 20 MHz, ATTN of 20 dB, a phase margin of 55°, a loop bandwidth of 20 kHz, an output frequency of 3.2

## Power Combiner/Dividers?

No, we don't make them, we make them **PERFORM** better!



Barry now offers RESISTORS with low capacitance and high power for all your Power Divider/Combiner applications.

From 20 to 250 watts, this new Resistor Series is specifically designed to offer maximum performance in Power Divider and Combiner applications. Available in Aluminum Nitride and BeO, on a flange; as a chip with leads; or as a stand-alone chip. These resistors will finally put an end to choosing what to sacrifice.

Barry provides a full line of power and precision thick film resistors, terminations and attenuators on Alumina, BeO, BeO Free™ and Aluminum Nitride for your microwave and RF Applications. We are vertically integrated and offer our own LTCC Foundry and Design, Machining Center, and Plating Division.



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



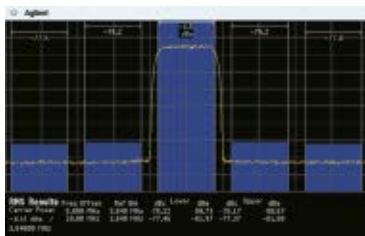
ISO 9001:2000  
ITAR Registered  
RoHS Compliant

**Your Total Ceramic Solutions Provider**  
**508-226-3350**



# A signal generator with an ACLR of $-76$ dBc

Nothing else has a range this deep.



## Agilent MXG Signal Generator

ACLR (3GPP W-CDMA)	-71 dBc spec., -76 dBc meas. (1-carrier) -65 dBc spec., -70 dBc meas. (4-carrier)
Switching speed (SCPI)	1.2 ms
Simplified self-maintenance	Onsite calibration in less than 1 hour
Signal Studio software	W-CDMA, WiMAX, cdma2000/1xEV, GSM/EDGE, WLAN, TD-SCDMA



u.s. 1-800-829-4444, ext. 5461  
canada 1-877-894-4414, ext. 5461  
[www.agilent.com/find/possible1](http://www.agilent.com/find/possible1)

Explore the boundaries of what's possible. The new Agilent MXG signal generator allows you to test the limits of your own designs. Change in wireless technology is no longer simply emerging, it's surging. It's not merely a question of test technology keeping pace, it has to anticipate. Stay ahead, find the edge, move it forward.

To see how the new Agilent MXG lets you measure at levels never before possible, go to [www.agilent.com/find/possible1](http://www.agilent.com/find/possible1). It's signal generation at the edge of possibility.



**Agilent Technologies**

GHz, a charge pump current of 50  $\mu$ A and a VCO gain of 153 MHz/V.

Furthermore, with the filter components previously calculated, the total reference spurs are at -73 dBc and the total phase noise of the synthesizer is shown in **Figure 8**, both results being obtained with Simusyn.

### SYNTHESIZER BUILDING BLOCKS


Once the specifications of each block have been established, the de-

sign of each one is presented. Furthermore, the input specifications of the synthesizer will be determined with higher precision thanks to the use of CADENCE, allowing a more accurate prediction of its phase noise, reference spurs and lock time.

**Figure 9** shows the schematic circuit of the VCO. The proposed architecture is a fully integrated differential NMOS VCO with a self-biasing current source. This architecture has

been selected to maximize its tuning range. Two cross-coupled transistors with minimum dimensions M1 and M2 generate the negative impedance required to cancel the losses in the LC-tank. An oscillation safety factor of two and on-chip planar inductors have been used in this design. The key to the design of a low phase-noise oscillator is a high quality inductor. Therefore, a thick metal (2  $\mu$ m) has been used to reduce the series resistance of the inductor. Its geometry has been selected to maximize the

**INTRODUCING A NEW VCO...**



**... THAT WILL ROCK YOUR WORLD!**

**A NEW OCTAVE: 3 - 6 GHz**

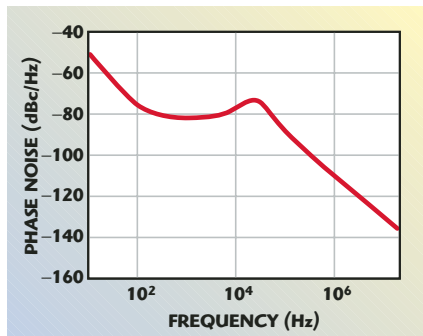
- 3000 MHz to 6000 MHz FREQUENCY RANGE
- MICRO TLS PACKAGE 0.35" x 0.35"
- TUNING RANGE OF 0V to 15V
- SUPPLY VOLTAGE OF 5V
- CURRENT IS 30mA OR LESS
- PHASE NOISE IS -85dBc/Hz AT 10 KHz OFFSET OR BETTER
- AVAILABLE IN TAPE AND REEL
- 100% TESTING WITH SERIALIZED DATA

**CALL US WITH YOUR VCO NEEDS**

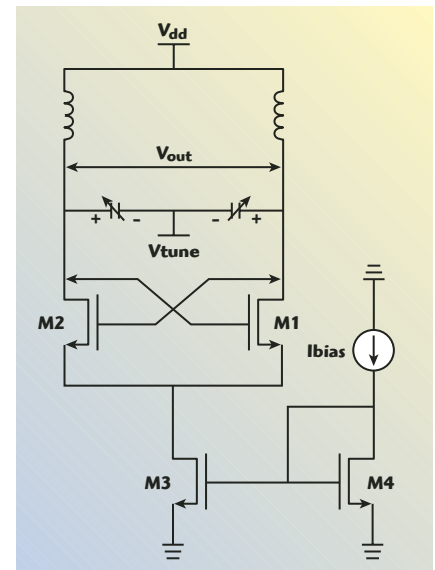
SETTING THE STANDARD FOR QUALITY, CUSTOMER SERVICE & RELIABILITY.

**EMHISER MICRO-TECH**

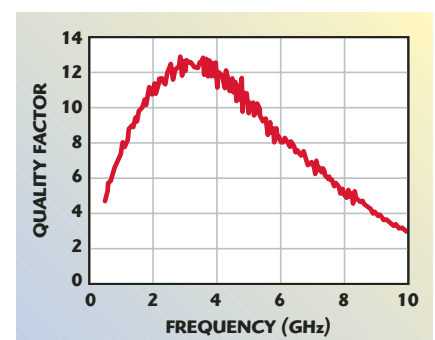
PH: (775) 345-0461 FAX: (775) 345-1152  
 WEB: [www.emhiser.com/vco](http://www.emhiser.com/vco) EMAIL: [vco@emhiser.com](mailto:vco@emhiser.com)



▲ Fig. 8 Phase noise of the synthesizer.



▲ Fig. 9 Schematic circuit of the VCO.



▲ Fig. 10 Inductor quality factor.



**Adapters, Attenuators, Blind Mate Connectors, Cable Assemblies, Connectors, Delay Lines, Duplexers Equalizers, Fine Grain Equalizers, Gain Amplitude Equalizers, Line Stretchers, Machines, Phase Adjusters Push - On Connectors & Adapters, Quick Connections Terminations ( Coax- ), Tools, Waveguide to Coax-Adapters & Transmissions, etc....**

**# 8 &  
# 12  
Contacts**

**per  
MIL-C-39029/59D  
& /60D**



**Spectrum**  
Elektrotechnik GmbH

**when Quality is needed**

**80905 Munich, Germany**

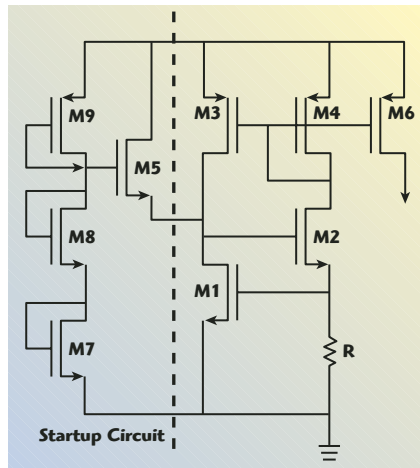
**P.O. Box 450533**

**Telephone: +49-89-3548-040**

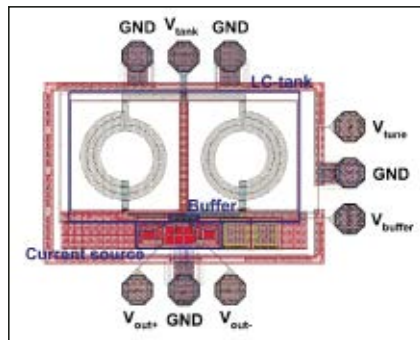
**Facsimile: +49-89-3548-0490**

**WWW.SPECTRUM-ET.COM \* Email: specelek@compuserve.com**

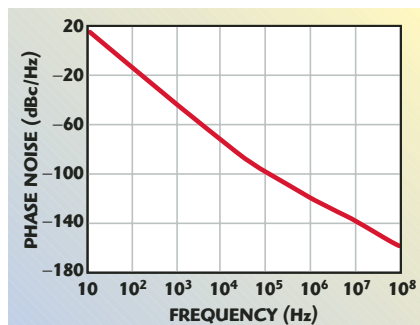
quality factor. As a result, two spiral inductors of 2.2 nH with a quality factor of 12 at 3.2 GHz have been



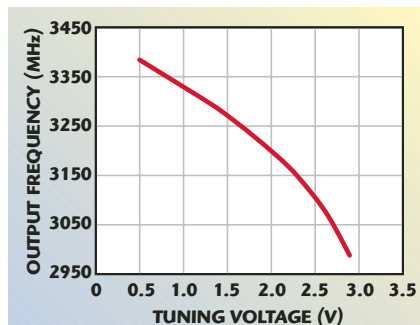
▲ Fig. 11 Schematic circuit of the self-biasing current source.



▲ Fig. 12 Layout of the VCO.



▲ Fig. 13 VCO phase noise obtained from post-layout simulation.



▲ Fig. 14 VCO tuning range obtained from post-layout simulation.

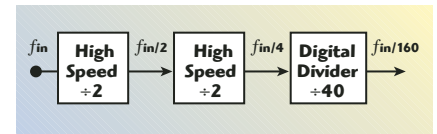
employed. The electromagnetic simulation tool Momentum of ADS has been used to achieve high accuracy in its design. Before designing the VCO, the inductors have been measured and modeled. **Figure 10** shows the measured quality factor of the inductor. As can be seen, this quality factor is optimized at the output frequency of the synthesizer (3.2 GHz).

The varactors are P-N junction capacitors with a maximum capacitance of 0.88 pF. Each varactor is laid out with 65 fingers, which are 10  $\mu\text{m}$  wide and 161  $\mu\text{m}$  long. The quality factor of these varactors at 3.2 GHz is estimated to exceed 40. The varactors have also been previously measured. The current of the tank is supplied by the self-biasing source shown in **Figure 11**. A startup circuit has been

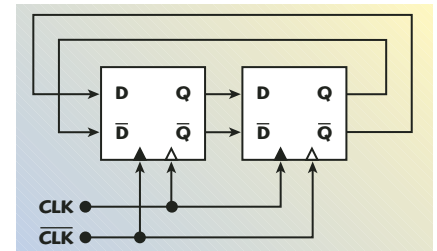
employed to avoid  $I_{\text{bias}}$  being zero. The  $I_{\text{bias}}$  variation is lower than one percent for voltage supply variations of 10 percent.<sup>11</sup> The layout of the VCO is shown in **Figure 12**, which measures  $850 \times 1000 \mu\text{m}^2$ , including pads. The two inductors of the oscillator are situated at the top and the varactors are just below. The output buffer and negative resistance transistors are located in the middle of the die, whereas the current source is placed on the bottom.

Post-layout simulations allow determining the specifications of the VCO with high accuracy. In this way, the differential output amplitude of the VCO is 1.73 V, for a total tank current of 6 mA. This amplitude allows obtaining a phase noise of -120 dBc/Hz at 1 MHz offset. The phase noise and tuning

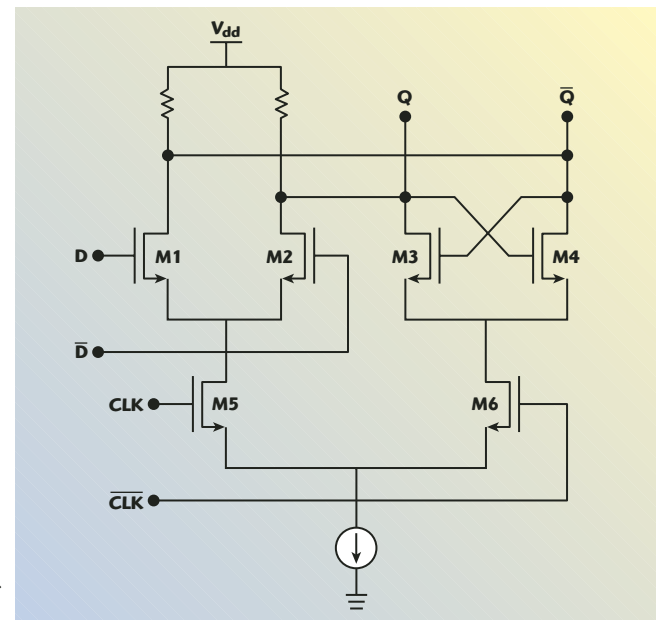
range obtained from post-layout simulations are shown in **Figures 13** and **14**, respectively. In order to predict with Simusyn the phase noise, spurs



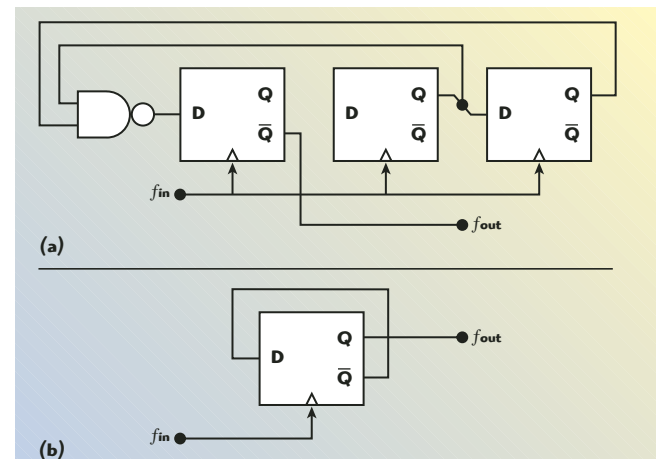
▲ Fig. 15 Divider block diagram.



▲ Fig. 16 High speed divide-by-two.



▲ Fig. 17 Schematic circuit of each high frequency flip-flop.



▲ Fig. 18 The (a) digital divide-by-five and (b) digital divide-by-two.



**FINAL**

# Satellite Gazette

**FINAL**

## TAMPA MICROWAVE ADDS NEW PRODUCT LINES

On Display at Satellite 07 Feb. 19-22

See What's New  
at Booth 1407

There will be lots to see when Satellite 07  
brings you the latest and greatest from  
Tampa Microwave. Satellite 07 will take  
place at the 2007 at the



## COME SEE WHAT'S NEW AT BOOTH 1407.

(WE'RE JUST TWO AISLES FROM THE CONVENTION CENTER RESTAURANT)

New products—and the same rapid response dependability, build-to-order flexibility, and personal attention you'll get only from Tampa Microwave.

We're your supplier of choice for up/down converters, loop test translators, and custom RF assemblies for military and commercial SATCOM. And we've added two exciting new product lines to our family of solutions:

- VIGILCOM™ line of measurement products for surveillance and remote monitoring of terrestrial and satellite communications
- SIGINT products for defense-related signal monitoring in the HF-UHF spectrum

We'll see you at Booth #1407!



UP/DOWN BLOCK CONVERTERS • LOOP TEST TRANSLATORS REMOTE SIGNAL MONITORING • SIGINT • CUSTOM RF ASSEMBLIES

**813-855-2251 • [www.tampamicrowave.com](http://www.tampamicrowave.com)**

THE RAPID RESPONSE SUPPLIER OF CHOICE

Visit <http://mwj.hotims.com/11713-137> or use RS# 137 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)

and lock time with greater safety, the maximum VCO gain will be utilized ( $\sim 250$  MHz/V). This gain is reached when the tuning voltage is 2.8 V. Finally, in order to improve the VCO performance, the following layout issues must be considered: to ensure layout symmetry to minimize the even-order distortion in the differential output signal, the metal track in the tank must be as short as possible to reduce the parasitic capacitance and as wide as possi-

ble to reduce the parasitic resistance, choosing a compromise between both of them, differential pairs have a common center to minimize the effect of the process gradient, and to take into account the inductance introduced by the metal track that interconnects the two inductors.

### Frequency Divider

**Figure 15** shows the divider block diagram. It consists of two high speed

divide-by-2 and a digital divide-by-40. The block diagram employed to implement each high speed frequency divider is shown in **Figure 16**, which consists of two D flip-flops connected in a master/slave configuration. Each D flip-flop is triggered by two complementary inputs clock signals, CLK and CLKBAR. **Figure 17** shows the schematic circuit of a D flip-flop, which has been implemented using source-coupled logic (SCL).<sup>6</sup> The main advantages of this architecture include: as it does not utilize PMOS transistors and the signal goes through only two gates per cycle, this topology is very fast; and it allows very small swings for the input clock. The digital divide-by-40 is made up of three divide-by-2 and one divide-by-5. These digital dividers are implemented with digital D flip-flops and **Figure 18** shows their diagram.<sup>8</sup> The design of the first two divide-by-2 has been done especially carefully due to the high specification frequency. Proper sizing of the transistors results in a reasonable speed-power trade-off at gigahertz rates. Since it is a differential device, the layout symmetry plays an essential role in its performance characteristics. The phase noise of the divider obtained from post-layout simulations is  $-143$  dBc/Hz at 10 kHz offset. The layout of the divider is shown in **Figure 19**. It measures  $663 \times 734 \mu\text{m}^2$ , including pads. The high frequency divide-by-4 is placed at the top and the digital divider is located just below. It has been necessary to include a buffer at the output of the divider in order to allow its measurement out of the synthesizer. This buffer is situated at the bottom of the layout. Lastly, the main layout issues, in order to improve the VCO performance, lie in the high frequency divider. As this divider is a differential circuit, the same differential recommendations proposed for the

## NO LONGER THE BEST KEPT SECRET IN THE HIGH FREQUENCY WORLD

- Microwave Radio
- Mobile Satellite
- Earth Station
- Instrumentation
- Telemetry
- Radar
- Aviation

- Multi-Octave Power Divider/Combiners
- Octave Band Directional Couplers
- Attenuators, Terminations, Isolators/Circulators
- L, S, C, X and Ku Bands

New Catalog Supplement  
"Focus on High Frequency"

**MECA DELIVERS HIGH FREQUENCY COMPONENTS OFF THE SHELF!**

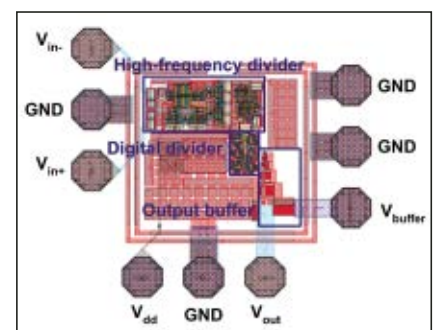


**Microwave Electronic Components of America**

1.866.444.6322 | sales@e-meca.com | www.e-meca.com

459 East Main Street • Denville, NJ 07834 • 973.625.0661 • Fax: 973.625.9277

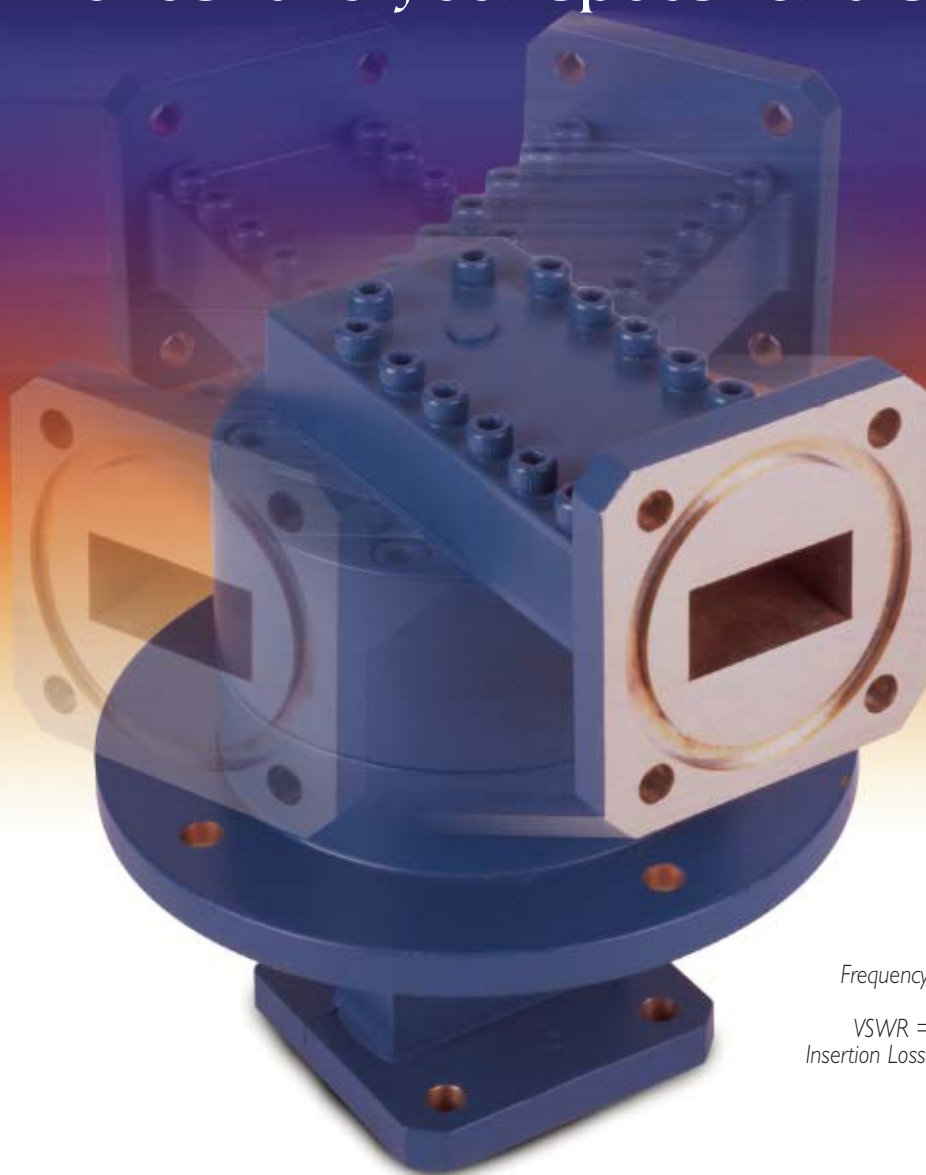
**Rugged and Reliable RF/Microwave Components  
Since 1961 – Made in USA**



▲ Fig. 19 Layout of the divider.



# Let us take your specs for a spin.



Frequency: 14.0 – 14.5 GHZ  
10.75 – 12.75 GHZ  
VSWR = 1.20 MAX  
Insertion Loss = .20 Db MAX

## Custom Dual Band Rotary Joints

As the demand for higher frequencies and broader band widths grow, MDL engineers stay a step ahead. With the very latest in SolidWorks, Ansoft HFSS, and our own proprietary software, we'll design and build precision dual band rotary joints to your size and specs in impressively little time.

## Call us.

Quality from CAD to crate is what has made us the industry's largest manufacturer of high quality cast components and waveguide packages. Call an MDL specialist today at 800-383-8057 or visit us at [mdllab.com](http://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](mailto:mdlsales@mdllab.com) [www.mdllab.com](http://www.mdllab.com)

Visit <http://mwj.hotims.com/11713-76> or use RS# 76 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)

VCO can be also applied. Furthermore, the parasitic capacitances of this divider play an important role at high frequencies. With the aim of reduce them, the following issues must be taken into account: the most external metal layer must be used to make the interconnections, the parallel metal tracks must be very widely spaced, the length of all metal tracks must be minimized and crosses must be avoided between metal tracks.

### Phase-frequency Detector and Charge Pump

As shown in **Figure 20**, the phase detector employed is a phase-frequency detector (PFD), which consists of two digital D flip-flops, a logic gate NAND and a delay that is composed of a certain number of inverter gates. This delay in the PFD reset path is used to avoid the dead zone of the synthesizer, which is the region where the charge pump currents cannot flow proportion-

ally to the phase error. In order to avoid the dead zone, the minimum reset delay of the PFD must be equal to the charge pump switching time. This time can be approximated by the average of the rise time and the fall time of the UU signal.<sup>13</sup> The reset delay is also related to the reference spurs and  $\mathcal{L}_{1\text{Hz}}$ . For this design, four inverter gates have been employed. **Figure 21** shows the schematic circuit of the charge pump.<sup>14</sup> This architecture has been implemented to mitigate charge injection errors induced by the parasitic capacitors of the switches and current source transistors. A meticulous sizing of the charge pump transistors and a proper layout are essential for high performance since the reference spurs depend on the charge pump mismatches and unequal transistor turn-on times. The transistors M1 and M2 turn on at every phase comparison instant, therefore any mismatch between their magnitudes, duration, or absolute timing results in a net current that is drawn from the loop filter. Finally, the base\_pulse\_spur and  $\mathcal{L}_{1\text{Hz}}$  specifications must be predicted with high precision before building the device. They both have been specified by means of the CADENCE simulation tool. The normalized phase detector noise floor has been considered as a cyclostationary noise. A noise is cyclostationary if its autocorrelation is periodic in time. In this case, the origin is a periodic bias current generating shot noise. Therefore, **Figure 22** shows the contribution of noise sources at 20 MHz to the total phase detector noise as a function of time. Calculating the average in a period, a phase detector noise of  $2.7267 \text{ pA/Hz}^{1/2}$  is obtained. From this result and by means of Equation 14, it is possible to calculate a 1 Hz normalised noise floor of  $-202.3 \text{ dBc/Hz}$ . Consequently, a PLL noise floor of  $-85.2 \text{ dBc/Hz}$  is achieved. Last of all, CADENCE must also be used to specify the base\_pulse\_spur constant with greater accuracy. Therefore, by processing the discrete Fourier transform (DFT) of the synthesizer output signal for different loop filters when the PLL is locked, a base\_pulse\_spur value of  $-289 \text{ dBc}$  is obtained. **Figure 23** shows the layout of the phase-frequency detector and the charge pump, which measures  $850 \times 1000 \mu\text{m}^2$ , including pads. The PFD is situated in the middle and on the left, whereas the charge

## Comprehensive Solutions for Your Wireless Communications Systems

**Site Analyzer SA-EX Series**  
A comprehensive tool for maintaining your Transmission and Antenna Systems. In addition to Power Measurements, it provides VSWR, Return Loss, and DTF measurements.

**5000-EX Digital Power Meter**  
Rugged, Hand-Held display for use with any of the Sensors shown here.

**5010B ThruLine® RF Power Sensor**  
General purpose, highly flexible sensor for average and peak power measurements. Power ranges from 12.5 mW to 2500W, and frequency ranges from 2 MHz to 2.7 GHz.

**5011 Terminating RF Power Sensor (TPS)**  
Broadband, low-cost, durable, high accuracy, wide dynamic range Power Sensor ideally suited for iBOC and HDTV.

**5012 Wideband RF Power Sensor**  
All in one sensor with wide frequency range. Ideal for use with 3G, TETRA and P25 communication systems.

Engineering you can trust. Products you can depend on. As a knowledgeable and innovative supplier of R.F. Solutions, Bird Technologies Group provides test & measurement instruments to the Wireless Communications industry that are highly accurate, rugged and easy to use. Our wireless family consists of antenna and cable testing products, R.F. power measurement, and complete test systems.




RF Measurement and Management in Your World



866-695-4569 | sales@bird-technologies.com | www.bird-technologies.com





Now you can use that  
hot plate for what it was  
really made for.



**Thermal engineered, oven-fired packages from Thunderline-Z provide hermeticity module after module.**

If the time has come to increase the reliability of your feedthru installations, maybe it's time to put the hot plate aside. Thunderline-Z packages are oven-fired and inspected for feedthru integrity and hermeticity. Our SolderTight™ technology employs time-tested oven profiling and fixturing techniques to establish proper heat transfer and solder flow for each module. And, with our years of mechanical engineering experience, we'll assist you with choosing hole sizes, counterbores, feedthrus, housing materials and solders for your application and budget.

Now you can confidently deliver tested hermetic modules with aligned components, and clean, reliable solder joints. So, enjoy your hot coffee and leave the packages to us.

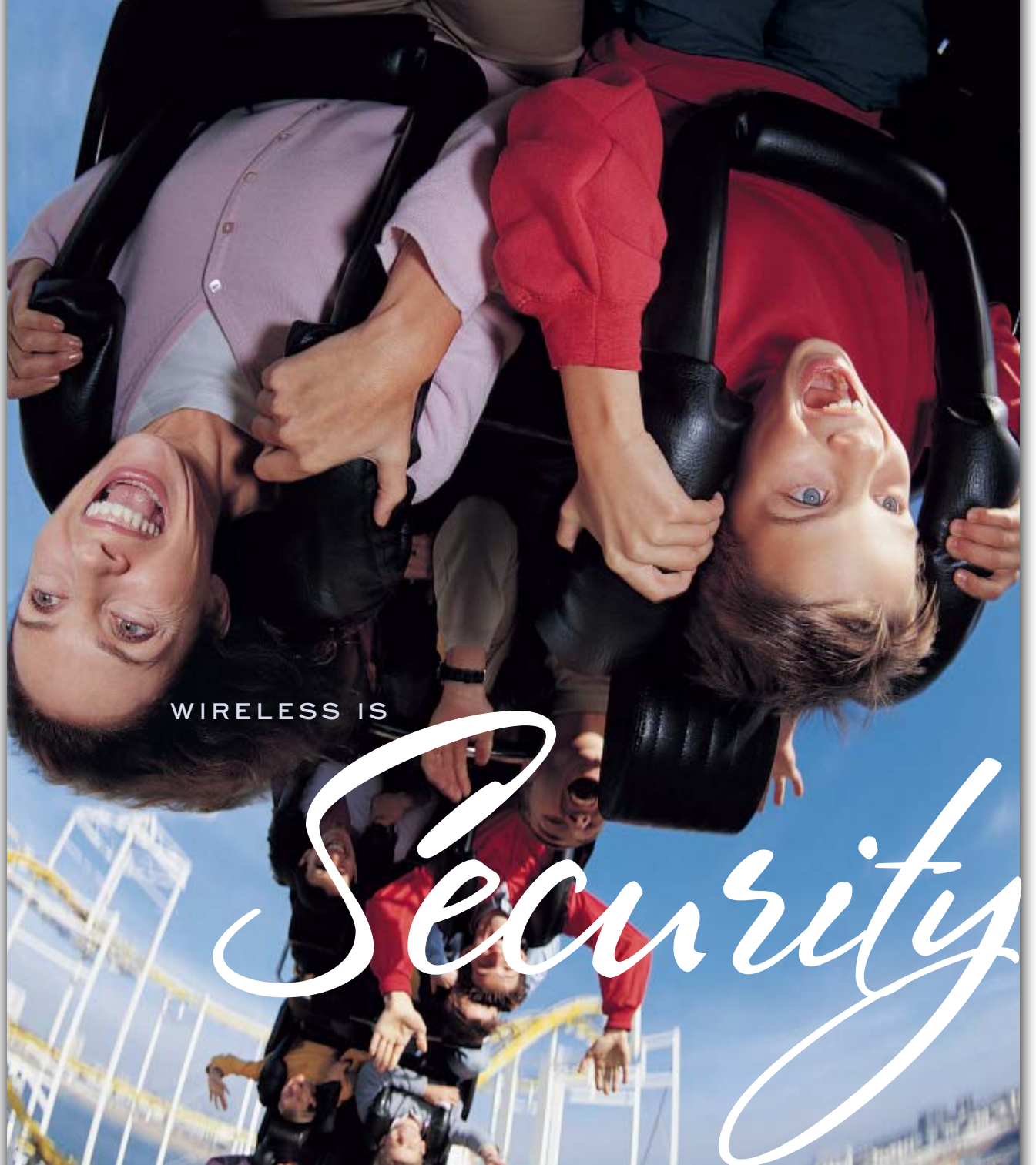
THUNDERLINE 

www.thunderlinez.com  
603.329.4050

  
**EMERSON**

**EMERSON. CONSIDER IT SOLVED.™**

Visit <http://mwj.hotims.com/11713-142> or use RS# 142 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)



WIRELESS IS

Security

CTIA WIRELESS 2007 is the world's largest wireless marketplace, drawing tens of thousands of attendees, featuring more than 1,000 exhibitors, 20% international participation from over 100 countries, and representing a \$500 billion global industry with 2.3 billion subscribers worldwide.



*What is wireless to you?*

FIND IT AT

**CTIA WIRELESS 2007**  
A Division of CTIA-The Wireless Association®

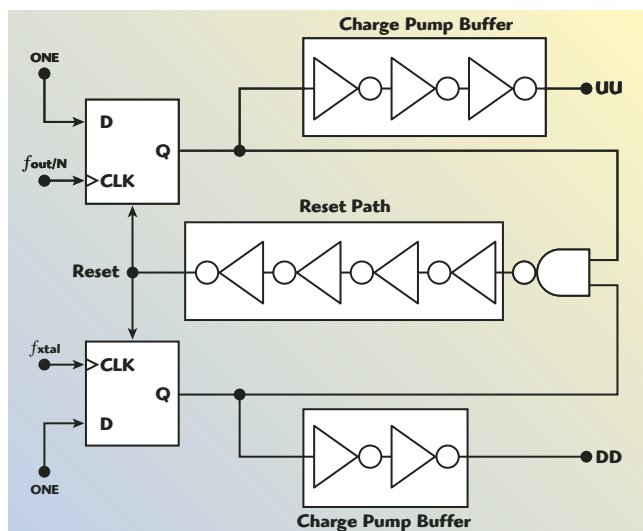
MARCH 27-29, 2007 ORLANDO, FL [WWW.CTIA.ORG/CTIAWIRELESS](http://WWW.CTIA.ORG/CTIAWIRELESS)

ORANGE COUNTY CONVENTION CENTER

**CTIA**  
The Wireless Association®

Visit <http://mwj.hotims.com/11713-36> or use RS# 36 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)





▲ Fig. 20 Phase-frequency detector.

pump is located just on the right. A lot of effort has been put into the reduction of charge injections at the switching times. Coupling of the digital signals in the phase-frequency detector and the charge pump to the VCO through the power supply, and non-complete cancelling of the charge injection in the charge pump switches will modulate the output with a frequency equal to the reference frequency. The charge pump design has been optimised with respect to this aspect, and care has been taken to provide sufficient symmetry in the layout. The layout also contains some power supply decoupling capacitors.

### Loop Filter

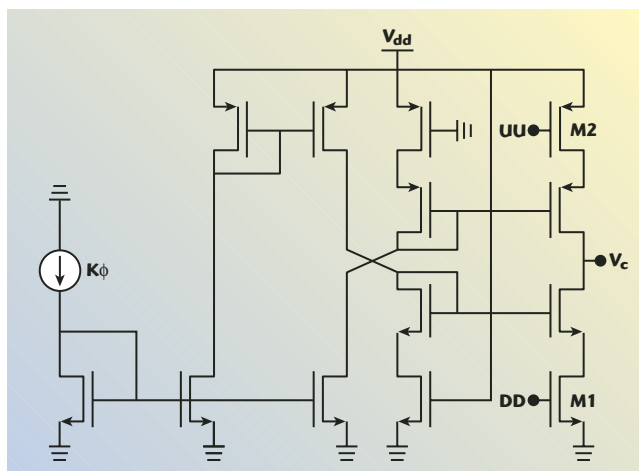
In the synthesizer architecture shown previously, an off-chip passive third-order filter has been employed to filter the charge pump pulses. As the VCO frequency range can be obtained with a tuning voltage variation from 0.5 to 2.8 V, a passive filter has been chosen. Furthermore, it is of a third-order to give an added attenuation to the reference spurs. Last of all, it is off-chip since the values of its components are too high to integrate them into the chip. Using Simusyn again and the application note AN1001,<sup>15</sup> the values of the filter com-

ponents are  $C1 = 1.14 \text{ nF}$ ,  $C2 = 5.01 \text{ nF}$ ,  $C3 = 114.7 \text{ pF}$ ,  $R2 = 2.68 \text{ k}\Omega$  and  $R3 = 208.16 \Omega$ . These values have been calculated utilizing the maximum VCO gain ( $\sim 250 \text{ MHz/V}$ ) in order to predict with Simusyn the phase noise, spurs and lock time with greater safety. This gain has been obtained by means of CADENCE and is reached when the tuning voltage is 2.8 V. The other

Simusyn inputs to calculate these values coincide with those given in the determination and prediction of the synthesizer specifications section. Once all Simusyn inputs have been determined with high accuracy using CADENCE, it is possible to predict with Simusyn the phase noise and the spurs of the synthesizer minimizing the estimation error. **Figure 24** shows the total phase noise of the synthesizer before its fabrication. In the same way, the reference spurs level obtained with Simusyn does not exceed  $-70 \text{ dBc}$ . Both results fulfill the performance requirements.

### RESULTS

The WLAN synthesizer has been implemented using a  $0.18 \mu\text{m}$  one-poly six-metal CMOS technology. **Figure 25** shows a micrograph of the synthesizer die with an area of  $1 \times 1.2 \text{ mm}$ , including pads. The circuit has been tested with a 3.3 V supply. The loop filter is



▲ Fig. 21 Schematic circuit of the charge pump.



## RF & Microwave Solutions

Fast.  
Flexible.  
For you.

Whether it's custom filters or stock components, you need solutions tailored for your unique requirements. And you need them fast.

At Trilithic, innovation is about more than engineering and technology. It's about listening to your needs and expectations. So together we can create solutions that work for you – today and tomorrow.



To find out more, call  
**(800) 344-2412** or  
visit **www.trilithic.com**.

Technology

IT Professionals

Wireless Providers

Public Safety

Dealers

# 2007 iwce

INTERNATIONAL WIRELESS  
COMMUNICATIONS EXPO

## International Wireless Communications Exposition & Conference


**College of Technology Workshops:** March 26-27, 2007

**Conference & Exposition:** March 28-30, 2007

**Las Vegas Convention Center**

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

**IWCE is the ONE place where all industries and all communications professionals come together to share thoughts and ideas on wireless communications technologies.**

 "I was blown away by the size and amount of communication power in the building. I am hooked; it was a lot of fun and I can't wait to go back."

- Andrew Allen Anderson  
Tri-States Communications

### WHO SHOULD ATTEND:

ANYONE who is responsible for planning and implementing an organization's wireless technology future...

- Technology end users from all industries
- IT professionals
- Public safety agencies
- Dealers and consultants
- Wireless service providers

### WHAT YOU'LL GET AT IWCE:

- North America's largest forum on communications technologies developed for all industry sectors
- A one-stop opportunity to shop for ideas and solutions from emerging wireless and Internet technologies at the industry's leading event featuring 350+ exhibitors
- Content-rich education and training developed by industry professionals
- Keynote Presentation by Morgan Wright, Global Industry Solutions Manager, Public Safety and Homeland Security, Cisco Systems, Inc.
- General Sessions: Point/Counterpoint: Public Safety's Wish List and Technology's Reality and 800 MHz Rebanding: Are We Any Closer?
- Two Levels of College of Technology Workshops - Level 100 for IT professionals and others new to the wireless world and Level 400 "graduate level" courses for communications engineers
- In-Depth Conference Sessions on Spectrum Utilization, Land Mobile Radio, 800 MHz Rebanding, Broadband Mobile, Emerging Technologies and Interoperability
- New Dealer Day Workshops - share best practices with other dealers and learn about new technologies in special workshops for dealers
- Unparalleled networking opportunities

IWCE is your best opportunity for training, contacts/networking, and seeing what's new from industry suppliers. IWCE has something for everyone regardless of what industry you are from.

**If your job includes wireless communications, IWCE can help!**

**For more information or to register, visit our website at [www.iwceexpo.com](http://www.iwceexpo.com) or call 800-927-5007 or 203-358-3751**

**Interested in exhibiting?  
Call Stephanie McCall, Sales Manager at 913-981-6146**

Sponsored by: **MRT**

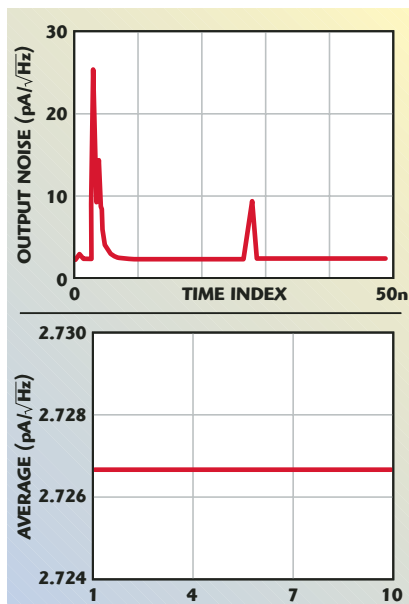
Visit <http://mwj.hotims.com/11713-62> or use RS# 62 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)



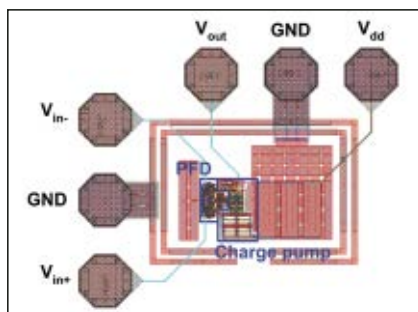
not included on the chip because of the large values of its components.

More than 300 MHz (11 percent of the center frequency) of VCO tuning range is achieved for a tuning voltage variation from 0.5 to 2.8 V. **Figure 26** shows a comparison between the measured and simulated VCO tuning range. As can be seen, the operating frequency is reached when the tuning voltage is exactly half that of the power supply (1.65

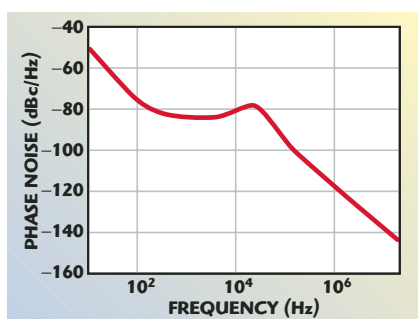
V). The measured phase noise of the synthesizer is shown in **Figure 27**. This phase noise is compared with two phase-noise simulations. The blue simulation trace has been obtained with Simusyn for the inputs given, whereas the yellow simulation trace refers to the phase noise simulated with Simusyn when its inputs are specified with CADENCE. The phase noises at 1 and 17.3 MHz offset frequencies are measured to be -118 and -143 dBc/Hz, respectively, which agree well with the values of the last simulation. Therefore, the phase-noise measurements fulfill the initial requirements. The total inte-



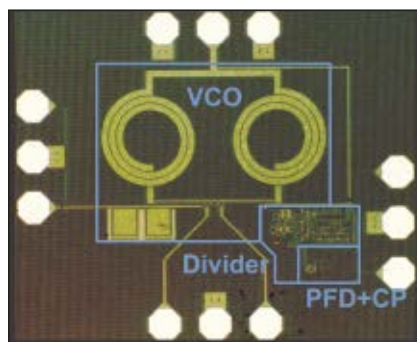
▲ Fig. 22 Cyclostationary noise of the phase detector.



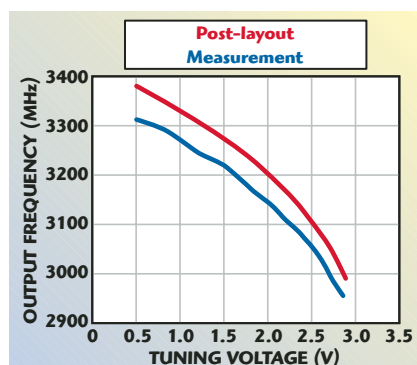
▲ Fig. 23 Layout of the phase-frequency detector and charge pump.



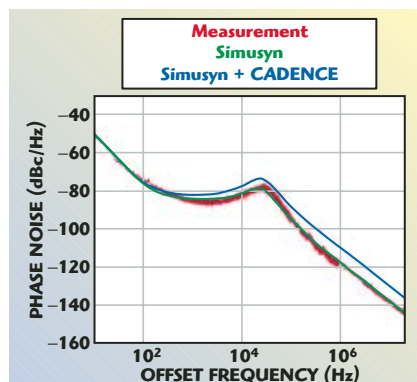
▲ Fig. 24 Phase noise of the synthesizer using Simusyn and CADENCE.



▲ Fig. 25 Microphotograph of the synthesizer die.



▲ Fig. 26 Comparison between measured and simulated tuning range of the VCO.



▲ Fig. 27 Comparison between measured and simulated phase noise of the synthesizer.



## RF & Microwave Components

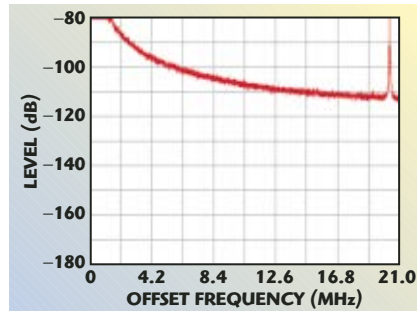
The right solution.  
Right now.

Immediate delivery of  
quality components  
from stock.

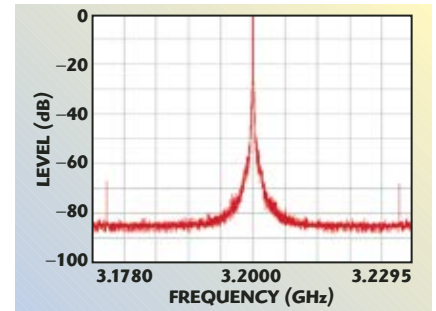
- DC-18GHz Fixed Attenuators
- Wilkinson Power Dividers
- 3GHz Manual Variable Attenuators
- Programmable Attenuators
- DC-18GHz terminations
- Solid-State Multi-throw switches 10MHz – 4.2GHz



To find out more, call  
**(800) 344-2412** or  
visit **www.trilithic.com**.



▲ Fig. 28 Measured phase noise of the synthesizer as a function of offset frequency.



▲ Fig. 29 Measured spectrum of the synthesizer output signal.

grated phase noise over the channel bandwidth does not exceed  $-32$  dBc. Furthermore, the measured phase noise of the synthesizer at  $17.3$  MHz offset is shown in **Figure 28**. The phase noise of the synthesizer measured at offset frequencies beyond the PLL bandwidth is the inherent phase noise of the VCO. Thus, the phase noise of the VCO at  $100$  kHz

offset is extrapolated to be  $-98$  dBc/Hz, considering a slope of  $20$  dB per decade. As shown in **Figure 29**, the reference spurious tones are more than  $64$  dB below the carrier. This result is also much lower than the original requirement ( $-59$  dBc). The power of the synthesizer differential output signal is approximately  $0$  dBm, which is much higher than the required power by the down-conversion mixer. **Table 1** summarizes the performance of the synthesizer. Of the  $53$  mW total power consumption, less than  $33.1$  mW is consumed by the VCO. The self-biasing current source consumes  $13.3$  mW to supply a tank current of  $6$  mA. The frequency divider and phase detector consume  $19.1$  and  $0.8$  mW, respectively.

Finally, **Table 2** presents some of the latest works reported on synthesizers, operating for IEEE 802.11a standard for the UNII band from  $5.15$  to  $5.35$  GHz. Clearly, the work in this article compares well with state-of-the-art designs in terms of phase noise, reference spurs, operation frequency and technology.

## CONCLUSION

A low phase-noise fully integrated synthesizer, suitable for a  $5$  GHz wireless LAN receiver in the UNII band

**TABLE I**  
MEASURED SYNTHESIZER  
PERFORMANCE

### Synthesizer Performance

Output frequency (GHz)	3.2
Reference frequency (MHz)	20
Channel spacing (MHz)	20
Frequency range (MHz)	> 300
Reference spurs (dBc)	$-64$
Phase noise@1 MHz (dBc)	$-118$
Loop bandwidth (kHz)	20
Total integrated phase noise (dBc)	$< -32$
Output power (dBm)	0
Frequency tolerance (ppm)	$< 1$

### Power Consumption

VCO (mW)	33.1
Divider (mW)	19.1
PFD + charge pump (mW)	0.8
Supply voltage (V)	3.3

### Implementation

Die area ( $\text{mm}^2$ )	1.2
Technology	$0.18 \mu\text{m CMOS}$

**TABLE II**

### COMPARISON BETWEEN SYNTHESIZERS FOR THE IEEE 802.11a WLAN STANDARD

	Operation Frequency (GHz)	CMOS Tech. ( $\mu\text{m}$ )	Phase Noise @ 1 MHz (dBc/Hz)	Reference Spurs (dBc)	Power Supply (V)	Power Consumption (mW)
This design	3.2	0.18	$-118$	$-64.3$	3.3	53
[16]	5.2	0.18	$-115$	$-65$	1.8	N/A
[17]	5.2	0.18	$-110$	N/A	1.8	N/A
[2]	3.5	0.18	$-120$	N/A	1.8	N/A
[18]	5.4	0.18	$-110$	$-68$	1.8	N/A
[19]	4.9	0.24	$-101$	$-54$	1.5/2	25
[20]	4.3	0.25	N/A	$-58$	2.5	117.5

**RESPONSIVE DELIVERY**

**EXTRAORDINARY RELIABILITY**

**HAND-CRAFTED AFTER**

When thinking of **QUALITY, RELIABLE, PRECISION** Chip Resistors...think **M-S-I**.

Premier Resistor Manufacturer, since 1968!

Is **SIZE** a **CRITICAL** factor?

**NEW** Chip Resistor Sizes  
 $0.024'' \times 0.012''$   
 $0.012'' \times 0.009''$   
 $0.010'' \times 0.010''$

Thick/Thin Film Chip Resistors:  
 ~TCR's starting at  $\pm 2\text{ppm}/^\circ\text{C}$   
 ~Tolerances starting at  $0.01\%$   
 ~Lead-free solders available

Further info.? Visit us on the web or call us 508-695-0203.

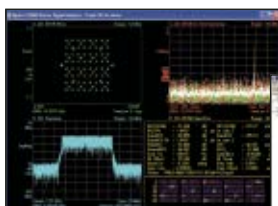
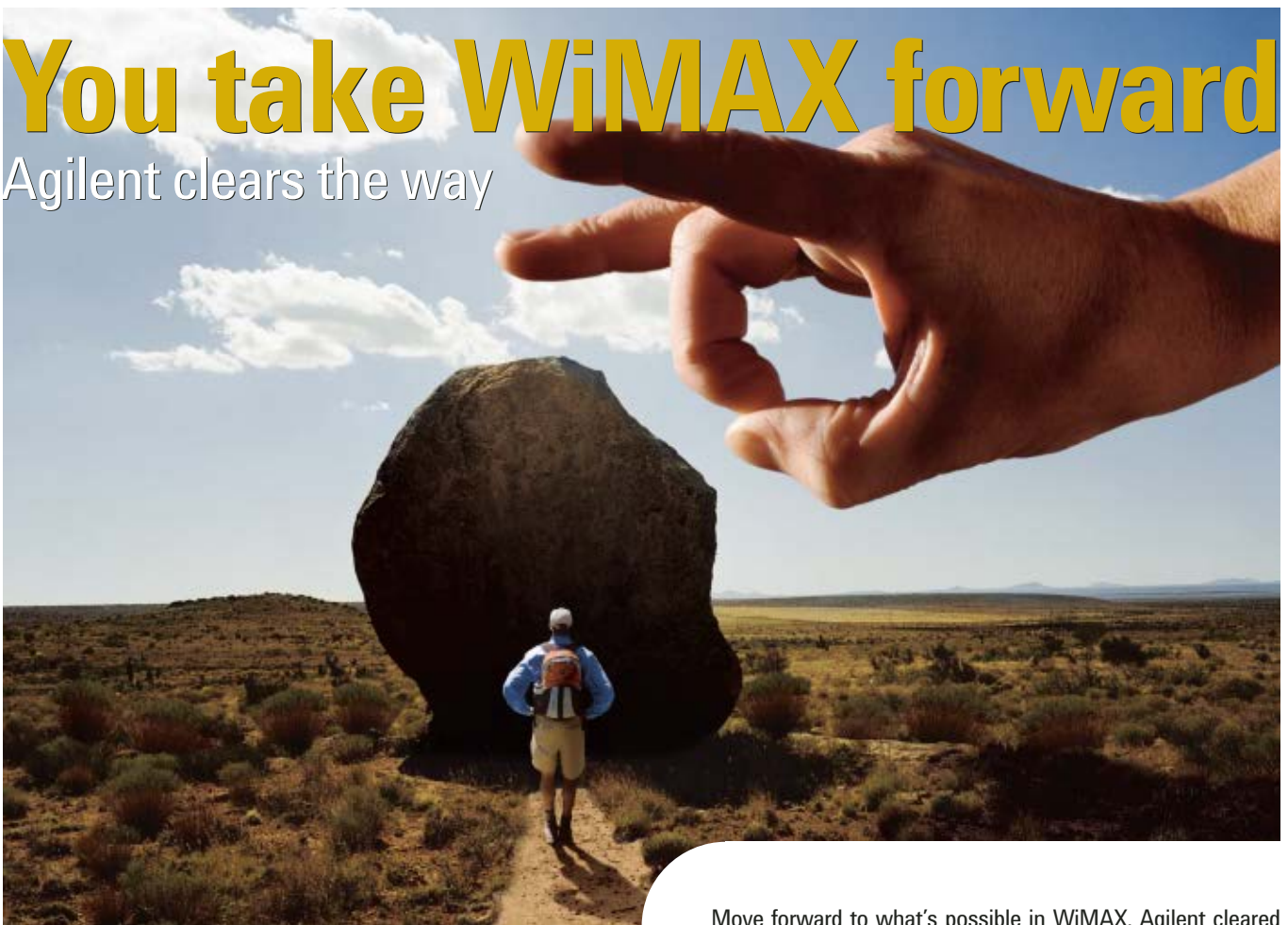
**M S I**

www.Mini-SystemsInc.com

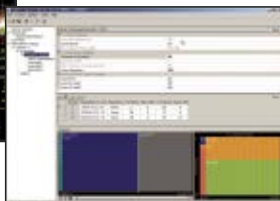


# You take WiMAX forward

Agilent clears the way



89601A 802.16 WiMAX  
modulation analysis software



Signal Studio for 802.16 WiMAX



New Agilent MXA and MXG  
for 802.16 WiMAX

u.s. 1-800-829-4444

canada 1-877-894-4414

[www.agilent.com/find/wimaxad](http://www.agilent.com/find/wimaxad)

Move forward to what's possible in WiMAX. Agilent cleared the way for fixed and mobile WiMAX and WiBro with the industry's first design tools. Tools like our Advanced Design System, the ESG signal generator with Signal Studio software, and VSA modulation analysis software have made WiMAX possible. Now, our latest products, like the Agilent MXG signal generators and MXA signal analyzers, can help you anticipate potential roadblocks and get you through them fast and efficiently. Stay ahead, find the edge, move it forward.

To see how Agilent's WiMAX test solutions let you bring your products to market faster, go to [www.agilent.com/find/wimaxad](http://www.agilent.com/find/wimaxad). It's WiMAX testing at the edge of possibility.



**Agilent Technologies**

from 5.15 to 5.35 GHz, has been designed. Through the development of Simusyn, the synthesizer's phase noise, reference spurs and lock time have been predicted with high accuracy before its fabrication. The use of high quality inductors, optimized at the operation frequency, allows obtaining a low phase-noise VCO. The use of a self-biasing current source in the tank provides a greater safety in the transconductance value and permits

operation along more extreme operating points. The integrated synthesizer consists of a VCO with 0 dBm of output power and phase noise of  $-98$  dBc/Hz at 100 kHz offset, a charge pump that mitigates the charge injection errors induced by the parasitic capacitors of the switches and current source transistors, and a fixed divide-by-160 circuit. The total phase noise of the synthesizer is  $-143$  dBc/Hz at 17.3 MHz offset and the reference spurious

does not exceed  $-64$  dBc. With this phase noise and a loop bandwidth of 20 kHz, the total integrated phase noise of the synthesizer over the channel bandwidth is less than  $-32$  dBc. Finally, the designed synthesizer consumes 53 mW with a power supply of 3.3 V. ■

## References

1. T.H. Lee, H. Samavati and H.R. Rategh, "5 GHz CMOS Wireless LANs," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 50, No. 1, January 2002, pp. 268-280.
2. P. Zhang, T. Nguyen, C. Lam, D. Gambetta, T. Soorapanth, B. Cheng, S. Hart, I. Sever, T. Bourdi, A. Tham and B. Razavi, "A 5 GHz Direct-conversion CMOS Transceiver," *IEEE Journal of Solid-State Circuits*, Vol. 38, No. 12, December 2003, pp. 2232-2237.
3. "Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications: High Speed Physical Layer in the 5 GHz Band," *IEEE Standard 802.11a-1999*, 2000.
4. J. Bhattacharjee, D. Mukherjee, E. Gebara, S. Nuttink and J. Laskar, "A 5.8 GHz Fully Integrated Low Power Low Phase Noise CMOS LC VCO for WLAN Applications," *2002 IEEE MTT-S International Microwave Symposium Digest*, Vol. 1, pp. 585-588.
5. B. Côme, R. Ness, S. Donnay, L. Van der Perre, W. Eberle, P. Wambacq, M. Engels and I. Bolsens, "Impact of Front-end Non-idealities on Bit Error Rate Performances of WLAN-OFDM Transceivers," *Proceedings of the 2000 RAWCON*, pp. 91-94.
6. B. Razavi, *RF Microelectronics*, Prentice Hall, Los Angeles, CA, 1997.
7. D. Banerjee, *Performance, Simulation and Design*, Second Edition, National Semiconductor, 2001.
8. J. Craninckx and M. Steyaert, *Wireless CMOS Frequency Synthesizer Design*, Kluwer Academic Publishers, Boston, MA, 1998.
9. J. Craninckx and M.S.J. Steyaert, "A 1.8 GHz Low Phase-noise CMOS VCO Using Optimized Hollow Spiral Inductors," *IEEE Journal of Solid State Circuits*, Vol. 32, No. 5, May 1997, pp. 736-744.
10. <http://www.ume.com>.
11. R.J. Baker, H.W. Li and D.E. Boyce, *Circuit Design, Layout, and Simulation*, IEEE Press, New York, NY, 1998.
12. F.W. Grover, *Inductance Calculations*, Van Nostrand, New York, NY, 1962.
13. H. Lee, T. Ahn, D. Jung and B. Park, "Scheme for No Dead Zone, Fast PFD Design," *Journal of the Korean Physical Society*, Vol. 40, No. 4, April 2002, pp. 543-545.
14. C. Lam and B. Razavi, "A 2.6 GHz/5.2 GHz Frequency Synthesizer in 0.4  $\mu$ m CMOS Technology," *1999 VLSI Circuits Symposium Digest of Technical Papers*, pp. 117-120.
15. W.O. Keese, "An Analysis and Performance Evaluation of a Passive Filter Design Technique for Charge Pump Phase-locked Loops," *National Semiconductor, Application Note 1001*, May 1996.
16. I. Vassiliou, K. Vavelidis, T. Georgantas, S. Plevridis, N. Haralabidis, G. Kamoulakos, C. Kapnistis, S. Kavadias, Y. Kokolakis, P. Merakos, J.C. Rudell, A. Yamanaka, S. Bouras and I. Bouras, "A Single-chip Digitally Calibrated 5.15 to 5.825 GHz, 0.18  $\mu$ m CMOS Transceiver for 802.11a Wireless LAN," *IEEE Journal of Solid-State Circuits*, Vol. 38, No. 12, December 2003, pp. 2221-2229.
17. A.R. Behzad, Z.M. Shi, S.B. Anand, L. Lin, K.A. Carter, M.S. Kappes, T. Lin, T. Nguyen, D. Yuan, S. Wu, V. Fong, A. Rofougaran and Y.C. Wong, "A 5 GHz Direct-conversion CMOS Transceiver Utilizing Automatic Frequency Control for the IEEE 802.11a Wireless LAN Standard," *IEEE Journal of Solid-State Circuits*, Vol. 38, No. 12, December 2003, pp. 2209-2220.
18. P. Zhang, L. Der, D. Guo, I. Server, T. Bourdi, C. Lam, A. Zolfaghari, J. Chen, D. Gambetta, B. Cheng, S. Gower, S. Hart, L. Huynh, T. Nguyen and B. Razavi, "A CMOS Direct-conversion Transceiver for IEEE 802.11a/b/g WLANs," *Proceedings of the 2004 IEEE Custom Integrated Circuits Conference*, pp. 409-412.
19. H. Rategh, H. Samavati and T. Lee, "A CMOS Frequency Synthesizer with an Injection-locked Frequency Divider for a 5 GHz Wireless LAN Receiver," *IEEE Journal of Solid-State Circuits*, Vol. 35, No. 5, May 2000, pp. 780-787.
20. F. Herzel, G. Fischer and H. Gustat, "An Integrated CMOS RF Synthesizer for 802.11a Wireless LAN," *IEEE Journal of Solid-State Circuits*, Vol. 38, No. 10, October 2003, pp. 1767-1770.

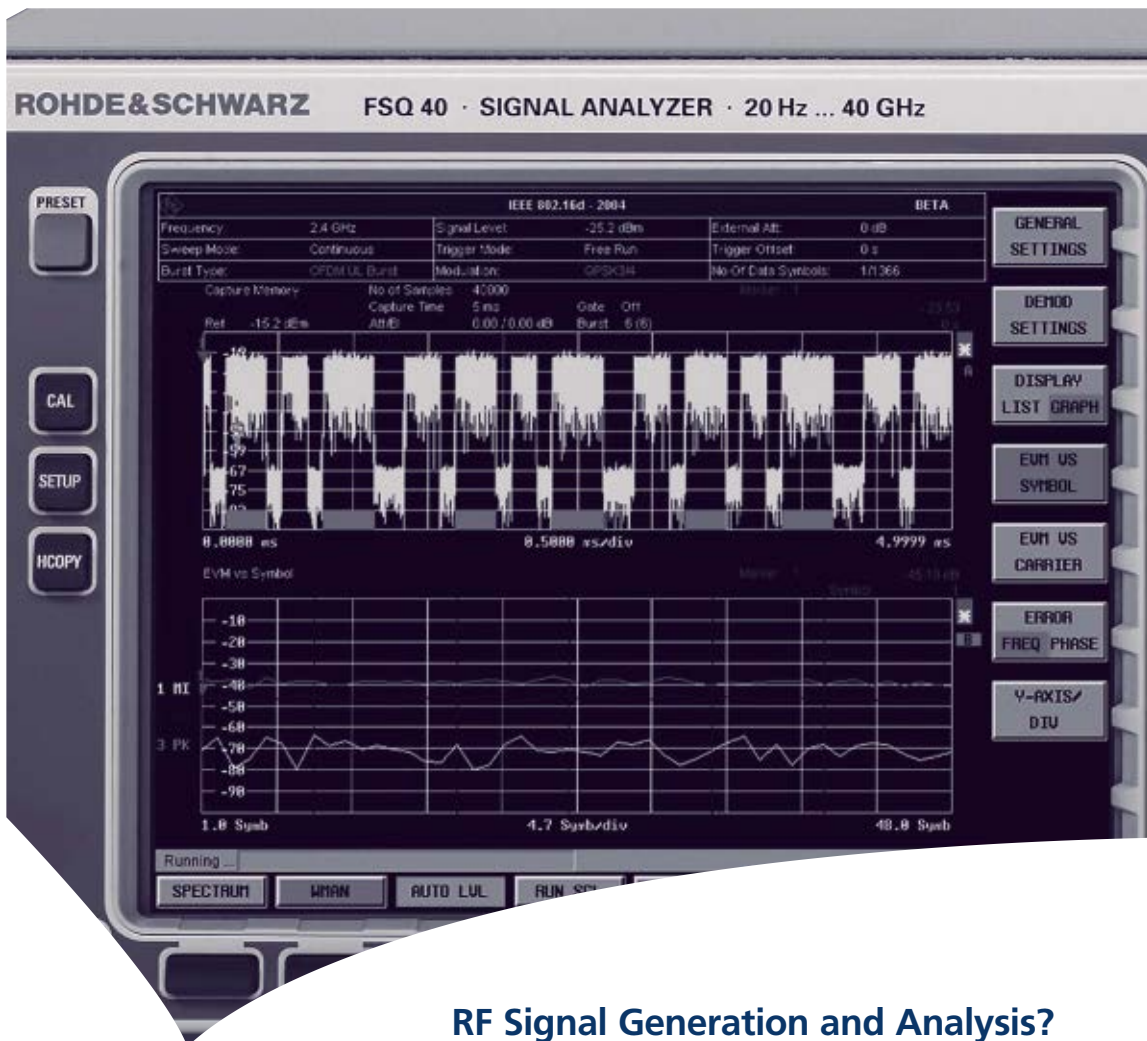
# NEED CABLE ASSEMBLIES FAST?



Visit the  
Custom  
Cable Assembler  
at  
[mwjournal.com](http://mwjournal.com)







## RF Signal Generation and Analysis?

Look inside for a selection of test equipment available for R&D, Production and Field applications



**Livingston**

The Right Technology - when you want it!

## Vector Network Analysis

High-end Instruments for complex Vector Analysis Measurements



Agilent E5071C Network Analyser

### Agilent E5071C Network Analyser

The Agilent E5071C Network Analyser offers the highest RF performance and fastest speed in its class, with a wide frequency range and versatile functions. The Agilent E5071C is the ideal solution for manufacturing and R&D engineers evaluating RF components and circuits from 9kHz to 8.5GHz.

### Rohde & Schwarz ZVB Vector Network Analyser

The Rohde & Schwarz ZVB Vector Network Analyser covering the frequency range from 300kHz to 8GHz and 10MHz to 20GHz has been designed for universal measurements on passive and active components.

### Anritsu MS462xA Transmission/Reflection Analyser

The MS462xA is the economical choice for transmission/reflection analysis (one path - two port network analyser). The "A" model has a 2-port configuration and is available in the frequency ranges of 10MHz to 6GHz (or 3GHz).

### Anritsu MS2024 Vector Network Analyser

VNA Master MS2024A is a handheld Vector Network Analyser designed to make accurate vector corrected 1-port magnitude, phase, and Distance-To-Fault measurements and 1-path 2-port magnitude and phase measurements from 2MHz to 4GHz.

## Spectrum Analysis

Spectrum Analysers to cope with the demands of modern RF Design



Rohde & Schwarz FSQ Signal Analyser

### Rohde & Schwarz FSQ Signal Analyser

The Rohde & Schwarz FSQ Signal Analyser combines two instruments in one. It offers signal analysis at a demodulation bandwidth of up to 120MHz with the dynamic range of a high-end spectrum analyser.

### Agilent E4407B Spectrum Analyser

The Agilent ESA-E Series mid-performance spectrum analyser sets the performance standard in measurement speed, dynamic range, accuracy, and resolving power for similarly priced products. Its flexible platform design appeals to R&D, manufacturing, and field service engineers.

### Tektronix RSA3408A Real Time Spectrum Analyser

The Tektronix RSA3408A offers the ability of Real-Time Analysis, capturing up to 36MHz into memory, providing a unique understanding of time varying RF signals.

### Anritsu MS2721A Spectrum Analyser

The MS2721A is the first fully-functional handheld spectrum analyser designed to conduct highly accurate analysis on the new wave of wireless LAN and cellular signals, including 802.11a, 3G, ultra-wideband and WiMAX.

If you can't see what you're looking for, please give us a call.

**Tel 0845 4583274**



## Signal Generation

Signal Sources with the added flexibility of scalable Modulation Encoders



Agilent N5182A Signal Generator

### Agilent N5182A Signal Generator

Featuring fast frequency, amplitude, and waveform switching, industry-best ACPR performance, high reliability, and simplified self-maintenance – all in two rack units (2RU) – Agilent MXG vector is optimised for manufacturing cellular communications and wireless connectivity components.

### Rohde & Schwarz SMU200A Vector Signal Generator

The Rohde & Schwarz SMU200A Vector Signal Generator has been designed to meet all requirements encountered in research and development of modern communication systems as well as in their production.

### Anritsu MG3681A Digital Modulation Signal Generator

The MG3681A is a high performance digital modulation signal generator that incorporates a broadband vector modulator. It has a frequency range of 250kHz to 3000MHz, covering the frequency bands of all major mobile communications systems.

### Rohde & Schwarz SMJ100A Vector Signal Generator

The SMJ100A covers all the important frequency bands essential in digital RF transmission. The internal baseband generator option handles a multitude of digital standards, e.g. GSM/EDGE, W-CDMA, Wi-Max. Its characteristics make the R&S SMJ100A the ideal all-purpose vector signal generator.

## RF Miscellaneous

Essential tools for all Radio Frequency Engineers/Designers



Agilent N8975A Noise Figure Analyser

### Agilent N8975A Noise Figure Analyser

The Agilent N8975A is a high performance noise figure analyser designed to make fast, accurate and repeatable noise figure measurement.

With the N8975A ease of use features, you can set up complex measurements simply and easily giving you repeatable and reliable results you can trust.

### Rohde & Schwarz NRT Power Meter

Compared to low-cost instruments, power meters like NRT provide a number of benefits: most importantly high measurement accuracy through excellent directivity and a measurement method that determines the average power like a thermal power meter.

### Anritsu ML2480A Power Meter

The ML2480A series power meter and MA2491A Wideband Sensor have been designed for modern high-speed communication and aerospace applications. The ML2480A series has a 20MHz Signal Bandwidth and a 64 MS/s sample rate.

### Agilent E4419B Power Meter

The E4419B power meter is designed for bench and automatic test equipment (ATE) use. It provides true dual-channel power meter capability, with two simultaneous power readings and fast measurement speed (up to 100 readings per second) over the GPIB, with E-series sensors.

Or go on-line to view our product catalogue.

[www.livingston.co.uk](http://www.livingston.co.uk)



RF Components and Circuits need to be characterised and specified as part of the design, production and often, commissioning process. With the right test equipment for the job, the process can be straightforward, reliable and repeatable. Here at Livingston we aim to have a solution for all your RF needs from Vector Network and Spectrum Analysis to Signal Generation and Power measurements. Depending on your specific needs, choose from our range of Short Term Rental, Project Rental or Leasing solutions.

**To find out how we can support your RF generation and measurement requirements now and in the future, please call our Applications Engineers on 0845 4583274 or visit our website [www.livingston.co.uk](http://www.livingston.co.uk)**

#### **Livingston UK Limited**

**United Kingdom**  
Livingston House  
2 Queens Road  
Teddington  
Middlesex  
TW11 0LB

t 020 8943 5151  
f 020 8977 6431  
e [sales@livingston.co.uk](mailto:sales@livingston.co.uk)

**Scotland**  
Phoenix House  
13b Oakbank Parkway  
Livingston  
West Lothian  
EH53 0TH

t 01506 442288  
f 01506 442289  
e [alba@livingston.co.uk](mailto:alba@livingston.co.uk)

[www.livingston.co.uk](http://www.livingston.co.uk)



**Livingston**

: The Right Technology - when you want it!  
.....





## PUTTING THE COMPONENTS TOGETHER SHOULDN'T BE A PUZZLE.

At Advanced Control Components we've been putting great ideas together since 1982. We provide the quality components and assemblies that are a perfect fit for your important projects.

Our industry leading team of design engineers will put all the pieces in place for you. They have extensive experience and an impressive track record in passive and active component design and sub-system integration up to 40GHz. Utilizing the latest and most advanced CAD software, they can solve the toughest design puzzles with comprehensive solutions.

Advanced Control Components supplies high performance solid-state RF and microwave components and sub-systems to the military, aerospace, commercial and instrumentation markets. *Let us put the pieces together for you.*

- **AMPLIFIERS**
- **ATTENUATORS**
- **DETECTORS**
- **LIMITERS**
- **SWITCHES**
- **SWITCH MATRICES**
- **PHASE SHIFTERS**
- **FREQUENCY CONVERTERS**
- **SYNTHESIZERS**
- **INTEGRATED ASSEMBLIES**



**Advanced  
Control  
Components**  
INC.

611 Industrial Way West, Eatontown, NJ 07724 • Tel 732 460-0212 • Fax 732 460-0214 [www.advanced-control.com](http://www.advanced-control.com)

**Celebrating our 25th ANNIVERSARY**

Visit <http://mwj.hotims.com/11713-1> or use RS# 1 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)

# VCOs

10 to 4400MHz <sup>\$11<sup>95</sup></sup>  
from <sub>ea. (qty. 5)</sub>

Want a miniature surface mount, shielded plug-in, or rugged connectorized 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 bandwidths. Select from models with low phase noise, linear tuning, load insensitivity, dual output, wide modulation bandwidths, or 5V models optimized for PLL ICs and synthesizers. And pick from an innovative array of miniature surface mount packages as small as 0.25" square, all featuring our exclusive glue-down process on each circuit component to give you ultimate reliability during reflow soldering. You can quickly find the model you need using our online catalog or "The YONI2 Search Engine" at the Mini-Circuits web site. With YONI2, you just enter your specs...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 fast response, low prices, and quick turnaround. For your commercial, industrial, and military applications, choose Mini-Circuits VCOs!

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



**RoHS COMPLIANT**  
RoHS models available, consult factory.





**Agilent Technologies**

For high reliability, all Mini-Circuits  
VCOs are tested with the  
Agilent E5052A Signal Source Analyzer.  
[www.agilent.com/find/ssa](http://www.agilent.com/find/ssa)



Detailed Performance Data & Specs For Mini-Circuits VCOs  
Available Online at: [www.minicircuits.com/oscillat.html](http://www.minicircuits.com/oscillat.html)

**Mini-Circuits®**  
ISO 9001 ISO 14001 CERTIFIED

**ALL NEW**  
[minicircuits.com](http://minicircuits.com)

P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661 For detailed performance specs & shopping online see Mini-Circuits web site



The Design Engineers Search Engine Provides ACTUAL Data Instantly From MINI-CIRCUITS At: [www.minicircuits.com](http://www.minicircuits.com)

**RF/IF MICROWAVE COMPONENTS**

402 Rev B

Visit <http://mwj.hotims.com/11713-85> or use RS# 85 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)

# DESIGN OF A NOVEL QUAD-BAND MICROSTRIP BPF USING QUARTER-WAVELENGTH STEPPED-IMPEDANCE RESONATORS

*In this article, a new quad-band microstrip bandpass filter (BPF) is proposed. The BPF is composed of resonators whose first four resonant frequencies can be tuned to the desired passbands. Each resonator is formed by combining two unequal-size stepped-impedance resonators (SIR) with part of their structures shared. The designed quad-band BPF is implemented on an RT/Duroid 6010 substrate. The measured fractional bandwidths (minimum insertion losses) for the 1.57 GHz (GPS), 2.45 GHz (ISM), 3.55 GHz (WiMAX) and 5.25 GHz (WLAN) bands are 6.4 percent (1.85 dB), 8.2 percent (1.4 dB), 8.7 percent (2 dB) and 12.2 percent (1.06 dB), respectively, which agree well with the simulated results. For miniaturization purposes, the resonators are meandered to give an overall circuit size of only  $12.3 \times 9.1$  mm.*

Due to the increasing competition in the global wireless communication markets, many wireless terminals, such as mobile phones, personal dispatching assistants (PDA) and laptop computers, are being constructed to integrate more than one communication standard into the same apparatus. This allows the end-users to access different systems that provide various services. Since different communication standards may use different frequency bands, front-end components capable of supporting multiple frequency bands have received much attention.<sup>1,2</sup> These front-end components include couplers,<sup>3-6</sup> antennas<sup>7,8</sup> and bandpass filters (BPF).<sup>9-13</sup> In the literature, most multi-band

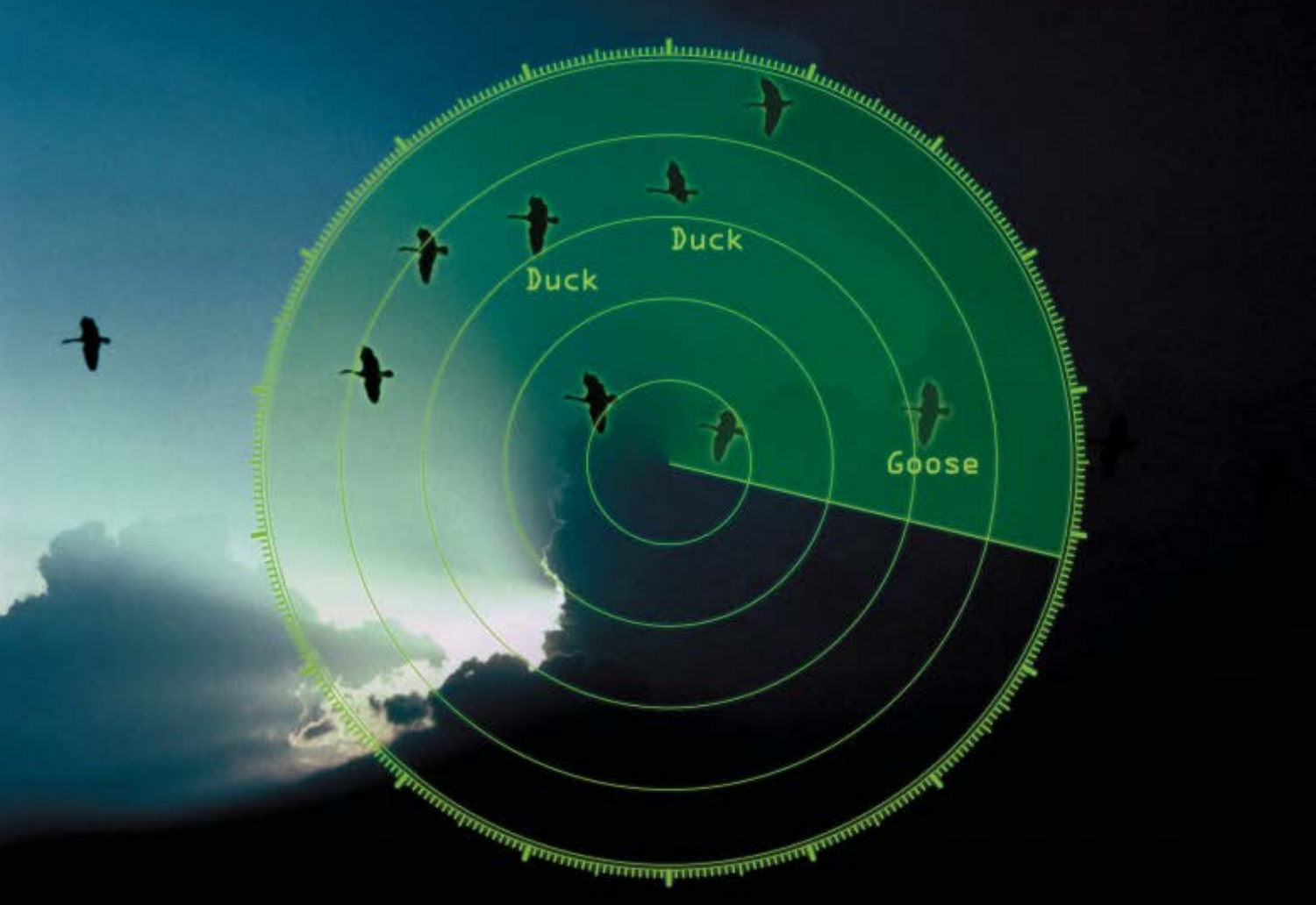
couplers reported can support only two frequency bands<sup>3-6</sup> because of the high complexities involved in the design. However, antennas that can be operated in two or more frequency bands are very common.<sup>7,8</sup> In this work, the design of multi-band BPFs is the primary interest. Recently, dual-band BPFs have been intensively investigated,<sup>9-11</sup> where-

---

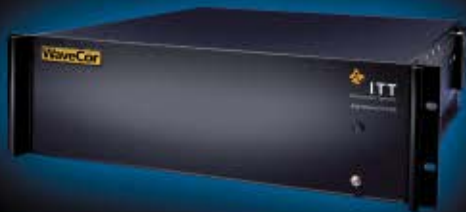
CHUNG-I G. HSU  
Da-Yeh University  
Changhua, Taiwan, ROC

CHING-HER LEE AND HE-KAI JHUANG  
National Changhua University of Education  
Changhua, Taiwan, ROC





## Digital Reveals the Details



**ITT**

Microwave Systems

*Engineered for life*

978-441-0200 • [www.ittmicrowave.com](http://www.ittmicrowave.com)

The difference between one wing span and another can be critical. But to provide this kind of accuracy, you need exceptionally clean RF output and superior waveform control—the kind of capability only ITT's microwave synthesizers provide.

Our patented direct digital synthesis technology features non-linear FM, wideband modulation, waveform sequencing, precise pulse control, <200 ns switching speed, and ultra-low phase noise and spurious. And it's available in either our off-the-shelf WaveCor™ synthesizers or a customized solution up to 40 GHz.

With this capability at your disposal, you can build a system that provides the ultimate bird's eye view of any environment.

To learn more, visit our Web site.

Visit <http://mwj.hotims.com/11713-61> or use RS# 61 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)

as the study of tri-band BPFs, which can support three practical commercial communication bands, is relatively scant.<sup>12</sup> Furthermore, a quad-band BPF that can simultaneously support four frequency bands is not yet available.

The most intuitive way of constructing a multi-band component is to build an individual circuit for each frequency band and then combine them in parallel, resulting in a large circuit size. Nevertheless, Miyake, et al.<sup>9</sup> have successfully extended the parallel-cascade structure<sup>13</sup> (originally proposed for a single-band BPF design) to implement a miniaturized, low temperature, co-fired ceramic dual-band BPF by stacking two stripline filters, one for the 900 MHz band and the other for the 1900 MHz band. Although highly compact, this filter needs extra impedance matching networks at its input/output ports. A more clever way of designing a dual-band BPF is to use resonators whose second resonant frequency can be tuned over a very wide frequency range. Stepped-impedance resonators (SIR), originally proposed by M. Makimoto, et al.,<sup>14</sup> possess such a property, and were successfully employed in a dual-band BPF design.<sup>10</sup> Alternatively, a dual-band BPF can be created by loading a transmission line with three unequal-length shunt open stubs,<sup>11</sup> which yield three transmission zeros. Similarly, a tri-band BPF can be constructed by placing four unequal-length open stubs in shunt to a transmission line,<sup>12</sup> resulting in four transmission zeros. Although this idea can be extended to implement a multi-band BPF supporting more than three frequency bands, so far, to the authors' knowl-

edge, a quad-band BPF has not been reported in the literature. This is probably because too many open stubs will make the filter bulky and because mutual loading effects among the stubs have rendered the quad-band BPF topology impractical. Moreover, since the shunt stubs are open-ended, low frequency and DC signals will not be blocked by these filters,<sup>11,12</sup> a property that can be regarded as a drawback.

The aim of this article is to design a quad-band BPF that can pass signals in the 1.57 GHz (GPS L1 channel), 2.45 GHz (ISM), 3.55 GHz (WiMAX) and 5.25 GHz (WLAN) bands. Two quarter-wavelength ( $\lambda/4$ ) SIRs, when properly designed, can be combined to form a single resonator that resonates at the four desired frequencies. Because a  $\lambda/4$  SIR offers a smaller circuit size and a higher third resonant frequency compared with a  $\lambda/2$  SIR, it is used here as the building blocks of a BPF. In addition, the SIRs are meandered to reduce the size of the fabricated BPF, which measures only  $12.3 \times 9.1$  mm. Since the quadruple-frequency resonators used in the BPF are mutually separated, low frequency and DC signals will be highly attenuated.

### QUADRUPLE-FREQUENCY MICROSTRIP RESONATOR DESIGN

A BPF can be constructed by combining resonators with the same resonant frequencies in a proper manner. A resonator, with its four main resonances located at the desired frequencies, can be used as the building block of a quad-band BPF. Such a resonator can be composed of two primary resonators, each of which has its first two resonant frequencies identical to two of the four desired frequencies. The prime resonating structure adopted here is a  $\lambda/4$  SIR, as shown in **Figure 1**. The  $\lambda/4$  SIR consists of two microstripline sections having characteristic impedances  $Z_1$  and  $Z_2$  and electric lengths  $\theta_1$  and  $\theta_2$ . One end of the  $\lambda/4$  SIR is grounded through a via of diameter  $D$ . For simplicity, the two resonator sections are assumed to have the same electrical length, that is,

$\theta_1 = \theta_2 = \theta_0$ . By neglecting the parasitic effects of the via and the step junction between the two line sections, the parallel resonance condition can be derived as  $\tan^2 \theta_0(f) = Z_2/Z_1 = R_z$ , from which the resonant frequencies can be determined.<sup>14</sup> Here,  $R_z$  stands for the impedance ratio. Denote the  $n$ th resonant frequency of the SIR by  $f_n$ ; then, for a given fundamental resonant frequency ( $f_1$ ) of a  $\lambda/4$  SIR, the associated second and third resonant frequencies, respectively, can be written as<sup>14</sup>

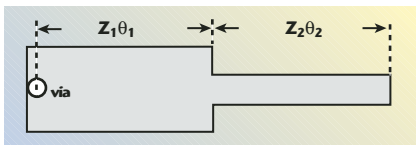
$$f_2 = f_1 \left( \frac{\pi}{\tan^{-1} \sqrt{R_z}} - 1 \right) \quad (1)$$

and

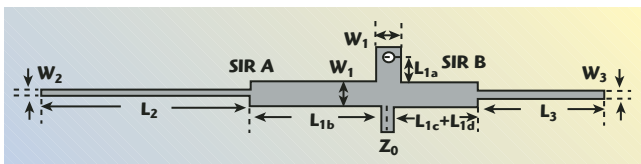
$$f_3 = f_2 + 2f_1 \quad (2)$$

This implies that, for a given  $f_1$ , the second resonant frequency  $f_2$  can be freely designed by choosing an appropriate  $R_z$  value for the  $\lambda/4$  SIR. Furthermore, if both  $f_1$  and  $f_2$  are given, then  $f_3$  is fixed and can be considered spurious.

As mentioned, two dual-frequency SIRs (designated as SIR A and SIR B) are needed in order to construct a quadruple-frequency resonator. Let  $f_{A1} = 1.57$  GHz and  $f_{A2} = 3.55$  GHz be the first two resonant frequencies of SIR A; thus,  $R_{ZA} = 2.07$  and  $\theta_{0A}(f_{A1}) = 55.2^\circ$ . Similarly, let  $f_{B1} = 2.45$  GHz and  $f_{B2} = 5.25$  GHz be associated with SIR B;  $R_{ZB}$  should then be 2.42 and  $\theta_{0B}(f_{B1}) = 57.3^\circ$ . Note that the first spurious resonant frequencies  $f_{A3}$  (6.69 GHz) and  $f_{B3}$  (10.15 GHz) for SIRs A and B, respectively, are both greater than the highest of the four desired frequencies. In this article, the filter circuit is to be designed on a 0.635 mm-thick RT/Duroid 6010 substrate with a dielectric constant of 10.2 and a loss tangent of 0.0023. For SIR A, if  $Z_1 = 30.2 \Omega$  ( $W_1 = 1.4$  mm), then  $Z_2 = 62.5 \Omega$  ( $W_2 = 0.3$  mm). In order to combine SIR B with SIR A, the width and characteristic impedance of the first section of SIR B are set to be the same as those of SIR A. For differentiation purposes, the width and characteristic impedance of the second section of SIR B are denoted by  $W_3$  and  $Z_3$ , respectively. The value of  $R_{ZB} = Z_3/Z_1$  thus leads to  $Z_3 = 72.6 \Omega$  ( $W_3 = 0.2$  mm). These two SIRs can be combined into a single resonator, as



▲ Fig. 1 Geometry of the  $\lambda/4$  stepped-impedance resonator.



▲ Fig. 2 Geometry of the quadruple frequency resonator with a 50  $\Omega$  microstrip tap.



**4 Week Delivery**



# Oscillators Break Through the 20 GHz Barrier

**Revolutionary oscillator phase noise performance to 20 GHz is now available from Micro Lambda Wireless, the leader in YIG-based components.**

## **MLXB-Series 1.25" Square YIG-tuned Oscillators**

- 8-18 GHz, 6-18 GHz & 8-20 GHz frequency bands.
- Phase noise of -123 dBc/Hz @ 100 kHz offset at 20 GHz guaranteed.

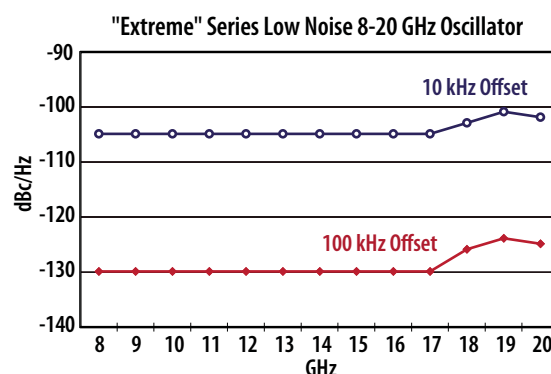
## **MLXS-Series 1.75" Cylinder YIG-tuned Oscillators**

- 8-18 GHz, 6-18 GHz & 8-20 GHz frequency bands.
- Phase noise of -123 dBc/Hz @ 100 kHz offset at 20 GHz guaranteed.

## **MLXM-Series 1" Cube YIG-tuned Oscillators**

- 8-18 GHz & 6-18 GHz frequency bands.
- Phase noise of -125 dBc/Hz @ 100 kHz offset at 18 GHz for 8-18 GHz model guaranteed.

Detailed data sheets are available on our website.



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

**MICRO LAMBDA WIRELESS, INC.**

*"Look to the leader in YIG-Technology"*

46515 Landing Parkway, Fremont CA 94538 • (510) 770-9221 • [sales@microlambdawireless.com](mailto:sales@microlambdawireless.com)

Visit <http://mwj.hotims.com/11713-75> or use RS# 75 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)

# 5V, 1W MMIC Solution

FTTH / CATV / Wireless  
Application

- GaAs HBT Gain 18dB
- E-pHEMT up to 33dBm, Pout
- MESFET Linear MMIC

		P1 (dBm)	N.F (dB)	Gain (dB@2GHz)
E pHEMT	LNA	20	0.8	18
	Linear LNA	24	1.2	16
	Power Amp.	29	2.0	13
		32	2.2	12
MESFET	Linear Amp.	22	2.5	12
		24	2.7	12
HBT	Gain Block	20	3.0	18
		19	5.5	18
		18	5.0	15

## GaAs MESFET MMIC Hybrid Active Mixer

	Up	Down
RF Freq. (MHz)	700-3600	700-3600
IF Freq. (MHz)	50-200	50-200
Gain (dB)	2-10	2-10
OIP3 (dBm)	20-26	20-26
NF (dB)	6-9	6-9

## MEMS Divider, Coupler

- Freq. 700-3800 MHz
- Isolation 20-30 dB
- Insertion Loss 0.4-0.7 dB
- Coupling -15 dB

**RFHIC**  
www.rfhic.com

Tel) 82-31-250-5011  
Fax) 82-31-250-5088  
E-mail) rfsales@rfhic.com

shown in **Figure 2**, where SIRs A and B share part of the  $W_1$ -wide section. This common section has a length of  $L_{1a}$ , which is measured from the center of the via to the upper edge of the horizontal  $W_1$ -wide section. Also shown is the  $50\ \Omega$  tapping microstrip that feeds the resonator at the junction of the two SIRs.

## QUAD-BAND MICROSTRIP BPF IMPLEMENTATION

Note that the value of  $L_{1a}$  must be appropriately selected so as to meet the bandwidth requirements for the four passbands centered at  $f_{A1}$ ,  $f_{B1}$ ,  $f_{A2}$  and  $f_{B2}$  in the quad-band BPF design. The fractional bandwidths needed are approximately 3 percent (1557

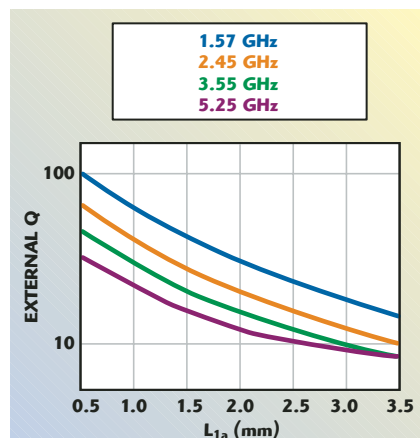
to 1593 MHz), 4 percent (2400 to 2484 MHz), 8.5 percent (3.4 to 3.7 GHz) and 4 percent (5150 to 5350 MHz), respectively. Using a second-order Butterworth response as the target, the element values for the low pass filter prototype are  $g_0 = g_3 = 1$  and  $g_1 = g_2 = \sqrt{2}$ . The required external quality factors (defined by  $Q_{ei} = g_0 g_1 / \Delta$  with  $\Delta$  being the 3 dB fractional bandwidth of the filter)<sup>15</sup> for these four bands are in general different. Let the external quality factor for the  $i$ th resonant frequency be denoted by  $Q_{ei}$  ( $i = A_1, B_1, A_2$  and  $B_2$ ), which can be computed by<sup>10</sup>

$$Q_{ei} = Z_0 \frac{f_i}{2} \frac{dB(f)}{df} \bigg|_{f=f_i} = \frac{Z_0}{2} \cdot \left\{ f \frac{d}{df} [B_0(f) + B_A(f) + B_B(f)] \right\} \bigg|_{f=f_i} \quad (3)$$

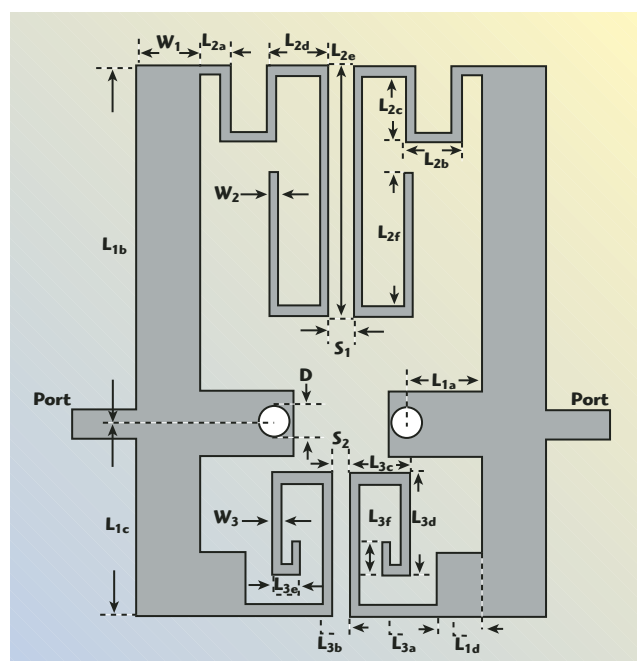
where

$Z_0$  = characteristic impedance of the tapping microstrip

Moreover, the total input susceptance, looking from the tapping position toward the resonator, is  $B(f)$ , which can be decomposed into  $B_0(f)$ ,  $B_A(f)$  and  $B_B(f)$ , that is the susceptances looking from the junction of SIRs A and B toward the upper side (toward the via), the left side and the right side of the quadruple-frequency resonator, respectively. The expressions for  $B_0(f)$ ,  $B_A(f)$  and  $B_B(f)$  are easy to derive and are omitted here for brevity. Nevertheless, the expressions of  $f dB_j(f)/df$ ,  $j = 0, A, B$  are listed in **Appendix A** for completeness. The  $Q_e$  versus  $L_{1a}$  curves, computed using Equation 3 for the four desired center frequencies, are shown in **Figure 3**, which indicates that  $Q_e$  decreases with  $L_{1a}$ . Hence, the larger the value of  $L_{1a}$ , the larger the fractional



▲ Fig. 3 External  $Q$  versus the resonator shared length.

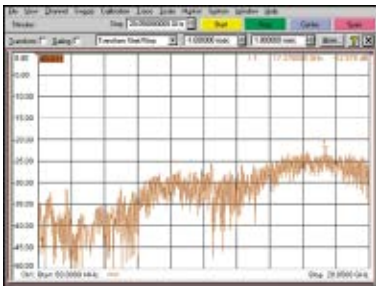


▲ Fig. 4 Layout of the proposed quad-band microstrip BPF.

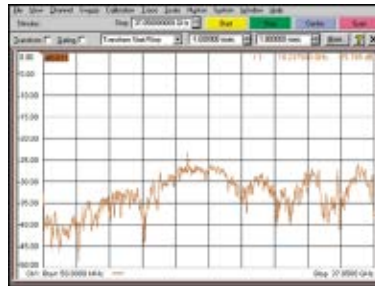


# Rosenberger® SMA<sup>+</sup> Cables

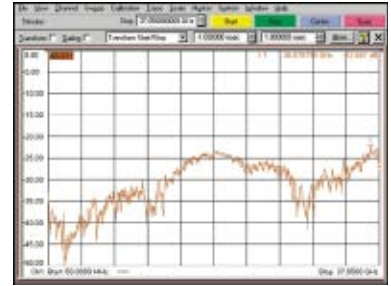
## THE **PLUS** MEANS 36GHz PERFORMANCE AT A FRACTION OF THE COST.



Mated with SMA



Mated with 3.5mm



Mated with 2.92mm

### Features and Benefits

- High-performance, high-frequency test cables built for day-to-day applications
- Available in Rosenberger RTK-Flex 405 (flexible) cable or RTK-FS-085 (conformable) cable. Or, special order in 085 semi-rigid cable built to your specifications
- Excellent performance over a broad frequency range (see chart)
- Standard SMA interface — intermatable with SMA, 3.5mm and 2.92mm (K\*) connectors
- Gold-plated center contacts, passivated stainless steel coupling nuts and a proprietary dielectric
- Unique over-molded strain relief is exceptionally rugged and durable
- Temperature range: -55°C to +125°C
- Minimum return loss: -18dB when mated with SMA, 3.5mm or 2.92mm (K\*) connectors

\* K Connector® is a registered trademark of Anritsu Corporation



Warranty—If there is a connector failure during the first six months following shipment, we will repair or replace (at our option) your cable (providing the damage was not caused by misuse or abuse).

## Rosenberger®

North America: Rosenberger of North America, LLC, (USA) 717-290-8000  
Europe: Rosenberger Hochfrequenztechnik GmbH & Co KG (Germany) Tel: + 49/86 84/18-0  
Asia: Rosenberger Asia Pacific Tel: (China) + 86/10/80 78 1995  
South America: Rosenberger Sudamerica Ltda. (Chile) + 56/2/2 75 29 08  
Email...info@rosenbergerna.com WEB...www.rosenbergerna.com

**"Off-the-shelf availability from RFMW"**  
**Call 877 FOR RFMW (877 367 7369)**  
**[www.rfmw.com/rosenberger](http://www.rfmw.com/rosenberger)**

Visit <http://mwj.hotims.com/11713-121> or use RS# 121 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)

# GSM UMTS WiMAX Solution

## GaN PA Hybrid Amplifier

- ▶ OFDM 30 dBm, EVM 2%
- ▶ Gain 21 dB, BW 200 MHz
- ▶ Low Cost



## LNA Hybrid

- ▶ N.F. 0.6 ~ 1.7 dB
- ▶ OIP3 27 ~ 45 dBm
- ▶ Gain 12 ~ 33 dB



## GaAs MMIC

EpHEMT, HBT, MESFET, pHEMT

- ▶ N.F. 1.0 ~ 5.5 dB
- ▶ OIP3 27 ~ 41 dBm
- ▶ Gain 10 ~ 20 dB

	MEMS	IL	ISO	Power
2 Way Divider	0.5	23	2W	
15dB Coupler	0.6	20	2W	



## Up/Down Converter & PLL Synthesizer

- ▶ Wideband BW 200 MHz
- ▶ Low Phase Noise



# RFHIC

www.rfhic.com

Tel) 82-31-250-5011

Fax) 82-31-250-5088

E-mail) rfsales@rfhic.com

Come see us at

RF & Hyper

CNIT - Paris La Defense

Booth# E38

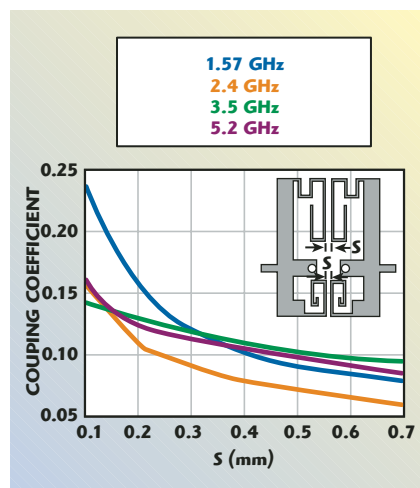
27~29 March 2007

http://www.rfhyper.com

bandwidth  $\Delta$  (since  $\Delta = g_0 g_1 / Q_c$ ). Obviously, the four required lengths of  $L_{1a}$  for the four desired passbands may be all different. Among them, the largest  $L_{1a}$  value must be selected to ensure that all the four passband bandwidths be greater than or equal to the actual required ones. If an  $L_{1a}$  value other than the largest one is chosen, some passband bandwidths will be smaller than needed, thus resulting in partial signal blocking in those particular passbands. Note that in Equation 3 and the associated expressions listed in Appendix A, many

factors have been neglected, including the dielectric loss, the conductor loss, the dispersion properties of the microstrip sections in the resonator and the effects of the structural discontinuities. Hence, the aforementioned largest  $L_{1a}$  value can only serve as a good start in the optimization process of designing the quad-band BPF and may still have to be fine-tuned in the design.

The geometry of the proposed quad-band BPF is shown in **Figure 4**, where the two quadruple-frequency resonators are placed back to back with gaps  $S_1$  and  $S_2$  in the horizontal direction. The upper part of the BPF is the main path for signals around  $f_{A1}$  and  $f_{A2}$ , whereas the lower part is for signals around  $f_{B1}$  and  $f_{B2}$ . Since the resonators have been bent to reduce the circuit size, the structural parameters ( $W_1$ ,  $W_2$ ,  $W_3$ ,  $\theta_{0A}(f_{A1})$ ,  $\theta_{0B}(f_{B1})$ ,  $L_{1a}$  and so on) may need to be further tuned during the full-wave optimization. For the  $f_i$ -referenced fractional bandwidths  $\Delta_i$  ( $i = A1, B1, A2$  and  $B2$ ) determined for a selected  $L_{1a}$  value, the coupling coefficients between these two resonators can be computed using  $M_i = \Delta_i \sqrt{g_{1g_2}}$ . Once the values of  $M_i$  are known, the gaps between these two resonators can be determined through full-wave electromagnetic simulation.<sup>15</sup> **Figure 5** shows a set of simulated coupling coefficients as functions of the gap  $S$ . In the inset of the figure, the structure has been configured to have the same gap  $S$  for both the upper and the lower half of the juxtaposed resonators. This can be done by adjusting the individual lengths of  $L_{1c}$  and  $L_{1d}$  for a fixed  $L_{1c} + L_{1d}$ . Once the required

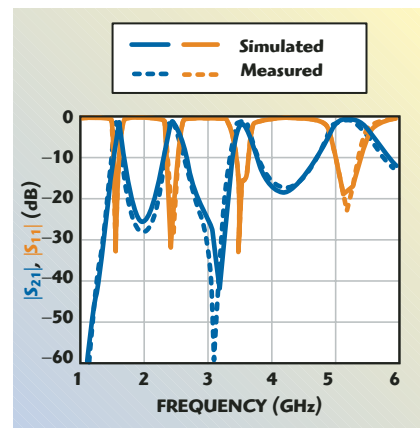


▲ Fig. 5 Simulated coupling coefficients versus the gap width between resonators.

TABLE I

OPTIMIZED DIMENSIONS  
OF THE QUAD-BAND BPF

Parameter	Value (mm)
$W_1$	1.40
$W_2$	0.15
$W_3$	0.20
$S_1$	0.60
$S_2$	0.30
$D$	0.60
$L_{1a}$	1.8
$L_{1b}$	8.0
$L_{1c}$	4.3
$L_{1d}$	1.0
$L_{2a}$	0.67
$L_{2b}$	1.19
$L_{2c}$	1.50
$L_{2d}$	1.29
$L_{2e}$	5.54
$L_{2f}$	3.03
$L_{3a}$	2.0
$L_{3b}$	3.2
$L_{3c}$	1.4
$L_{3d}$	2.3
$L_{3e}$	0.7
$L_{3f}$	0.8



▲ Fig. 6 Simulated and measured response of the quad-band BPF.



## McQ512 Trimmer Capacitor



Tusonix's smallest Miniature All-Ceramic Surface Mount Trimmer Capacitor - the McQ 512 Series - is offered in an incredibly compact size for those applications that demand high Q and space-saving solutions. The state-of-the-art McQ 512 Trimmer is perfect for an endless variety of applications that require miniaturized capacitance trimming, including avionics apparatus, communications equipment, oscilloscopes, crystal oscillators and crystal filters.

## Back Plane Mount Filtered Terminal Blocks



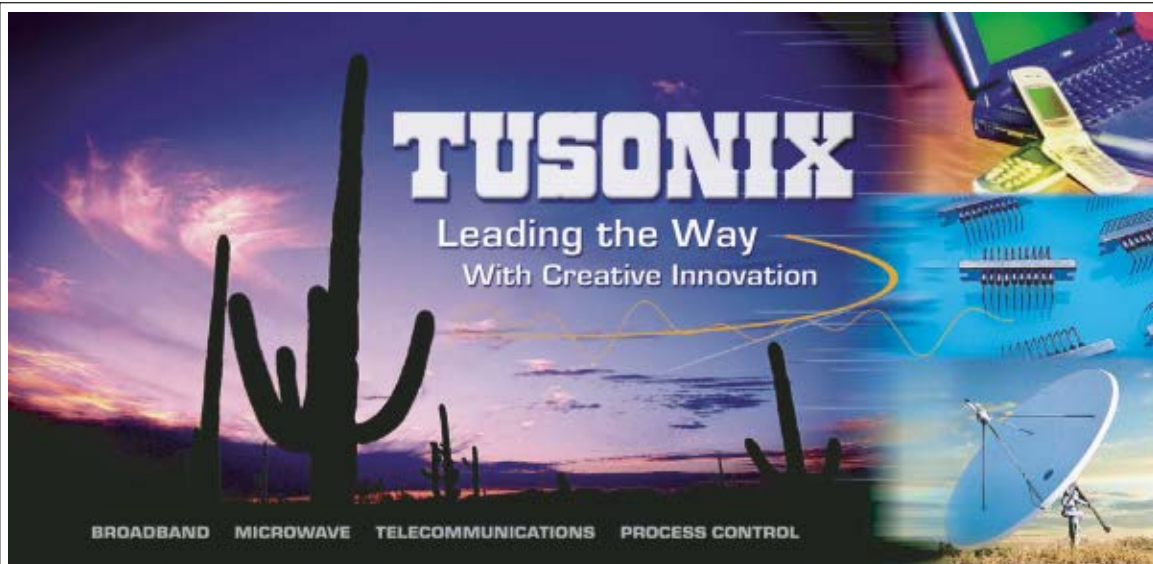
Tusonix now offers Back Plane Mount Filtered Terminal Blocks. These cost effective, premium filtered terminal blocks provide excellent EMI/RFI filtering of power and control lines. Available with 2-8 lines, our back plane mount terminal blocks (part no. 7602-551 through 7606-551) offer an effective insertion loss range from 10 MHz to 10 GHz. The capacitance range is 2000 pF to 5000 pF with a temperature range of -55°C to +105°C. And, each terminal block is tested for key parameters in efforts to ensure reliability.

## Redesigned Shoulder Feed-Thru Capacitors

Tusonix offers a newly redesigned shoulder feed-thru capacitor. Our capacitors in the 2461 and 2463 series are an excellent solution to your EMI needs that involve a wide range of telecommunications applications. These capacitors, which are offered with a capacitance range of 5 to 2,500 pF and insertion losses up to 40dB, are a low cost alternative for existing applications using a similar product.



**RoHS ✓  
Compliant**



## Your EMI/RFI Solution For Today's Technology

- OEMs around the globe count on Tusonix to provide cost effective EMI/RFI solutions for virtually every need. From design to application, we're there to work with your team. You can always depend on Tusonix for timely delivery of quality EMI/RFI filters, ceramic capacitors, filtered terminal blocks, filter assemblies and a vast array of disc, plate and variable capacitors. Tusonix continues to lead the way with creative solutions and quality products for a world-wide market.



► Visit us online: [tusonix.com](http://tusonix.com)

7741 N Business Park Drive / Tucson Arizona 85743 / PH 520-744-0400 / FAX 520-744-6155 / [sales@tusonix.com](mailto:sales@tusonix.com)  
Authorized Distributors: Avnet 1-888-286-3873 / Resco 1-800-638-1242 / RS Electronics 1-800-555-5312 / TTI 1-800-225-5884  
Microwave Components 1-888-591-4455

Visit <http://mwj.hotims.com/11713-147> or use RS# 147 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)

# GaN High Power

## 120W GaN High Power Pallet Amplifier

► UMTS, W-CDMA, WiMAX  
45dBm Output Power



## GaN High Power TR

	Gain (dB)	PTdB (dBm)	OIP3 (dBm)
RT233PD	14.0	33	43
RT240PD	13.0	40	50
RT243PD	12.0	43	52



## GaN Power Amplifier

- 4W, 20W 40~1000 MHz
- 20W, 40W 20~ 500 MHz,  
400~1000 MHz
- 39dBm OFDM,  
EVM 2%, 3.4~3.6GHz,  
2.5~2.7 GHz
- 45dBm W-CDMA, UMTS

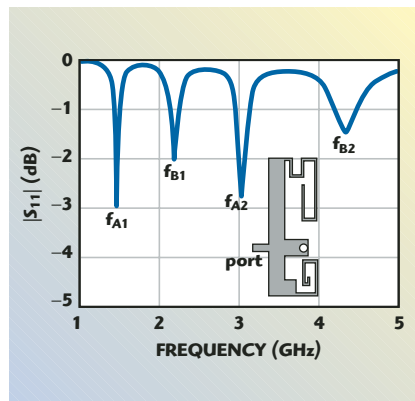


**RFHIC**  
www.rfhic.com

Tel) 82-31-250-5011  
Fax) 82-31-250-5088  
E-mail) rfsales@rfhic.com

Come see us at  
RF & Hyper  
CNIT - Paris La Defense  
Booth# E38  
27-29 March 2007  
http://www.rfhyper.com

TABLE II PERFORMANCE OF THE DESIGNED QUAD-BAND BPF			
		Simulation	Measurement
$f_{A1}$ (1.57 GHz)	Minimum insertion loss (dB)	1.53	1.85
	3 dB band (GHz)	1.5 to 1.6	1.51 to 1.61
	BW (%)	6.4	6.4
$f_{B1}$ (2.45 GHz)	Minimum insertion loss (dB)	1.12	1.4
	3 dB band (GHz)	2.35 to 2.54	2.34 to 2.54
	BW (%)	7.8	8.2
$f_{A2}$ (3.55 GHz)	Minimum insertion loss (dB)	1.5	2.0
	3 dB band (GHz)	3.38 to 3.72	3.40 to 3.71
	BW (%)	9.6	8.7
$f_{B2}$ (5.25 GHz)	Minimum insertion loss (dB)	0.9	1.06
	3 dB band (GHz)	4.9 to 5.5	4.92 to 5.56
	BW (%)	11.4	12.2

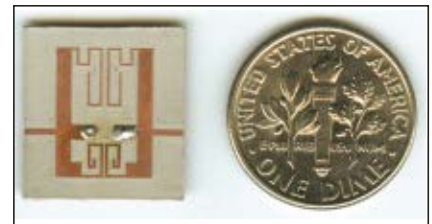


▲ Fig. 7 Simulated reflection coefficient of one-half of the BPF.

( $M_{A1}$ ,  $M_{A2}$ ) and ( $M_{B1}$ ,  $M_{B2}$ ) are obtained for two possibly different values of  $S$ ,  $S_1$  will be equated to the value of  $S$  pertaining to ( $M_{A1}$ ,  $M_{A2}$ ) and  $S_2$  to that pertaining to ( $M_{B1}$ ,  $M_{B2}$ ). If this task cannot be achieved, the values of  $L_{2e}$  and  $L_{3b}$  will have to be varied and another set of simulated coupling-coefficient curves generated. If still not successful, the value of  $L_{1a}$  may have to be changed to acquire a different set of  $\Delta_i$  (thus, a different set of  $M_i$ ) and search for an appropriate set of gaps ( $S_1$  and  $S_2$ ).

## EXPERIMENTAL RESULTS

For the fabricated quad-band BPF with the optimized dimensions shown in **Table 1**, the corresponding coupling coefficients ( $M_{A1}$ ,  $M_{B1}$ ,  $M_{A2}$ ,  $M_{B2}$ ) are approximately (0.0453, 0.052, 0.062, 0.0794) and the fractional bandwidths ( $\Delta_{A1}$ ,  $\Delta_{B1}$ ,  $\Delta_{A2}$ ,  $\Delta_{B2}$ ), computed from  $M_i = \Delta_i / \sqrt{g_1 g_2}$ , are 6.39, 7.4, 8.8 and 11.23 percent. **Figure 6** shows the simulated and measured frequency responses of the



▲ Fig. 8 The fabricated quad-band microstrip BPF.

BPF, which are also summarized in **Table 2** for comparison. The measured results agree quite well with those obtained from the simulation done using Ansoft HFSS, a full-wave electromagnetic simulator. The measured 3 dB fractional bandwidths for the four passbands centered at  $f_{A1}$ ,  $f_{B1}$ ,  $f_{A2}$  and  $f_{B2}$  are found to be 1510 to 1610 MHz (6.4 percent), 2340 to 2540 MHz (8.2 percent), 3400 to 3710 MHz (8.7 percent) and 4920 to 5560 MHz (12.2 percent), respectively. The minimum insertion losses measured for these four passbands in the same sequence are 1.85, 1.4, 2.0 and 1.06 dB, respectively. The simulated return loss for a single microstrip line-fed quadruple-frequency resonator (half of the BPF structure) is shown in **Figure 7** to verify that the designed resonator indeed resonates at the four desired frequencies. A photograph of the fabricated BPF is shown in **Figure 8**, which illustrates its very small area of only 12.3 × 9.1 mm.

## CONCLUSION

In this article, a new quad-band microstrip bandpass filter (BPF) has been proposed and implemented. The novel resonators composed of





## Green leader.

### High frequency laminates.

Unique lead-free capable and/or halogen-free high temp formulations, combined with excellent processability and the best electrical performance, assure Rogers position as an industry leader.

Rogers sets the benchmark for "Green-Performance".

## Lead-Free RoHS WEEE

Halogen-Free	RoHS	Lead-Free
RO4003™ R/flex® 3000 LCP Series TMM® Series	RT/duroid® 5000 Series RT/duroid® 6000 Series R/flex® 3000 LCP Series RO3000® Series RO4000® Series TMM® Series ULTRALAM® 2000	RT/duroid® 5000 Series RT/duroid® 6000 Series R/flex® 3000 LCP Series RO3000® Series RO4000® Series TMM® Series ULTRALAM® 2000

### Decomposition Temperature:

	Unit	RO4003C™	RO4350B™	RO3003™	High Tg Epoxy Blends
Td - TGA	°C	425°C	390°C	500°C	300 - 350°C

Learn more at [www.rogersgreenworld.com](http://www.rogersgreenworld.com)



**ROGERS**  
CORPORATION

The world runs better with Rogers.

Advanced Circuit Materials

two SIRs have been designed to resonate at four desired frequencies, and have been subsequently employed in the BPF design. The circuit size has been greatly reduced by meandering the resonators. The measured frequency responses of the designed BPF have been found to agree with the simulated ones. To the authors' knowledge, this BPF is the first one reported in the literature that can support four practical frequency bands. ■

## ACKNOWLEDGMENT

This work was supported by the National Science Council, Taiwan, ROC, under grant no. NSC 94-2213-E-018-006.

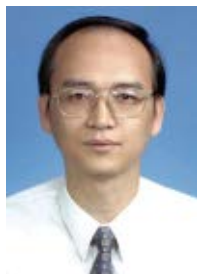
## References

1. S.F.R. Chang, W.L. Chen, S.C. Chang, C.K. Tu, C.L. Wei, C.H. Chien, C.H. Tsai, J. Chen and A. Chen, "A Dual-band RF Transceiver for Multi-standard WLAN Applications," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 53, No. 3, March 2005, pp. 1048–1055.
2. Y.S. Lin, C.C. Liu, K.M. Li and C.H. Chen, "Design of an LTCC Tri-band Transceiver Module for GPRS Mobile Applications," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 52, No. 12, December 2004, pp. 2718–2724.
3. K.K.M. Cheng and F.L. Wong, "A Novel Approach to the Design and Implementation of Dual-band Compact Planar 90° Branch-line Coupler," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 52, No. 11, November 2004, pp. 2458–2463.
4. M.J. Park and B. Lee, "Dual-band, Cross-coupled Branch-line Coupler," *IEEE Microwave and Wireless Components Letters*, Vol. 15, No. 10, October 2005, pp. 655–657.
5. I.H. Lin, M. DeVincentis, C. Caloz and T. Itoh, "Arbitrary Dual-band Components Using Composite Right/Left-handed Transmission Lines," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 52, No. 4, April 2004, pp. 1142–1149.
6. H.K. Jhuang, P.M. Hu, C.I.G. Hsu and C.H. Lee, "A Dual-band Branch-line Coupler Using Quasi-composite Right/Left-handed Transmission Lines," *Microwave Journal*, Vol. 49, No. 8, August 2006, pp. 176–184.
7. J.Y. Sze, C.I.G. Hsu and J.J. Jiau, "CPW-fed Circular Slot Antenna with Slit Backpatch for 2.4/5 GHz Dual-band Operation," *Electronics Letters*, Vol. 42, No. 10, May 2006, pp. 563–564.
8. N.C. Karmakar and M.E. Bialkowski, "Circularly Polarized Aperture-coupled Circular Microstrip Patch Antennas for L-band Applications," *IEEE Transactions on Antennas and Propagation*, Vol. 47, No. 5, May 1999, pp. 933–940.
9. H. Miyake, S. Kitazawa, T. Ishizaki, T. Yamada and Y. Nagatomi, "A Miniaturized Monolithic Dual-band Filter Using Ceramic Lamination Technique for Dual-mode Portable Telephones," 1997 *IEEE MTT-S International Microwave Symposium Digest*, Vol. 2, pp. 789–792.
10. J.T. Kuo, T.H. Yeh and C.C. Yeh, "Design of Microstrip Bandpass Filters with a Dual-passband Response," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 53, No. 4, April 2005, pp. 1331–1337.
11. C. Quendo, E. Rius and C. Person, "An Original Topology of Dual-band Filter with Transmission-zeros," 2003 *IEEE MTT-S International Microwave Symposium Digest*, Vol. 2, pp. 1093–1096.
12. C. Quendo, E. Rius, A. Manchec, Y. Clavet, B. Potelon, J.F. Favennec and C. Person, "Planar Tri-band Filter on Dual Behavior Resonator (DBR)," 2005 *European Microwave Conference Digest*, Vol. 1, pp. 269–272.
13. V. Osipenko and S.G. Vesnin, "Microwave Filters of Parallel-cascade Structure," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 42, No. 7, July 1994, pp. 1360–1367.
14. M. Makimoto and S. Yamashita, "Bandpass Filters Using Parallel Coupled Stripline Stepped-impedance Resonators," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 28, No. 12, December 1980, pp. 1413–1417.
15. J.S. Hong and M.J. Lancaster, *Microstrip Filters for RF/Microwave Application*, John Wiley & Sons Inc., Hoboken, NJ, 2001.



**Chung-I G. Hsu** graduated from the National Taipei Institute of Technology, Taiwan, in 1980. He received his MSc degree from the University of Mississippi and his PhD degree from Syracuse University, both in electrical

engineering, in 1986 and 1991, respectively. He spent the 1992 spring semester at the microwave and electromagnetics laboratory, Texas A&M University, doing research on the modeling of microstrip antennas. He has been on the faculty of Da-Yeh University since August 1992, where he is presently an associate professor in the department of electrical engineering.



**Ching-Her Lee** received his BS degree in electronic engineering and his MS degree in automatic control engineering from Feng-Chia University, Taichung, Taiwan, in 1977 and 1981, respectively, and his PhD degree in electrical engineering

from the University of Texas at Arlington, TX, in 1989. From 1981 to 1985, he was on the faculty of the Chin-Yih Institute of Technology, Taichung, Taiwan. In 1990, he joined the National Changhua University of Education,

where he is presently dean of the college of engineering. His research interests include planar microwave circuits and microstrip antennas.

**He-Kai Jhuang** received his BS degree in industrial education from the National Changhua University of Education, Changhua, Taiwan, in 2004, and is currently working toward his MS degree in electronic engineering from the same school. His current interests include microstrip filter design and passive components for wireless communications.

## APPENDIX A

The detailed expressions pertaining to Equation 3 are given as follows:

$$f \frac{d}{df} B_0(f) = \frac{\phi}{Z_1} \csc^2 \phi \quad (A1)$$

$$f \frac{d}{df} B_A(f) = \frac{1}{Z_1 [R_{ZA} - \tan \theta_{0A} \tan(\theta_{0A} - \phi)]^2} \cdot \left\{ \begin{aligned} & \left[ \theta_{0A} \sec^2 \theta_{0A} + R_{ZA} (\theta_{0A} - \phi) \sec^2 (\theta_{0A} - \phi) \right] \\ & \cdot [R_{ZA} - \tan \theta_{0A} \tan(\theta_{0A} - \phi)] \\ & + [\theta_{0A} \sec^2 \theta_{0A} \tan(\theta_{0A} - \phi) + (\theta_{0A} - \phi) \tan \theta_{0A} \sec^2 (\theta_{0A} - \phi)] \\ & \cdot [\tan \theta_{0A} + R_{ZA} \tan \theta_{0A} \tan(\theta_{0A} - \phi)] \end{aligned} \right\} \quad (A2)$$

The term  $fdB_B(f)/df$  can be obtained from Equation A2 by replacing the subscript A with B. Referring to Figure 2, one obtains

$$\phi(f) = \left( 2\pi f \sqrt{\epsilon_{r,eff,1}} / c \right) (L_{1a} + W_1 / 2) + \theta_{via}(f) \quad (A3)$$

$$\theta_{0A}(f) = \left( 2\pi f \sqrt{\epsilon_{r,eff,1}} / c \right) (L_{1a} + L_{1b} + W_1 / 2) + \theta_{via}(f) \quad (A4)$$

$$\theta_{0B}(f) = \left( 2\pi f \sqrt{\epsilon_{r,eff,1}} / c \right) (L_{1a} + L_{1c} + L_{1d} + W_1 / 2) + \theta_{via}(f) \quad (A5)$$

where  $\epsilon_{r,eff,1}$  is the effective dielectric constant of the microstripline having a width of  $W_1$  and  $c$  is the speed of light in free space. Furthermore,  $\theta_{via}(f) = 2\pi f \sqrt{\epsilon_r} h / c$  is an approximate phase correction term representing the phase delay from the via, where  $h$  and  $\epsilon_r$  are the height and dielectric constant of the substrate, respectively.



# Passive Aggressive



**Call your RFMW Specialist or visit  
RFMW.com for your *RF Filter* needs.**

**Call 877.FOR.RFMW (877.367.7369)**

RFMW, Ltd. • 90 Great Oaks Blvd., Ste. 203, San Jose, CA 95119  
(Ph) 877.367.7369 (North America) • (Ph) 408.414.1450 (all other areas)  
(Fax) 408.414.1461 • sales@rfmw.com • www.rfmw.com/passive

Offices located throughout North America and the UK. Se habla Español: 954.476.8630



**RFMW Relief!**

# Microwave

Honolulu, Hawai'i

Reserve a room at conference rates now at [www.IMS2007.org](http://www.IMS2007.org)



International Microwave Symposium  
RFIC Symposium · ARFTG Symposium



IEEE



[www.IMS2007.org](http://www.IMS2007.org)  
[www.gohawaii.com](http://www.gohawaii.com)

Photo by Laszlo Ilyes



# Week 2007

3–8 June 2007

## The premier microwave and wireless conference featuring technical sessions and workshops for commercial and military applications

- Field Analysis and Guided Waves
  - Frequency Domain Techniques
    - Time Domain Techniques
- CAD Algorithms and Techniques
  - Linear Device Modeling
  - Nonlinear Device Modeling
- Nonlinear Circuit Analysis and System Simulation
  - Transmission Line Elements
  - Passive Circuit Elements
- Planar Passive Filters and Multiplexers
- Non-Planar Passive Filters and Multiplexers
  - Active and Integrated Filters
- Ferroelectric, Ferrite and Acoustic Wave Components
  - MEMS Components and Technologies
- Semiconductor Devices and Monolithic IC Technologies
  - Signal Generation
  - Frequency Conversion and Control
- HF/VHF/UHF Technologies and Applications
- Power Amplifier Devices and Integrated Circuits
  - High Power Amplifiers
  - Low Noise Components and Receivers
- Millimeter-wave and Terahertz Components and Technologies
  - Microwave Photonics
- Digital Circuits and Systems at GHz Speeds
  - Packaging, Interconnects, MCMs and Hybrid Manufacturing
- Instrumentation and Measurement Techniques
  - Biological Effects and Medical Applications
  - Smart Antennas, Spatial Power Combining and Phased Arrays
- Radars and Broadband Communication Systems
- Wireless and Cellular Communication Systems
  - Sensors and Sensor Systems
- Full guest program for the family



[www.IMS2007.org](http://www.IMS2007.org)

For further information, please  
contact Kristen Dednah at:  
[kdednah@mwjournal.com](mailto:kdednah@mwjournal.com)  
or 781-769-9750

# A COMPACT MICROSTRIP STEPPED-IMPEDANCE RESONATOR AND FILTER

*The resonant performance of T-shaped microstrip resonators, a kind of stepped-impedance resonator (SIR), is computed and analyzed. Two novel SRI filters, a double-T-shaped bandstop filter and a double-H-shaped bandpass filter, are designed and their performances are calculated and optimized. The results show that the performance of the filters can be effectively improved by using defected ground structures (DGS), which suppress spurious responses by rejecting harmonics in the microwave circuits. The measured results are in good agreement with the simulated ones. The proposed filters have advantages such as a simple structure, wide bandwidth and high attenuation, and are quite useful in future applications in RF circuits.*

Microstrip resonators have very important applications in microwave or millimeter-wave systems. They are important components of microstrip filters,<sup>1-2</sup> microstrip oscillators<sup>3</sup> and microstrip antennas,<sup>4</sup> and enable microwave equipment miniaturization with improved performance. A stepped-impedance resonator (SIR) is the fundamental resonant element that can operate from RF to millimeter-wave frequencies and can be used in many kinds of filters, oscillators and mixers. The performance of a microstrip resonator relies on electromagnetic field distribution, the resonant frequency and quality factor  $Q$ . Microstrip filters have advantages such as low cost, small volume, high selectivity and are widely used in a variety of microwave systems to transmit energy in one or more passbands and to attenuate energy in one or more stopbands.

A defected ground structure (DGS)<sup>5,6</sup> is a novel technique for improving the performance of filters or other microwave components and is formed by etching a pattern in the ground plane. This structure can change the current and its distribution in the ground plane, and thus increase the effective capacitance and inductance of the microstrip. Peri-

---

JIAN-KANG XIAO

South China University of Technology  
Guangzhou, China

SHI-WEI MA

Shanghai Key Laboratory of Power Station  
Automation Technology  
Shanghai, China

YING LI

College of Science, Shanghai University  
Shanghai, China





**Was.**

**Is.**

## Components engineered for what will be.

### Xinger® 0805, low-profile power dividers



At last, better performance than printed and lumped-element solutions – in a low-profile, high-volume SM package! Our subminiature-sized Wilkinson power dividers offer:

- > Low-profile, sub-miniature SM format, only .079 x .049 x .021" (2 x 1.25 x .53mm)
- > Models covering 400-8000MHz
- > Models suitable for GSM, WCDMA, 802.11 b, g; MIMO b, g; Bluetooth®; Zigbee
- > Good output port isolation and return loss
- > Input/output impedance of 50Ω and 75Ω
- > Insertion loss as low as 0.6dB typ
- > Non-conductive surface
- > Proven, high-volume manufacturing capability

**Broadcast!** Models available for DVB-H (Europe & US) and DVB-S

**RoHS compliant**

Call for free samples or our complete CCG engineering kit (qualified inquiries).

### Xinger® 0805, ultra-low profile hybrid couplers



3dB couplers don't get any smaller than this! Our new Hybrids are ideal for balanced power and low-noise amplifiers – and anywhere low-insertion loss and tight amplitude/phase balance are required:

- > Ultra-low profile, SM package measures a mere only .079 x .049 x .028" (2 x 1.25 x .7mm)
- > Models covering 1700-3600MHz
- > Designed for PCS, DCS, DECT, WCDMA-3G jobs
- > Insertion loss as low as 0.3dB
- > Isolation as high as 22dB
- > Port impedance of 50Ω
- > Proven, high-volume manufacturing – shipped on tape and reel

**RoHS compliant**

Call for our free samples or our complete CCG engineering kit (qualified inquiries).

### Xinger® 0404, nano-profile baluns



While matching ceramic baluns on performance, our Xinger-brand unbalanced to balanced transformers are a "must" for modern, consumer applications. Featuring:

- > Nano-profile, sub-miniature SM format, only .039 x .039 x .026" (1 x 1 x .65mm)
- > Models covering 2400-5900MHz
- > Compliance with 802.11 a, b, g; MIMO b, g; Bluetooth®; Zigbee
- > Low losses: 0.6dB typ
- > Typical return loss: >16dB
- > Wide variety of differential impedances
- > Non-conductive surface
- > Proven, high-volume manufacturing capability

**Modular!** Choose from dual, triple, and quad configurations!

**RoHS compliant**

Call for our free samples or our complete CCG engineering kit (qualified inquiries).

Visit <http://mwj.hotims.com/11713-19> or use RS# 19 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)

800-411-6596 > [www.anaren.com](http://www.anaren.com)

# Anaren®

What'll we think of next?™

In Europe, call 44-2392-232392 > ISO 9001 certified  
Visa/MasterCard accepted (except in Europe)

odic and non-periodic DGSs have the property to reject certain microwaves in some frequencies, permitting elimination of spurious responses due to harmonics. In this article, a novel double-T-shaped microstrip bandstop filter with DGS and a novel double-H-shaped microstrip bandpass filter with DGS are proposed and their performances simulated and optimized. The calculated results show that the performance of the filters can be effectively improved by DGS and the experimental results verify the improvement.

### ANALYSIS FOR CHARACTERISTICS OF A MICROSTRIP STEPPED-IMPEDANCE RESONATOR

A fundamental microstrip SIR is formed by joining together two microstrip transmission lines with different characteristic impedance  $Z_1$  and  $Z_2$ , as shown in **Figure 1**.  $Z_i$  is input impedance,  $Y_i$  is input admittance and  $\beta$  is phase constant.  $\ell_1$  and  $\ell_2$  are physical lengths corresponding to electric lengths  $\theta_1$  and  $\theta_2$ , respectively. The equivalent circuit of the SIR is derived, as shown in **Figure 1b**, where  $L$  is inductance,  $C$  is capacitance and  $R_L$  is loaded-impedance. If the discontinuity of microstrip step and fringe capacitance of open-circuit port are omitted,  $Z_i$  can be expressed as

$$Z_i = jZ_2 \frac{Z_1 \tan \theta_1 + Z_2 \tan \theta_2}{Z_2 - Z_1 \tan \theta_1 \tan \theta_2} \quad (1)$$

The parallel resonant condition can be obtained on the base of  $Y_i = 0$ ; it is

$$K = \tan \theta_1 \tan \theta_2 = \frac{Z_2}{Z_1} \quad (2)$$

Here,  $K$  is the impedance ratio. It can be seen from Equation 2 that the resonant conditions of SIR lie on  $\theta_1$ ,  $\theta_2$  and  $K$ . The total electric length of SIR can be expressed as

$$\theta_T = \theta_1 + \theta_2 = \theta_1 + \arctan\left(\frac{K}{\tan \theta_1}\right), K \neq 1 \quad (3)$$

$$\theta_T = \frac{\pi}{2}, K = 1 \quad (4)$$

It can be shown from Equation 3 that the resonator's length reaches a minimum value of  $0 < K < 1$ , and a maximum value for  $K > 1$ .<sup>7</sup> For  $K = 1$ , it is a conventional quarterwave uniform-impedance resonator (UIR), as shown in Equation 4.

On the resonant condition, SIR can also be equivalent by circuit,<sup>8</sup> as shown in **Figure 1c**. Here

$$L_0 = \frac{1}{\omega_0 b_s}, C_0 = \frac{b_s}{\omega_0}, R_0 = \frac{b_s}{Q_0} \quad (5)$$

where

$\omega_0$  = resonant angular frequency

$b_s$  = susceptibility slop

$Q_0$  = unloaded Q

$b_s$  can be expressed as

$$b_s = \frac{\omega_0}{2} \left. \frac{dB_s}{d\omega} \right|_{\omega=\omega_0} \quad (6)$$

where

$b_s(\omega)$  = susceptibility of resonator

If the susceptibility of quarter-wavelength SIR is defined as  $B_{SA}$  and the corresponding slop parameter is defined as  $b_{SA}$ , we have

$$B_{SA} = \text{Im} \left[ \frac{1}{Z_i} \right] = Y_2 \frac{\tan \theta_1 \tan \theta_2 - K}{\tan \theta_1 + K \tan \theta_2} \quad (7)$$

$$b_{SA} = \frac{\theta_{01} Y_2}{2} \left[ \frac{K}{(1 - K^2) \sin^2 \theta_{01} + K^2} + \frac{\ell_1}{\ell_2} \right] \quad (8)$$

where

$\theta_{01}$  = resonant value of  $\theta_1$

An H-shaped resonator is a symmetrical structure that consists of two transmission lines with different characteristic impedance, as shown in **Figure 2**. The electric length of outer step is  $\theta_2$ , and that of inner step is  $2\theta_1$ . Its equivalent transmission line model<sup>9</sup> is shown in **Figure 2b**, where

$$Z_{in1} = jZ_1 \frac{2Z_1 \tan \theta_1 \tan \theta_2 - Z_2 \tan^2 \theta_1}{Z_1 \tan \theta_2 - Z_1 \tan^2 \theta_1 \tan \theta_2 + 2Z_2 \tan \theta_1} \quad (9)$$

$$Z_{in2} = -jZ_2 \cot \theta_2 \quad (10)$$

$Z_{in} = jZ_2 \bullet$

$$\frac{2(1 + K^2) \tan \theta_1 \tan \theta_2 - K(1 - \tan^2 \theta_2)(1 - \tan^2 \theta_1)}{2(K - \tan \theta_1 \tan \theta_2)(\tan \theta_2 + K \tan \theta_1)} \quad (11)$$

The input admittance seen from the open-circuit port can be expressed as

$$Y_i = jY_2 \frac{2(K \tan \theta_1 + \tan \theta_2)(K - \tan \theta_1 \tan \theta_2)}{K(1 - \tan^2 \theta_1)(1 - \tan^2 \theta_2) - 2(1 - K^2) \tan \theta_1 \tan \theta_2} \quad (12)$$

Based on  $Y_i = 0$ , the resonant condition (impedance ratio) can be achieved as

$$K = \tan \theta_1 \tan \theta_2 \quad (13)$$

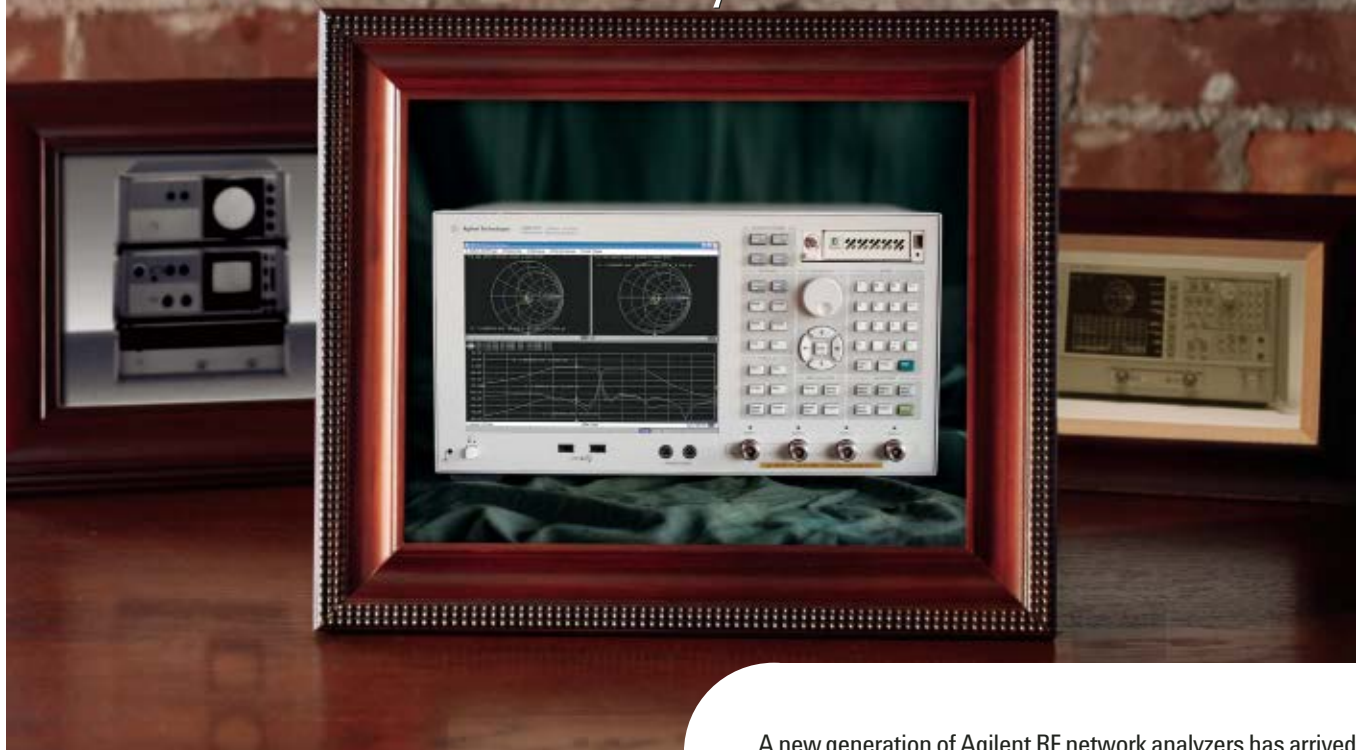
If  $\theta_1 = \theta_2 = \theta$  the resonant condition and input admittance can be simplified.

The T-shaped microstrip SIR is shown in **Figure 3**. The heights of the patches are  $W$  and  $W_1$ , and the widths are  $L_1$  and  $L_2$ , respectively. The dimensions of all the dielectric substrates mentioned in this article are fixed to  $50 \times 50 \text{ mm}^2$  and their relative dielectric constant is  $\epsilon_r = 2.2$  or  $\epsilon_r = 2.6$ . This kind of dielectric material has properties such as low dielectric loss ( $\tan \delta \leq 5.10^{-4}$ ), low cost and easy manufacturability. The relationship between the resonant frequency  $f_0$  and  $W$  is shown in **Figure 4**. It can be seen that  $W$  variations have little influence on the reso-



# It has great genes

The ENA carries on the family tradition



## **Agilent E5071C ENA**

9 kHz to 8.5 GHz frequency range

> 123 dB dynamic range

Trace noise < 0.004 dB rms at 70 kHz IF bandwidth

39 ms measurement speed (1601 points, full

2-port calibration)

2- or 4-port measurements

A new generation of Agilent RF network analyzers has arrived. And its Agilent 8753 ancestors would be proud. The ENA Series builds on the family's 40-year legacy of excellence to deliver new standards in speed, accuracy, and versatility for RF network analysis.

With the ENA Series, you'll get excellent performance across its entire frequency range. No other network analyzer can match its dynamic range, trace noise, or measurement speed. And no one else has a frequency range that reaches from 8.5 GHz down to 9 kHz.

It's the kind of performance you'd expect from the 8753 family. Only now, it goes even further to help you do more—and do it better. It helps to have great genes on your side.

Put the ENA Series to work for you. For application notes and more information, visit [www.agilent.com/find/genes](http://www.agilent.com/find/genes).

u.s. 1-800-829-4444

canada 1-877-894-4414

[www.agilent.com/find/genes](http://www.agilent.com/find/genes)



## **Agilent Technologies**

**ROSWIN**

Future of Component Technology

More Than You Expect



**Signal Sources**

- VCO
- PLL Modules
- Frequency Synthesizer

**Filters**

- Dielectric Filters
- Bandpass Filter
- Duplexer
- Multiplexer
- LC Filters

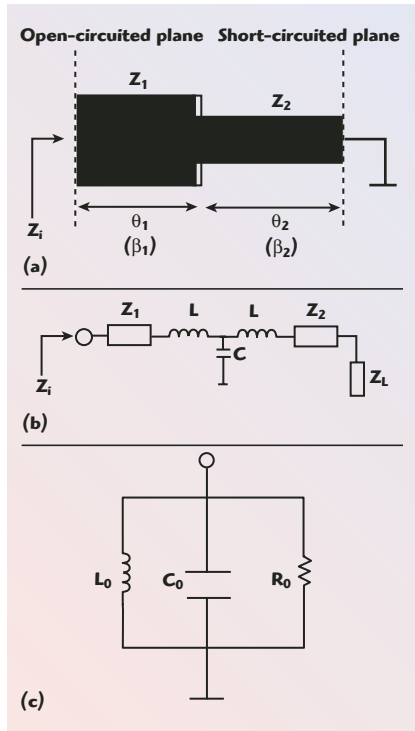
**RF Amplifiers**

- LNA
- HPA

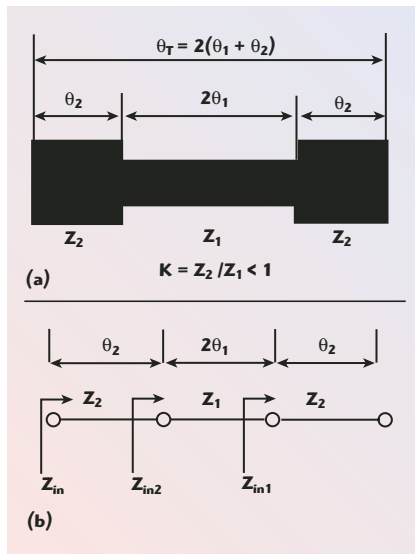
**Up/Down Converters**



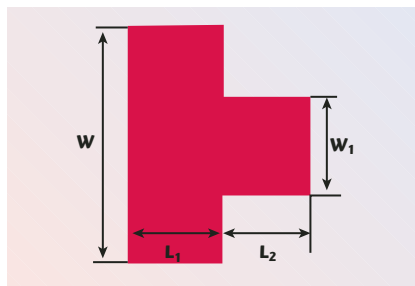
# 405, Cheonan Techno Town,  
5-2, ChaAm-Dong,  
Cheonan-Si, Chungnam,  
330-200, KOREA  
TEL : +82-41-621-4450  
FAX : +82-41-621-4451  
E-mail : sales@roswin.com



▲ Fig. 1 Electric parameter of an SIR (a) its equivalent circuit (b) and the equivalent circuit at resonance (c).

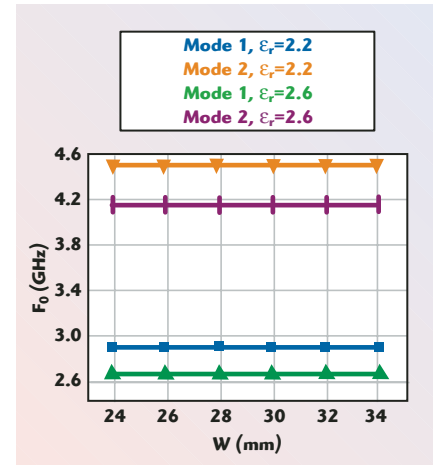


▲ Fig. 2 Electric structure (a) of an H-shaped resonator and its equivalent transmission line model (b).

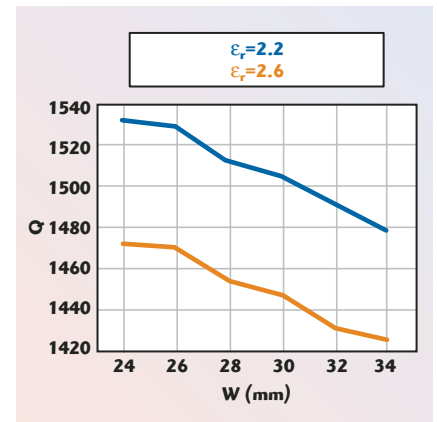


▲ Fig. 3 T-shaped microstrip resonator.

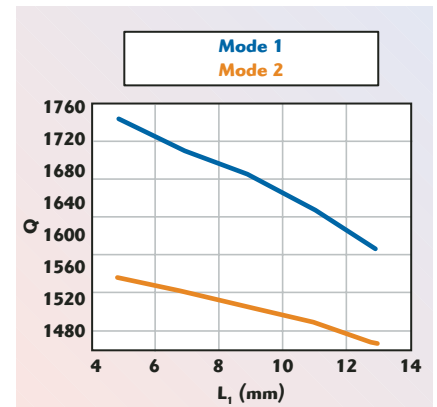
nant frequency. When  $W_1 = 10$  mm,  $L_1 = 10$  mm,  $L_2 = 10$  mm and  $\epsilon_r = 2.2$ , the resonant frequency of the dominant mode is nearly fixed at 2.85 GHz and that of the second-order mode is 4.52 GHz. When  $\epsilon_r = 2.6$ , the resonant frequency of the dominant mode is 2.6 GHz and that of the second-order mode is 4.15 GHz. The relationship curves of the quality factor



▲ Fig. 4 Resonant frequency versus W.



▲ Fig. 5 Relationship of Q and W for the dominant mode.



▲ Fig. 6 Relationship of Q and  $L_1$  ( $L_2 = 10$  mm).





**\$21<sup>95</sup>** **IN STOCK**  
From ea. Qty. (1-9)

## DC-13 GHz Low & High Pass **FILTERS**

**Mini-Circuits VLF Low Pass and VHF High Pass SMA Filters**, featuring excellent stopband rejection and passband matching, flat passband response, and sharp roll-off, are unparalleled solutions for RF filtering over a wide range of bandwidths from DC to 13 GHz. Our unique patented Unibody package measures less than 1½" in length and is designed to minimize interconnect losses and improve reliability. Combine that with the temperature stability, performance repeatability, and low cost from our LTCC ceramic technology, and the result is a very rugged, high performance, competitively priced series. These filters are ideal for test set-ups as well as transmitter/receiver filtering in both tactical and commercial applications.

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



For RoHS compliant requirements,  
**ADD + SUFFIX TO BASE MODEL No.** Example: VLF-80+

Model	Passband (MHz)	fco, Nom. Loss 3 dB (MHz) Typ.	Stopband Loss >20 dB (MHz) Min.	Model	Passband (MHz)	fco, Nom. Loss 3 dB (MHz) Typ.	Stopband Loss >20 dB (MHz) Min.
-------	----------------	--------------------------------	---------------------------------	-------	----------------	--------------------------------	---------------------------------

### Low Pass VLF Models \$21.95 ea. (1-9)

VLF-80	DC-80	145	200	VLF-1525	DC-1525	1750	2040
VLF-95	DC-95	165	220	VLF-1575	DC-1575	1875	2175
VLF-105	DC-105	180	250	VLF-1700	DC-1700	2050	2375
VLF-120	DC-120	195	280	VLF-1800	DC-1800	2125	2425
VLF-160+	DC-160	230	330	VLF-2250	DC-2250	2575	2900
VLF-180+	DC-180	270	370	VLF-2500	DC-2500	3075	3675
VLF-190+	DC-190	280	400	VLF-2600	DC-2600	3125	3750
VLF-225	DC-225	350	460	VLF-2750	DC-2750	3150	4000
VLF-320	DC-320	460	560	VLF-2850	DC-2800	3300	4000
VLF-400	DC-400	560	660	VLF-3000	DC-3000	3600	4550
VLF-490	DC-490	650	800	VLF-3800+	DC-3900	4850	6000
VLF-530	DC-530	700	820	VLF-4400+	DC-4400	5290	6700
VLF-575	DC-575	770	900	VLF-5000	DC-5000	5580	6850
VLF-630	DC-630	830	1000	VLF-5500+	DC-5500	6200	7200
VLF-800	DC-800	1075	1275	VLF-5850+	DC-5850	6540	7600
VLF-1000	DC-1000	1300	1550	VLF-6000	DC-6000	6800	8500
VLF-1200	DC-1200	1530	1865	VLF-6400+	DC-6400	7200	8300
VLF-1400	DC-1400	1700	2015	VLF-6700	DC-6700	7600	9300
VLF-1450	DC-1450	1825	2025	VLF-7200+	DC-7200	8150	9500
VLF-1500	DC-1500	1825	2100				

U.S. Patent Numbers 6,790,049 & 6,943,646

### High Pass VHF Models \$24.95 ea. (1-9)

VHF-650	710-2490	650	480	VHF-2275	2450-7000	2275	1770
VHF-740	780-2800	740	550	VHF-2700	2650-6500	2500	1800
VHF-880	950-3200	880	640	VHF-2700A+	2900-8700	2700	2150
VHF-1200	1220-4600	1180	940	VHF-3100+	3400-9900	3100	2450
VHF-1300	1400-5000	1300	930	VHF-3500+	3900-9800	3500	2800
VHF-1320	1400-5000	1320	1060	VHF-3800	4250-10000	3800	3200
VHF-1500	1600-5500	1550	1250	VHF-4400+	5000-10100	4400	3500
VHF-1600	1650-5000	1600	1290	VHF-4600+	5000-11000	4600	3800
VHF-1760	1900-5500	1760	1230	VHF-5050+	5500-10000	5050	4200
VHF-1810	1900-4750	1810	1480	VHF-5500	6000-11500	5500	4500
VHF-1910	2000-5200	1910	1400	VHF-7150+	7900-11000	7150	6150
VHF-2000	2260-6250	2000	1530	VHF-8400	9000-13000	8400	6000
VHF-2100	2200-6000	2100	1530				

U.S. Patent Number 6,790,049

**Mini-Circuits®**  
ISO 9001 ISO 14001 CERTIFIED

**ALL NEW**  
**minicircuits.com**

P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661 For detailed performance specs & shopping online see Mini-Circuits web site



The Design Engineers Search Engine Provides ACTUAL Data Instantly From MINI-CIRCUITS At: [www.minicircuits.com](http://www.minicircuits.com)

**RF/IF & MICROWAVE COMPONENTS**

394 Rev P

Visit <http://mwj.hotims.com/11713-86> or use RS# 86 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)



**Locus  
Microwave**

**High Performance & Custom  
Amplifiers and Converters  
...HF to 30 GHz...**



- **High Performance Amplifiers**
  - LNAs
  - SSPAs
  - High Dynamic Range
- **Frequency Converters**
- **Government & Commercial**
- **Specialists in MIL SATCOM apps**

	Frequency Bands						
	L	S	C	X	Ku	K	Custom
LNAs	✓	✓	✓	✓	✓	✓	✓
SSPAs	✓	✓	✓	✓	✓	✓	✓
LNBS				✓			✓
BUCs				✓			✓

✓ = NEW

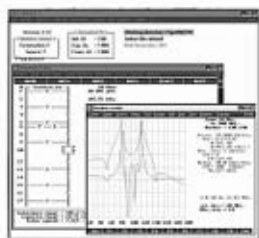
176 Technology Dr., Suite 200, Boalsburg, PA 16827  
Tel: +1 814 466 6275 Fax: +1 814 466 1104  
www.locusmicrowave.com  
email: info@locusmicrowave.com

Visit <http://mwj.hotims.com/11713-69>

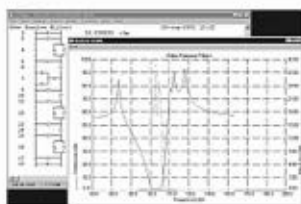
Series filter design software from

**ALK Engineering**

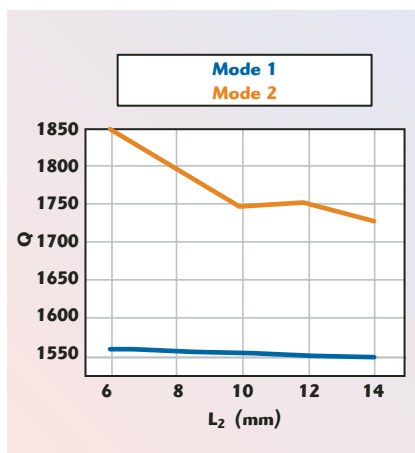
**PCFILT**



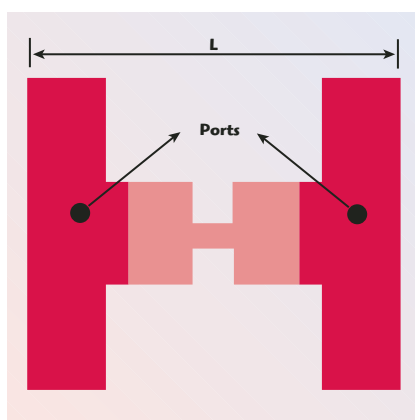
**DGS S/FILSYN**



**All new versions for  
Windows 98/NT/2000/XP  
<http://www.alkeng.com>  
(410) 546-5573**



▲ Fig. 7 Relationship of  $Q$  and  $L_2$  ( $L_1 = 5$  mm).

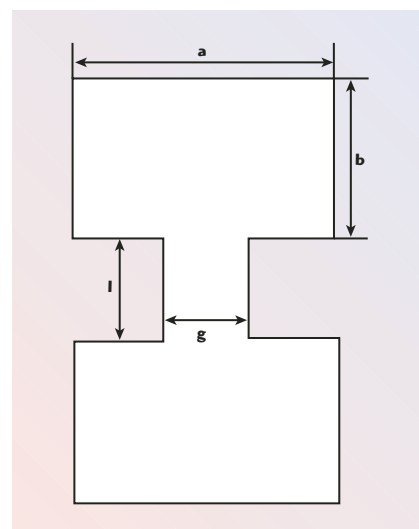


▲ Fig. 8 Double-T-shaped bandstop filter with DGS.

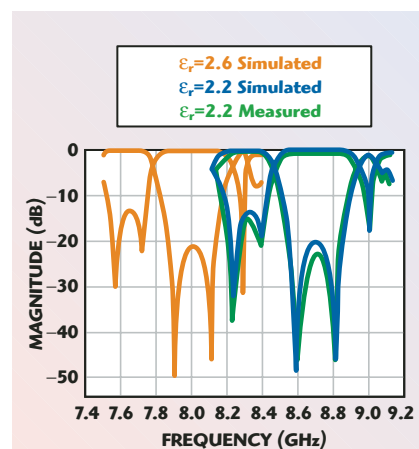
$Q$  and  $W$  are shown in **Figure 5**. It can be seen that the quality factor decreases when both  $W$  and  $\epsilon_r$  increase. The relationship curves of  $Q$  and  $L_1$ ,  $L_2$  are shown in **Figures 6** and **7**, respectively, with  $W = 30$  mm and  $W_1 = 10$  mm. They show that  $Q$  decreases when  $L_1$  and  $L_2$  increase and the  $Q$  of the second-order mode is larger than the one of the dominant mode.

### DESIGN OF NOVEL SIR COUPLING MICROSTRIP FILTERS

A novel double-T-shaped bandstop filter with DGS is shown in **Figure 8**. The dimensions of each T-shaped patch are  $W = 30$  mm,  $W_1 = 10$  mm,  $L_1 = 5$  mm and  $L_2 = 4$  mm. The overall width of the coupled patch is  $L = 26$  mm. The double-T-shaped resonators form a bandstop filter when coupled to each other, but the filter performance is not acceptable because of its narrow passbands near the stopband; consequently, DGS was used. The performance of the bandstop filter was calculated with Ansoft



▲ Fig. 9 DGS on the ground plane.



▲ Fig. 10 S-parameters of the double-T-shaped filter.

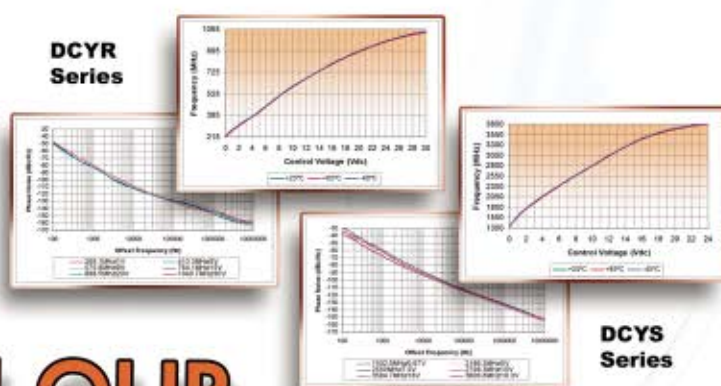
HFSS software. The dumbbell-shaped DGS on the ground plane is shown in **Figure 9**, where  $a = 10$  mm,  $b = 4$  mm,  $g = 3$  mm and  $l = 2$  mm.

The simulated S-parameters of the filter are shown in **Figure 10**. If the relative dielectric coefficient of dielectric substrate is  $\epsilon_r = 2.2$ , it can be seen that there is a wide stopband at a center frequency of 8.71 GHz, with a 0.49 GHz bandwidth (5.62 percent). If  $\epsilon_r = 2.6$ , there is a stopband at a center frequency of 8.004 GHz, with a 0.444 GHz bandwidth (5.55 percent). It can be seen that the attenuation within the stopband is greater than 20 dB, the stopband center frequency will shift with different dielectric substrates and the 3 dB bandwidth of the passband near the operational stopband is more than 200 MHz. The experimental results, measured with a HP8510 vector



OUT  
WITH  
YE OLD  
YIG  
SOURCES

# IN WITH OUR NEW PLANAR YIG REPLACEMENT VCOs



## FEATURES

- \* Octave & Higher Than Octave Tuning
- \* High Spectral Purity Signal
- \* Low Power Consumption
- \* Wide Modulation Bandwidth
- \* Low Microphonic Effects
- \* Low Cost
- \* Excellent Tuning Linearity
- \* Extended Temperature Range
- \* Superb Phase Noise Performance
- \* Low Post Thermal Drift
- \* High Reliability
- \* High Immunity To EMI & Phase Hits
- \* Compact Size: 0.5" x 0.5" & 0.75" x 0.75"
- \* Integrability To MMIC, Chip & Wire
- \* Standard & Customized Designs
- \* REL-PRO® - RoHS Compliant
- \* Patented Technology



Model	Frequency (MHz)	Tuning Voltage (VDC)	DC Bias VDC @ I (Max)	Typical Phase Noise @ 10 kHz (dBc/Hz)
DCYR2060-5	200 - 600	0.5 - 28	+5 @ 65 mA	-119
DCYR3097-5	300 - 970	0.5 - 28	+5 @ 40 mA	-112
DCYR50125-10	500 - 1250	0.5 - 25	+10 @ 50 mA	-110
DCYR100200-12	1000 - 2000	0.5 - 28	+12 @ 50 mA	-108
DCYS160360-5	1600 - 3600	0.5 - 24	+5 @ 60 mA	-90
DCYS200400-5	2000 - 4000	0.5 - 15	+5 @ 50 mA	-90
DCYS250500-5	2500 - 5000	0.5 - 20	+5 @ 50 mA	-75
DCYS300600-5	3000 - 6000	0 - 25	+5 @ 50 mA	-80
DCYR400800-5*	4000 - 8000	0 - 18	+5 @ 130 mA	-84
DCYR5001000-5*	5000 - 10000	0 - 25	+5 @ 130 mA	-75
DCYR6001200-5*	6000 - 12000	0 - 25	+5 @ 130 mA	-74

\* Sub-Harmonic suppression 35 dB typical.

Visit <http://mwj.hotims.com/11713-135> or use RS# 135 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)

For additional information, contact Synergy's sales and application team.

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

E-mail: [sales@synergymw.com](mailto:sales@synergymw.com) or [info@synergymw.com](mailto:info@synergymw.com)

Visit Our Web Site At [WWW.SYNERGYMWAVE.COM](http://WWW.SYNERGYMWAVE.COM)



## Variable Attenuators



Solid-state Variable Attenuators from 10MHz to 19GHz. Current Controlled, Linearized Voltage Controlled, or Linearized Digital Controlled.

### Product Line:

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

**Universal Microwave Components Corporation**  
 5702-D General Washington Drive  
 Alexandria, Virginia 22312  
 Tel: (703) 642-6332, Fax: (703) 642-2568  
 Email: umcc@umcc111.com  
**www.umcc111.com**

Visit <http://mwj.hotims.com/11713-150>

## LARGEST RADAR & RF INVENTORY IN THE WORLD!

SEND FOR FREE 28 PAGE CATALOG



- **RADAR & RF SOURCES:** 150 MHz to 35 GHz.
- **ANTENNA MOUNTS:** Autotrack, Search, X-Y, Nike Herc., Ajax, Capacity 50 to 20,000 lbs. Dishes to 60 ft.
- **RADAR INDICATORS**
- **PULSE MODULATORS**
- **HIGH VOLTAGE POWER SUPPLIES**
- **TUBES & WAVEGUIDE**

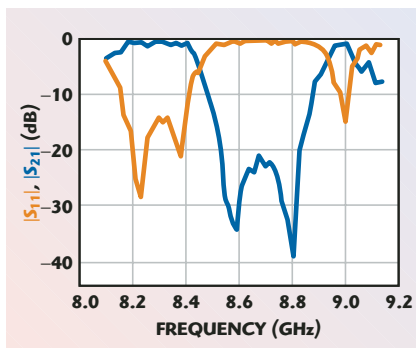
### NETWORK ANALYZER

.5-18 GHz. Computer controlled HP8542B

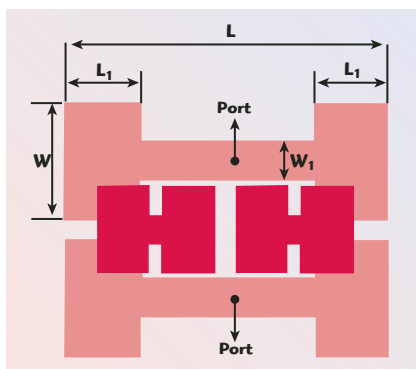
60" DISH & PEDESTAL AVAILABLE

**RADIO RESEARCH INSTRUMENT CO., INC.**  
 584 N. MAIN ST. WATERBURY, CT 06704  
 203-753-5840 FAX: 203-754-2567  
 www.radiores.com  
 E Mail: Radiores@prodigy.net

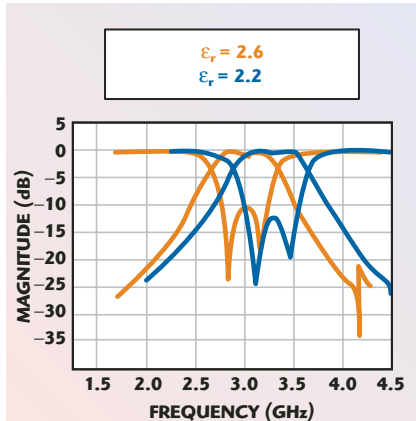
## TECHNICAL FEATURE



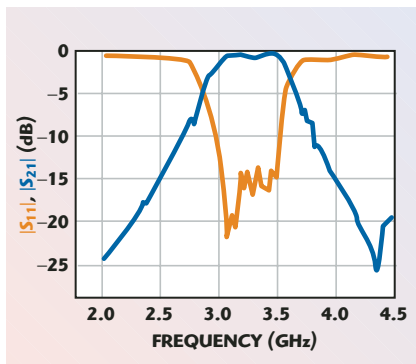
▲ Fig. 11 Measured S-parameters of the double-T-shaped filter.



▲ Fig. 12 Double-H-shaped bandpass filter with DGS.



▲ Fig. 13 Simulated S-parameters of the double-H-shaped filter.



▲ Fig. 14 Measured S-parameters of the double-H-shaped filter with  $\epsilon_r = 2.2$ .

network analyzer, are shown in **Figure 11** with  $\epsilon_r = 2.2$ . They agree with the simulated ones.

The layout of a novel double-H-shaped microstrip bandpass filter is shown in **Figure 12**. The dimension of every H-shaped patch is  $w = 15$  mm,  $w_1 = 5$  mm,  $L = 40$  mm,  $L_1 = 10$  mm. The coupling coefficient  $k$  is bandpass filter can be expressed as

$$k = \frac{B_r}{\sqrt{g_i g_{i+1}}} \quad (14)$$

where

$B_r$  = relative bandwidth  
 $g_i$  ( $i = 1, 2, \dots, n-1$ ) = low pass prototype value corresponding to the desired filter responses  
 $n$  = order of filter

In order to improve the performance of the filter effectively, a pair of DGSs is applied, and for each DGS,  $a = 9$  mm,  $b = 5$  mm,  $l = 4.2$  mm and  $g = 3$  mm. The simulated S-parameters of the double-H-shaped microstrip bandpass filter are shown in **Figure 13**, and the experimental results are shown in **Figure 14**. For  $\epsilon_r = 2.2$ , it can be seen that the center frequency is 3.275 GHz and there is an attenuation pole at 4.5 GHz. The 3 dB bandwidth is 0.75 GHz, the maximum insertion loss is 0.55 dB at the center frequency and the coupling coefficient is  $k = 0.229$ . For  $\epsilon_r = 2.6$ , the center frequency is 3 GHz, the 3 dB bandwidth is 0.676 GHz, the maximum insertion loss is 0.37 dB at the center frequency and the coupling coefficient is  $k = 0.225$ . There is an attenuation pole at 4.18 GHz, and the maximum attenuation is greater than 32 dB. It can be seen from the figures that the simulated and measured frequency responses are in good agreement.

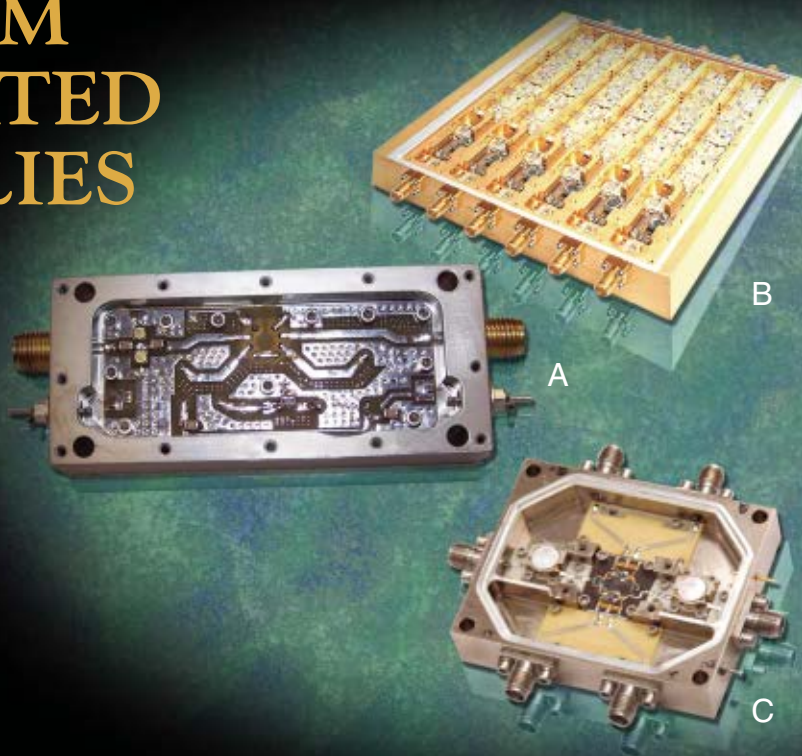
## CONCLUSION

In this article, the performance of stepped-impedance resonators are computed and analyzed. A novel double-T-shaped microstrip bandstop filter with DGS and a double-H-shaped microstrip bandpass filter with DGS are designed and their performance is calculated, measured and analyzed.



# CUSTOM INTEGRATED ASSEMBLIES

Teledyne Cougar's RF and Microwave engineering and manufacturing expertise provide reliable performance-based solutions for each challenge in your design block diagram.



## ***VHF Band 1.0 Watt Amplifier with RF Bypass (A)***

Output of 1 watt from 35 to 350 MHz, 29 dB gain and 3 dB noise figure, this amplifier assembly incorporates an RF bypass switch. You can route the RF through the amplification stages, or remove the DC bias from the switch and bypass the amplifier.

## ***2 to 18 GHz 6 Channel Downconverter (B)***

Teledyne Cougar's Six Channel 2 - 18 GHz (RF and LO) downconverter operates with an IF of ~960 MHz, providing 25 dB of RF-IF gain, and bandwidth of ~500 MHz. This downconverter operates on a single LO at -6 dBm which is amplified, split, then again amplified to each of the 6 channels. Integrated into each channel is a range extension switch, controlled by a TTL input and adding 20 dB attenuation. Noise figure is ~ 13.5 dB and output IP3 is ~25 dBm. The downconverter is 2-sided, hermetically sealed and designed for rugged applications.

## ***17 to 19 GHz QPSK Modulator (C)***

Differential Drive Digital QPSK (Quadrature Phase Shift Keying) modulator operates across the 17.0 to 19.0 GHz frequency range. Modulator utilizes differential drive digital inputs (180° apart) to drive both of the bi-phase modulators (mixers) integrated into the assembly. The QPSK modulator provides constant amplitude, 90° vector: 0 (ref.), 90°, 180°, 270° and operates across the -55° to 85° C temperature range.



**TELEDYNE COUGAR**

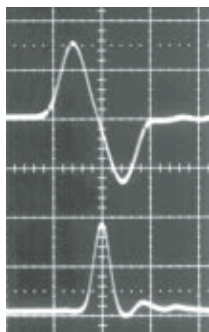
*A Teledyne Technologies Company*

ISO 9001-2000 • MIL-PRF-38534 • Class H & Class K Certified

927 Thompson Place • Sunnyvale, CA 94085 • 408-522-3838 • Fax 408-522-3839  
www.teledyne-cougar.com • email: Amp@cougarcorp.com

# Monocycle & Impulse Generators

**Ideal for Ground Penetrating Radar ~ Laser Diode Testing  
Ultra Wideband (UWB) development ~ SAW ~ Ultrasonics**



Avtech offers a comprehensive line of monocycle and impulse generators, offering amplitudes from 1-1000V center frequencies as high as 5 GHz, and pulse widths as low as 130 ps. A partial selection is outlined below:

## Monocycle Generators

Model	Vp-p	Center Freq.	PRF
AVE2-C	4V	3000-5000 MHz	1 MHz
AVD2-D-C	5V	100-250 MHz	100 MHz
AVB1-3-C	50V	400-900 MHz	100 kHz
AVB2-TB-C	400V	50-100 MHz	10 kHz
AVB3-TB-C	750V	75-100 MHz	10 kHz

Full details at [www.avtechpulse.com/monocycle/](http://www.avtechpulse.com/monocycle/)

## Impulse Generators

Model	Vmax	PW	PRF
AVH-S-1-C	10V	130 ps	1 MHz
AVMH-2-C	30V	400 ps	25 MHz
AVMH-4-C	100V	1 ns	10 MHz
AVG-3B-B	450V	2 ns	20 kHz
AVG-4C-C	1000V	8 ns	10 kHz

Full details at [www.avtechpulse.com/impulse/](http://www.avtechpulse.com/impulse/)

Many more models are available! A variety of instrument formats are available, including miniature DC-powered modules, manually-controlled benchtop instruments, and IEEE-488.2 GPIB-equipped instruments. Visit our web site today for details!

**Data sheets and pricing on the Web - [www.avtechpulse.com](http://www.avtechpulse.com)**



**NANOSECOND  
WAVEFORM ELECTRONICS  
SINCE 1975**

BOX 265, OGDENSBURG  
NY, 13669-0265

ph: 888-670-8729, +1-613-226-5772

fax: 800-561-1970, +1-613-226-2802

e-mail: [info@avtechpulse.com](mailto:info@avtechpulse.com)

<http://www.avtechpulse.com>

Germany / Aust / Switz: Schulz-Electronic  
France: K.M.P. Elec. Japan: Meisho Corp.  
Korea: MJL Crystek Taiwan, China: Quatek

Visit <http://mwj.hotims.com/11713-25>

## Call for Book and Software Authors

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

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

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

**Mark Walsh**  
Editor  
Artech House  
685 Canton St.  
Norwood, MA 02062

1-800-225-9977  
[mwalsh@artechhouse.com](mailto:mwalsh@artechhouse.com)

**Eric Willner**  
Commissioning Editor  
Artech House  
46 Gillingham Street,  
London SW1V 1AH, UK

Tel: +44(0) 207 596 8750  
[ewillner@artechhouse.co.uk](mailto:ewillner@artechhouse.co.uk)



**ARTECH HOUSE** | [www.artechhouse.com](http://www.artechhouse.com)

## TECHNICAL FEATURE

The simulated and measured frequency responses show good agreement. The proposed filters have advantages such as compact and simple structures, they are easily integrated and manufactured, and they show wide bandwidths, high attenuations and also demonstrate that the filters' performance can be effectively improved by using DGS. ■

## ACKNOWLEDGMENT

This work was supported by the Shanghai Leading Academic Discipline Project (No. T0103) and the National Natural Science Foundation of China (No. 60571054).

## References

1. J.S. Hong, M.J. Lancaster, D. Jedamzik, R.B. Greed and J.C. Mage, "On the Performance of HTS Microstrip Quasi-elliptic Function Filters for Mobile Communications Application," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 48, No. 7, July 2000, pp. 1240-1246.
2. J.S. Hong and M.J. Lancaster, "Aperture-coupled Microstrip Open-loop Resonators and Their Applications to the Design of Novel Microstrip Bandpass Filters," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 47, No. 9, September 1999, pp. 1848-1855.
3. L.H. Hsieh and K. Chang, "High Efficiency Piezoelectric-transducer-tuned Feedback Microstrip Ring-resonator Oscillators Operating at High Resonant Frequencies," *IEEE Transactions on Microwave Theory and Techniques*, Part 1, Vol. 51, No. 4, April 2003, pp. 1141-1145.
4. S.K. Satpathy, G. Kumar and K.P. Ray, "Compact Shorted Variations of Triangular Microstrip Antennas," *Electronics Letters*, Vol. 34, No. 8, 1998, pp. 709-711.
5. J.S. Yun, G.Y. Kim, J.S. Park, D. Ahn, K.Y. Kang and J.B. Lim, "A Design of the Novel Coupled Line Bandpass Filter Using Defected Ground Structure," *2000 IEEE MTT-S International Microwave Symposium Digest*, Vol. 1, pp. 327-330.
6. D. Ahn, J.S. Park, C.S. Kim, J. Kim, Y.X. Qian and T. Itoh, "A Design of the Low Pass Filter Using the Novel Microstrip Defected Ground Structure," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 49, No. 1, January 2001, pp. 86-93.
7. J.R. Crute and L. Davis, "A Compact Microstrip Interdigital Stepped-impedance Bandpass Filter With Enhanced Stopband," *Microwave and Optical Technology Letters*, Vol. 34, No. 5, 2002, pp. 336-340.
8. M. Makimoto and S. Yamashita, *Microwave Resonators and Filters for Wireless Communication*, Springer-Verlag, Berlin Heidelberg, 2001.
9. D.C. Chung and B.S. Han, "HTS Microstrip Filters Using H-Type Resonators," *IEEE Transactions on Applied Superconductivity*, Vol. 11, No. 1, January 2001, pp. 388-391.

**Jian-kang Xiao** received his BS degree in electronics from Lanzhou University, China, in 1996, and his MS degree in radio physics from Lanzhou University in 2004. He is currently working toward his PhD degree. Since 1996 he has been an electrical engineer at the Institute of Modern Physics, Chinese Academy of Sciences. His research interests include microwave and millimeter-wave theory and their applications.

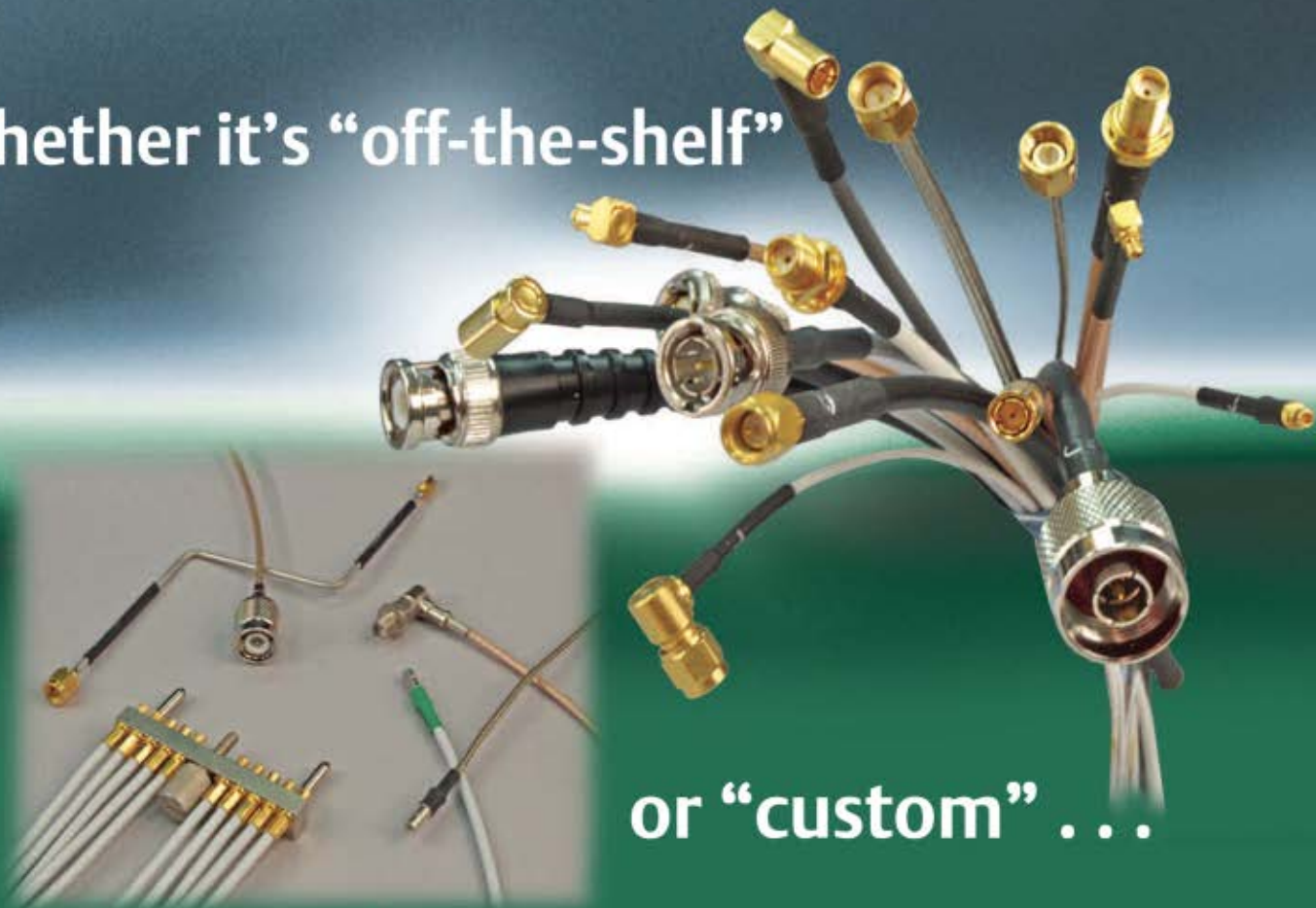
**Shi-wei Ma** received his BS, MS and PhD degrees in radio physics, electronics, control theory and control engineering from Lanzhou University, Shanghai University, China, in 1986, 1991 and 2000, respectively. After two years as an STA research fellow at the Japan National Institute of Industrial Safety, he is now an associate professor in the automation department of Shanghai University. His current research interests include signal processing, time-frequency analysis theory, and applications and microsystems integration.

**Ying Li** is currently a professor at Shanghai University. His research interests include electromagnetic theory, microwave and millimeter-wave techniques and their applications.



# Whether it's "off-the-shelf"

The Emerson logo is a trademark and service mark of  
Emerson Electric Co.  
©2005 Emerson Network Power  
Connectivity Solutions, Inc.



# or "custom" ...

## ... Emerson has your RF Coaxial Cable Assembly needs covered.

The Johnson® line of **RF Coaxial Fixed Length Cable Assemblies** includes a variety of interfaces ( SMA, SMB, MCX, MMCX, BNC and N ) in multiple lengths and cable types. Included is a new group of SMA hand-formable cable assemblies that offer users the high quality, low-cost solution that is readily available through our distributor network.

Should you require a custom RF Coaxial Cable Assembly we can fulfill your needs by providing a fast quote turnaround to your specifications, followed by a drawing and prototype samples. Flexible, hand-formable and semi-rigid cable options are available in DC – 40 GHz cable assemblies.

Let us fulfill all your RF Coaxial Cable Assembly needs today.

Contact **Emerson Network Power Connectivity Solutions** today to request more information on our new RF Coaxial Cable Assemblies.

ISO 9001:2000 certified

**Connectivity Solutions**

For product information:  
[www.EmersonNetworkPower.com/Connectivity](http://www.EmersonNetworkPower.com/Connectivity)  
or call 800-247-8256

**JOHNSON®**



**EMERSON**  
Network Power

**EMERSON. CONSIDER IT SOLVED.™**

Visit <http://mwj.hotims.com/11713-45> or use RS# 45 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)

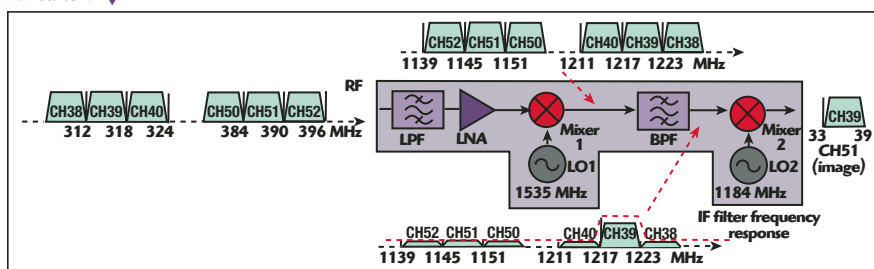
# A 40 TO 900 MHz CMOS BROADBAND DIFFERENTIAL LNA FOR A DTV RF TUNER

*This article describes a 40 to 900 MHz CMOS broadband differential LNA with gain control for a DTV RF tuner application. The LNA is fabricated in a TSMC 0.18  $\mu\text{m}$  CMOS process. The broadband differential LNA uses dual-feedback and shunt-shunt feedback topologies to achieve high gain and a flat broadband response. The LNA is designed with 75  $\Omega$  differential input and output impedances for a 75  $\Omega$  TV system application. The circuit measurement is performed using an FR-4 PCB test fixture. In the frequency range from 40 to 900 MHz, the LNA exhibits a gain of  $20.26 \pm 0.41$  dB, a noise figure less than 5 dB, and an input P1dB between  $-19.5$  and  $-20.3$  dBm. The gain tuning range is from 20 to  $-42.8 \pm 4.9$  dB over the 40 to 900 MHz range. The power consumption is 43 mW at  $V_{DD} = 1.8$  V.*

Digital TV offers a far wider choice of TV viewing and a reduction of the interference that may be experienced on analog TV. Recently, many RF circuits realized in the CMOS process have been reported and the 0.18  $\mu\text{m}$  process is a good candidate for highly integrated systems-on-chip (SOC) applications. The requirements of low power

and low cost push the trend toward a single radio chip. **Figure 1** shows the up-down architecture of a DTV RF tuner.<sup>1,2</sup> The RF signal is upconverted to 1.2 GHz by the first mixer and then downconverted by the second mixer to the IF. Rather than bulky tunable filters used traditionally in direct-down architec-

Fig. 1 Up-down architecture of a DTV RF tuner. ▼



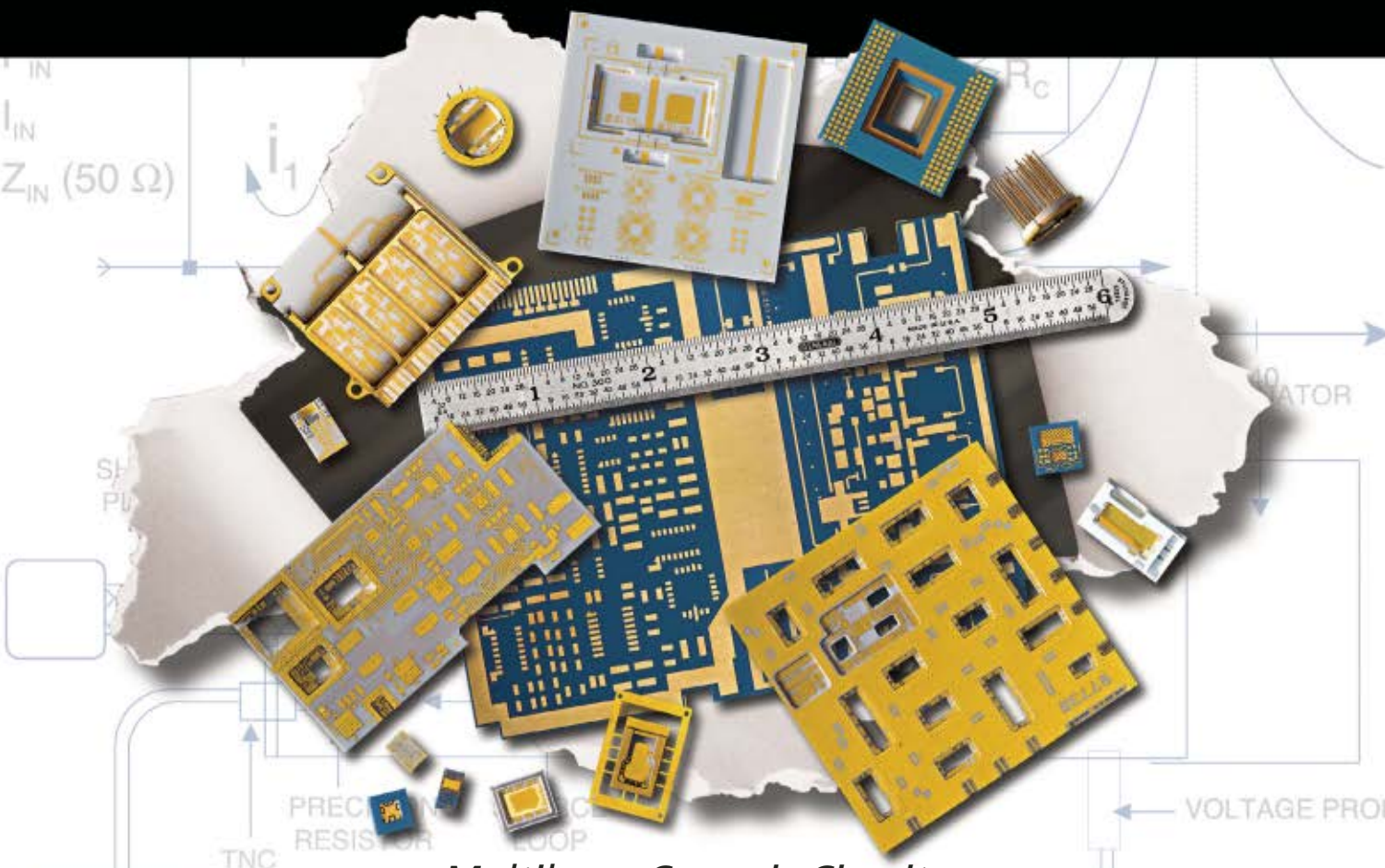
D.R. HUANG AND H.R. CHUANG  
National Cheng Kung University  
Tainan, Taiwan, ROC

Y.K. CHU  
Himax Technologies  
Tainan, Taiwan

C.L. LU  
Kun Shan University  
Tainan, Taiwan, ROC



# Another Breakthrough: *LTCC Products from ATC*



## *Multilayer Ceramic Circuits Utilizing ATC's LTCC Capabilities – Backed by Over 40 Years' Experience in Design and Manufacturing*

### Advanced Material Capabilities

- Consistent, superior quality and reliability
- High density packaging
- High volume manufacturing
- Low development costs

### Turn-Key Production Capabilities

- Board sizes up to 6.5" x 6.5" with simple or complex structures
- 100% inspection
- 40+ tape layers
- Surface thin film metalizations
- Design, assembly and test services

### The ATC Advantage

- Limited production runs to support engineering prototypes
- Manufacturing processes to achieve required tolerances
- Complete manufacturing process control
- Serialization for traceability

Applications: RF/Microwave/Millimeter-wave, Communications Systems, Fiber Optic Networks, Medical, Aerospace and Military

A M E R I C A N   T E C H N I C A L   C E R A M I C S



ATC North America

631-622-4700

sales@atceramics.com

ATC Europe

+46 8 6800410

sales@atceramics-europe.com

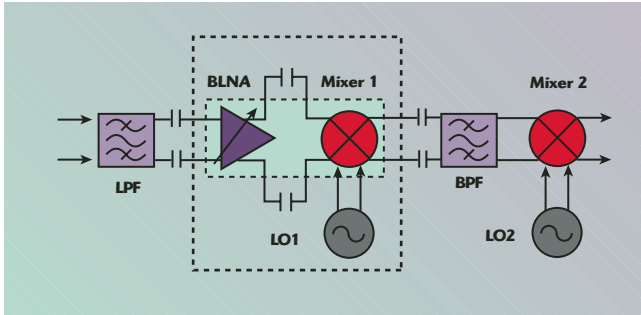
ATC Asia

+86-755-8366-4318

sales@atceramics-asia.com

www.atceramics.com

Visit <http://mwj.hotims.com/11713-17> or use RS# 17 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)



▲ Fig. 2 Block diagram of a DTV tuner differential RF front-end.

ture, the up-down architecture has the advantage of providing a good image rejection by using a 1.2 GHz bandpass filter.

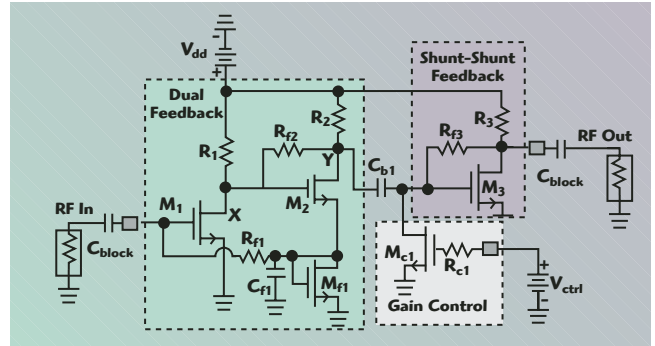
For an RF TV tuner application, the LNA not only requires low noise and high gain but also high linearity and flat response over the 40 to 900 MHz frequency range. In this article, a broadband differential LNA with gain-control, using dual-feedback and shunt-shunt feedback topologies, is adopted to achieve high gain and a flat broadband response. The controllable gain can prevent saturation of the receiver when the input signal level is relatively high. The broadband LNA is implemented in a TSMC 0.18  $\mu\text{m}$  CMOS process.

### LNA TOPOLOGY AND CIRCUIT DESIGN

Figure 2 shows the block diagram of a DTV tuner differential RF front-end, in which the presented three-stage LNA includes two feedback am-

plification stages and one gain-control stage (see Figure 3). It uses dual-feedback and shunt-shunt feedback stages to achieve a high and flat broadband response. The dual-feedback stage is the first stage and the shunt-shunt feedback stage is the second stage, to increase the gain. The gain-control stage is used to prevent saturation.

It is known that the differential circuit can mitigate the effects of common mode noise. As shown, this LNA, which did not use a high impedance at the source terminal, is a pseudo-differential circuit structure. The reason not to use a true differential amplifier circuit is that, for low voltage RFIC design (1.8 V, for example) a high impedance at the source terminal will compress the voltage headroom and output voltage swing, which will reduce the amplifier gain. Also, this pseudo-differential LNA circuit can still reject the common mode noise from  $V_{DD}$ .

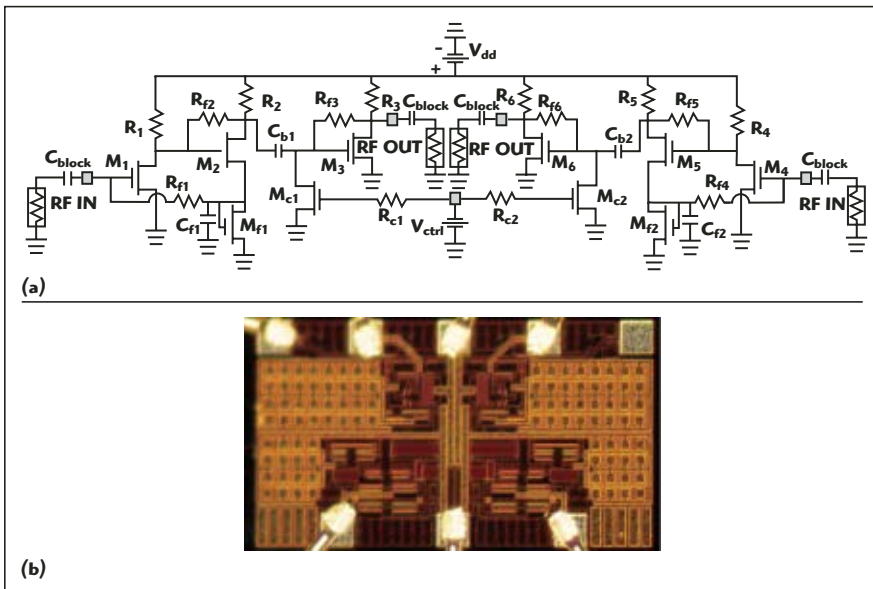


▲ Fig. 3 Half circuit schematic of the designed broadband differential LNA with gain control.

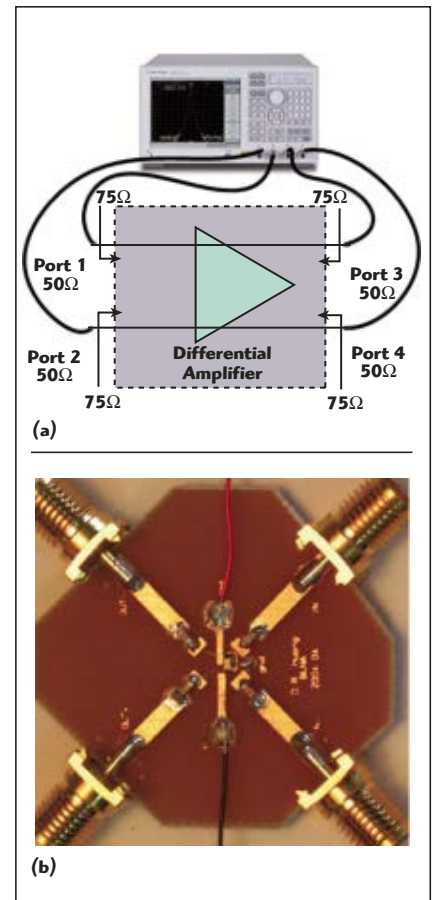
### Feedback Stages

The dual-feedback stage adopts the Kukeilka architecture.<sup>3-5</sup> This architecture is a refinement of the traditional shunt-series feedback. The output of the dual-feedback stage is capacitively coupled to the shunt-shunt feedback stage input through a DC block capacitor.

The  $M_1$  and  $M_2$  of the dual-feedback stage dissipates 2 and 4 mA of DC current, respectively. The aspect ratios (W/L) of  $M_1$  and  $M_2$  are chosen



▲ Fig. 4 Complete circuit schematic (a) and chip micrograph (b) of the designed differential LNA.



▲ Fig. 5 Block diagram (a) and photograph (b) of the PCB test fixture to measure the differential S-parameters.



# Smaller, Faster, Broadband Solutions



With a collective heritage of more than 50 years, Filtronic Signal Solutions provides a unique combination of technologies and talents to support the SIGINT, ESM, EW and Tactical Communications markets. Innovative solutions combine digital and RF technology in one multi-function assembly. From our filter pedigree and component heritage, suspended stripline technology results in broader frequencies of operation and lower loss characteristics.



## From antenna port to digital interface, Filtronic is the solution:

- **Frequency Converters** – broadband, small, integrated packages
- **IFMs/DFDs** – high accuracy and resolution, short RF pulse capture
- **Switched Filters** – integrated, low loss, packaged and discreet switches, narrowband and broadband dc–40 GHz
- **Multi-function Assemblies** – fully integrated, improves noise figures
- **WiMax Transceivers** – setting the standard
- **Couplers and Hybrids** – low loss, directivity, coupling flatness, low reflection
- **Filters and Multiplexers** – low loss, high selectivity, small footprint, combination of technologies (lumped element, combine, SSS, waveguide), band pass, band stop, multiplexers, equalizers. 60:1 pass bands possible
- **Power Dividers/Combiners** – amplitude balance, low VSWR, high isolation, low phase balance



Visit [www.filss.com](http://www.filss.com) to learn more about custom integration capabilities as well as premium-quality, highly reliable passive components. Call today and put our experience, innovative thinking and reliability to work for you. The Filtronic Solution.



Digital Communication Products • RF & Microwave Subsystems • Components



Hudson, New Hampshire  
P: (603) 459 1600 • F: (603) 459 1605  
E: [microwaveinfo@filss.com](mailto:microwaveinfo@filss.com)

Columbia, Maryland  
P: (410) 290 3918 • F: (410) 290 8146  
E: [digitalinfo@filss.com](mailto:digitalinfo@filss.com)

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

Visit <http://mwj.hotims.com/11713-53> or use RS# 53 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)

# COMPEX

## The Single Layer Specialists

Delivery in Days • Since 1976  
ISO 9001 : 2000



### Single Layer Capacitors

- Broadest variety available
- Gold or tin terminations
- 100pf X7R from 10 x 10 mils
- 1,000pf X7R from 30 x 30 mils



### Mounting Shorts

- Instant bonding pads
- Height matching reduces lead length
- Any size available



### Submounts

- Alumina, Aluminum Nitride, Quartz, Kovar
- Custom Patterns
- Thickness from 3 to 60 mils and beyond



# COMPEX CORP

electronic components

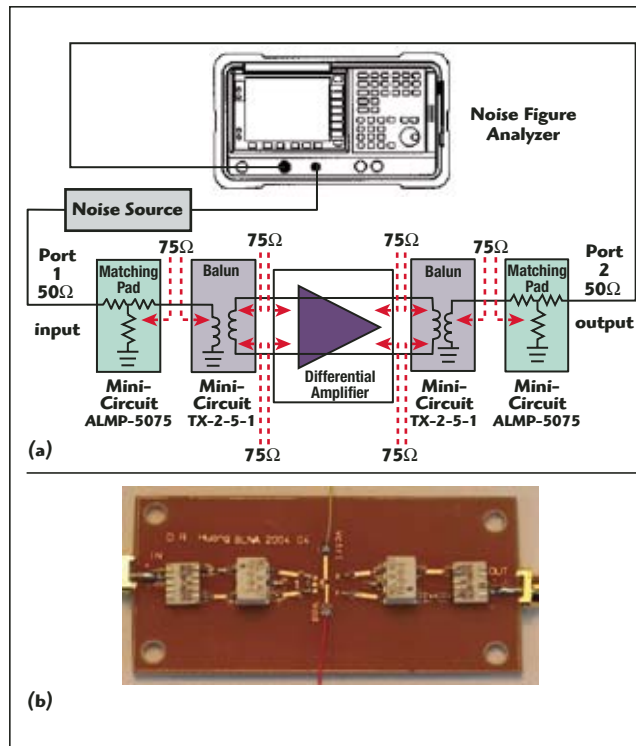
West Berlin, NJ 08091

e-mail: sales@compexcorp.com

856/335-2277 • fax: 856/335-7223

web: www.compexcorp.com

## TECHNICAL FEATURE



▲ Fig. 6 Block diagram of the 50 to 75Ω and single-ended to differential input/output conversion scheme (a) and photograph (b) of the test fixture.

to be the same. To ensure  $M_1$  is operating in the saturation region, the size of the diode-connected transistor,  $M_{f1}$ , is chosen to be twice that of  $M_1$ . In addition,  $C_{f1}$  is added in parallel with  $M_{f1}$  to compensate the over-damped characteristic of this structure. However, the dual-feedback stage does not provide the desired gain for the LNA. In order to achieve a higher gain, a shunt-shunt feedback stage<sup>6</sup> is added.  $M_3$  dissipates 6 mA of DC current and the shunt-shunt feedback stage dissipates 12 mA due to the differential topology.

### Gain-control Stage

As shown,  $M_{c1}$  is used to implement a gain-control mechanism. The voltage,  $V_{ctrl}$ , applied to  $M_{c1}$ , controls the variable gain. This topology yields a negative slope gain-control curve. The LNA has its maximum gain when the control voltage is zero and vice versa.

### SIMULATION AND MEASUREMENT RESULTS

Figure 4 shows the complete circuit schematic and chip micrograph of the designed differential LNA. The chip die size is  $1.007 \times 0.568$  mm. The circuit measurement is

performed using an FR-4 PCB test fixture. For differential S-parameter measurements, a four-port network analyzer was used. Since the four-port analyzer can support differential measurement, no baluns are needed. Figure 5 shows the block diagram and photograph of the test fixture for differential measurement environment. It is noted that, although this circuit is designed for 75 Ω DTV systems, 50 Ω instruments are used for measurement. In order to match the two different characteristic impedances used in the system,

matching pads (Mini-Circuit ALMP-5075) are used to convert the impedance from 50 to 75 Ω and vice versa. For single-ended instruments such as the signal generator, spectrum analyzer and noise figure analyzer, a balun (Mini-Circuit TX-2-5-1) is used to convert the differential input/output to single-ended input/output. Figure 6 shows the block diagram of the conversion scheme and a photograph of FR-4 PCB test fixture.

The simulated and measured results are shown in Figures 7 to 11, where the measurements of  $S_{21}$  and  $S_{12}$  are shown with the losses of the baluns and matching pads de-embedded. When the control voltage is zero (high gain mode), the LNA exhibits a gain of  $20.26 \pm 0.41$  dB, a noise figure less than 5 dB, an input P1dB between -19.5 and -20.3 dBm, and an IIP3 between -12.7 and -10.9 dBm from 40 to 900 MHz. When the control voltage is at 1.8 V (low gain mode), the LNA gain is  $-42.8 \pm 4.9$  dB. The power consumption is 43 mW at  $V_{DD} = 1.8$  V. It is noted that for the S-parameters, since the measurement with 50 Ω systems and the simulation using 50 Ω loads show good agreement, it is believed that



# RF Solutions



- **Fixed Attenuators & Terminations**
- **Programmable Attenuators**
- **Rotary Attenuators**
- **RF Switches**
- **Power Dividers**
- **Programmable RF Test Systems**
- **Matrix Switches**
- **RF Test Accessories**



ISO 9001:2000

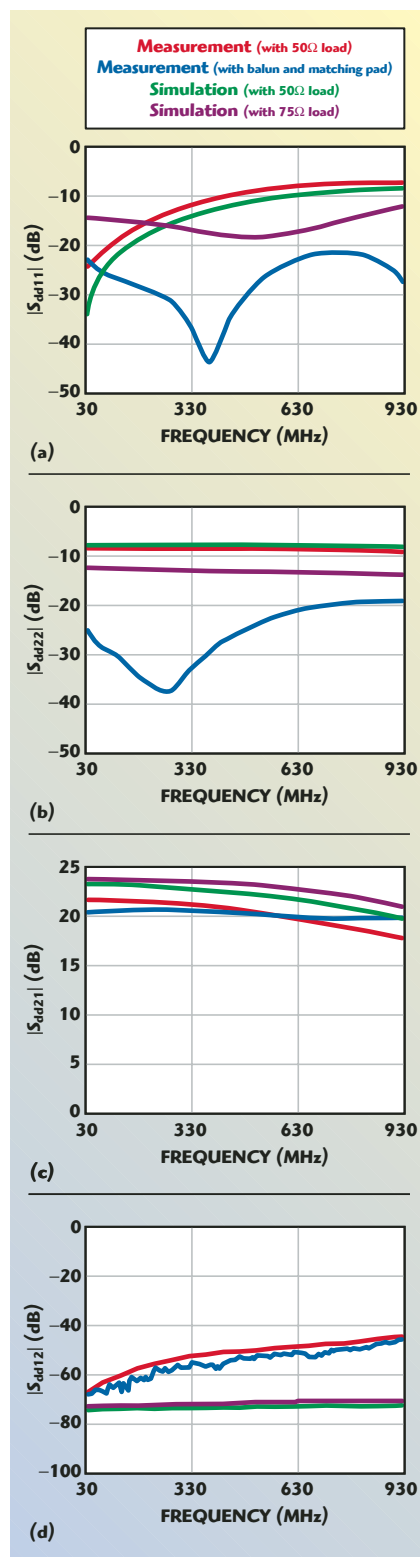
CE

For more information visit...

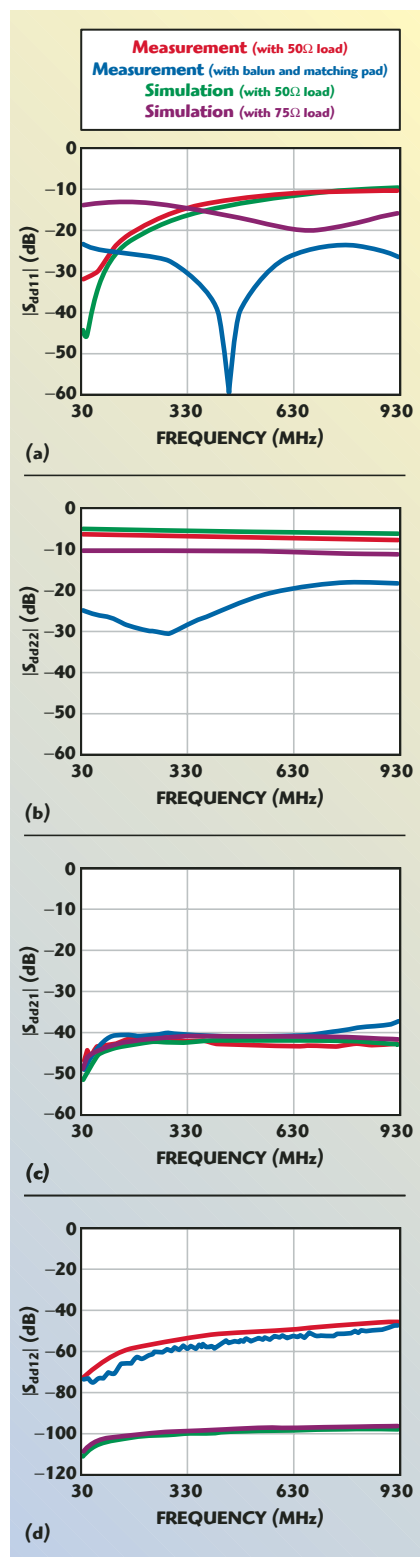
**[www.jfwindustries.com](http://www.jfwindustries.com)**

Call (317) 887-1340 toll free (877) 887-4539  
or send an email to... [sales@jfwindustries.com](mailto:sales@jfwindustries.com)

Visit <http://mwj.hotims.com/11713-66> or use RS# 66 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)



▲ Fig. 7 High gain mode S-parameters.

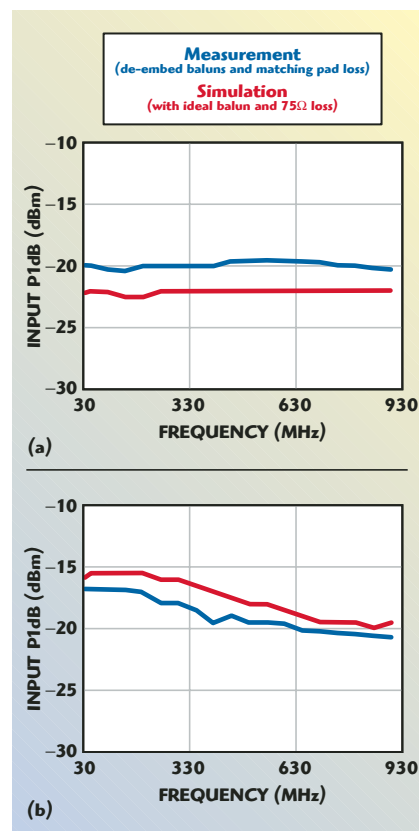


▲ Fig. 8 Low gain mode S-parameters.

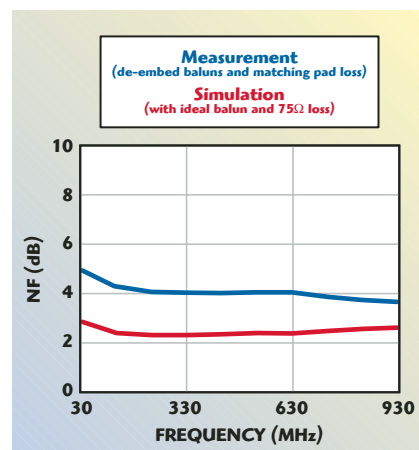
## CONCLUSION

A 40 to 900 MHz CMOS broadband differential LNA with gain control, implemented in a 0.18  $\mu\text{m}$  CMOS process, for a DTV RF tuner application is described. The LNA uses both a dual-feedback and shunt-

the measurements with a 75  $\Omega$  system (not provided) and the simulations will also be in good agreement. **Table 1** gives a summary of the measured and simulated performance of the CMOS broadband differential LNA with gain control.



▲ Fig. 9 Input P1dB versus frequency; (a) high gain mode and (b) low gain mode.

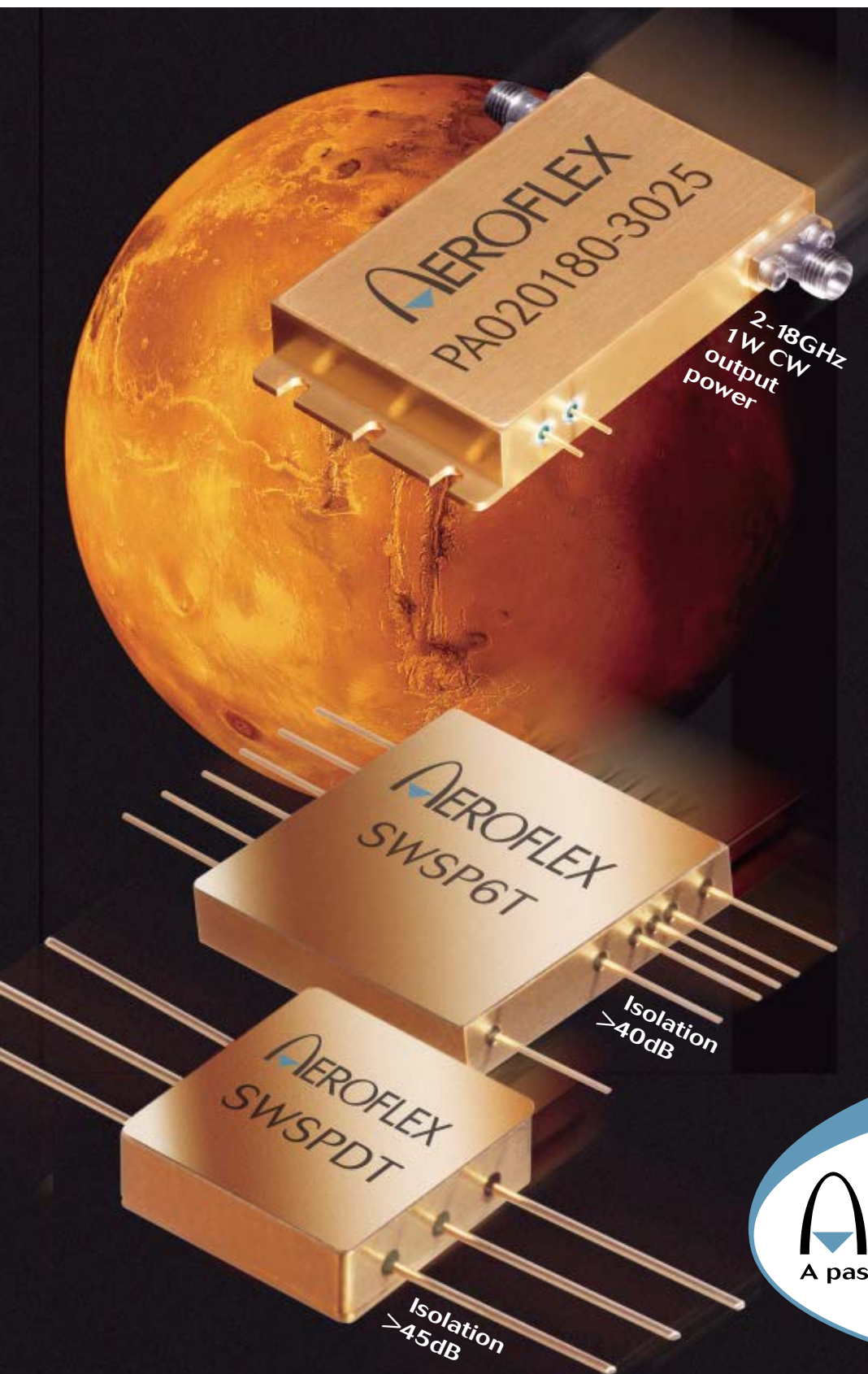


▲ Fig. 10 Noise figure versus frequency in the high gain mode.

shunt feedback topology to achieve a high and flat broadband response. The LNA is designed with 75  $\Omega$  differential input and output impedances. The chip die size is  $1.007 \times 0.568$  mm. The circuit measurement is performed using an FR-4 PCB test fixture. Since typical measurement instruments are 50  $\Omega$  systems, matching pads are used in the measurement to match the impedances between 50 and 75  $\Omega$ . For single-ended measurements such as with spectrum



# High-performance microwave switches and amps soar in space



## Space switches

- Direct replacement for legacy switches
- High Isolation
- Compact hermetic packages
- Integrated control logic
- Available in class K

## Broadband power amps

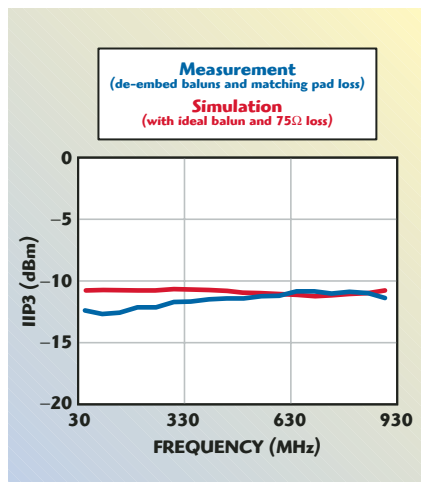
- Designs up to 65 GHz
- High efficiency and linearity
- Power up to 150W pulsed, up to 30W CW
- High reliability

At Aeroflex Plainview, we're all about experience, and offering cost-effective solutions that do not sacrifice performance and quality. We combine extensive space design and packaging expertise with cutting-edge, proven technologies to provide highly-integrated microwave assemblies, amplifiers, switches, and up/down converters that operate up to 65 GHz.

**800-645-8862**

[aeroflex.com/bband](http://aeroflex.com/bband)

**AEROFLEX**  
A passion for performance.



▲ Fig. 11 IIP3 versus frequency in the high gain mode.

and noise figure analyzers, a balun is used to convert the differential input/output to single-ended input/output. In the 40 to 900 MHz frequency range, the LNA exhibits a gain of  $20.26 \pm 0.41$  dB, a noise figure less than 5 dB, an input P1dB between -19.5 and -20.3 dBm, and an IIP3 between -12.7 and -10.9 dBm. The

gain tuning range is from 20 to -42.8  $\pm 4.9$  dB over the 40 to 900 MHz range. The power consumption is 43 mW at  $V_{DD} = 1.8$  V. ■

TABLE I

SIMULATED AND MEASURED PERFORMANCE  
OF A CMOS BROADBAND DIFFERENTIAL LNA WITH GAIN CONTROL

	Simulation	Measurement
Frequency range (MHz)	40~900	
Operating voltage (V)	1.8	
Current/power consumption	22.8 mA/41.04 mW	24 mA/43.2 mW
Input/output return loss (dB)	> 8.4/7.7 (50 $\Omega$ load) > 12.6/12.5 (75 $\Omega$ load)	> 7.4/8.5 (50 $\Omega$ load) —
Gain (dB)	21.6 $\pm$ 1.6	20.3 $\pm$ 0.4
Noise figure (dB)	< 2.8	< 5
Input P1dB (high gain/ low gain mode) (dBm)	-22~-22.5/ -15.5~-20	-19.5~-20.3/ -16.8~-20.7
IIP3 (high gain mode) (dBm)	-10.7~-11.1	-10.8~-12.7
Gain tuning range (dB)	21.6 $\pm$ 1.6~-46.1 $\pm$ 3.8	20.3 $\pm$ 0.4~-42.8 $\pm$ 4.9
Die size (mm)	1.007 $\times$ 0.568	

#### ACKNOWLEDGMENT

The authors would like to thank the Chip Implementation Center (CIC) of the National Science Council, Taiwan, ROC, for providing the TSMC CMOS process.

#### References

1. S. Birlleson, et al., "Silicon Single-chip Television Tuner Technology," 2000 ICCE Conference Digest of Technical Papers, pp. 38-39.
2. B. Taddiken, et al., "Broadband Tuner on a Chip for Cable Modem, HDTV and Legacy Analog Standards," 2000 IEEE RFIC Symposium Digest, pp. 17-20.
3. C.D. Hull and G.B. Mayer, "Principle of Monolithic Wideband Feedback Amplifier Design," International Journal of High Speed Electronics, Vol. 3, February 1992, pp. 53-93.
4. F.T. Chien and Y.J. Chan, "Bandwidth Enhancement of Transimpedance Amplifier by Capacitive-peaking Design," IEEE Journal of Solid-State Circuits, Vol. 34, August 1999, pp. 1167-1170.
5. Y.C. Chen and S.S. Lu, "Analysis and Design of CMOS Broadband Amplifier with Dual-feedback Loops," 2002 ASIA-PACIFIC Conference on ASICs.
6. B. Razavi, Design of Analog CMOS Integrated Circuits, McGraw-Hill, New York, NY, 2001.
7. B. Razavi, RF Microelectronics, Prentice Hall, Upper Saddle River, NJ, 1997.
8. D.A. Johns and K. Martin, Analog Integrated Circuits Design, John Wiley & Sons Inc., Hoboken, NJ, 1997.
9. D.E. Bockelman and W.R. Eisenstadt, "Combined Differential and Common-mode Scattering Parameters: Theory and Simulation," IEEE Transactions on Microwave Theory and Techniques, Vol. 43, No. 7, July 1995, pp. 1530-1539.

## Broadband RF/Microwave Solutions

- Fixed/Variable Attenuators
- Precision Adapters
- Terminations
- Dividers and Splitters
- RF Tuners
- DC - 40GHz
- 1 Watt to 1000 Watts
- New Products: RF Adapters, DC Blocks, Mountable Attenuators



**A Tradition of Quality  
A Commitment to Customer Service**



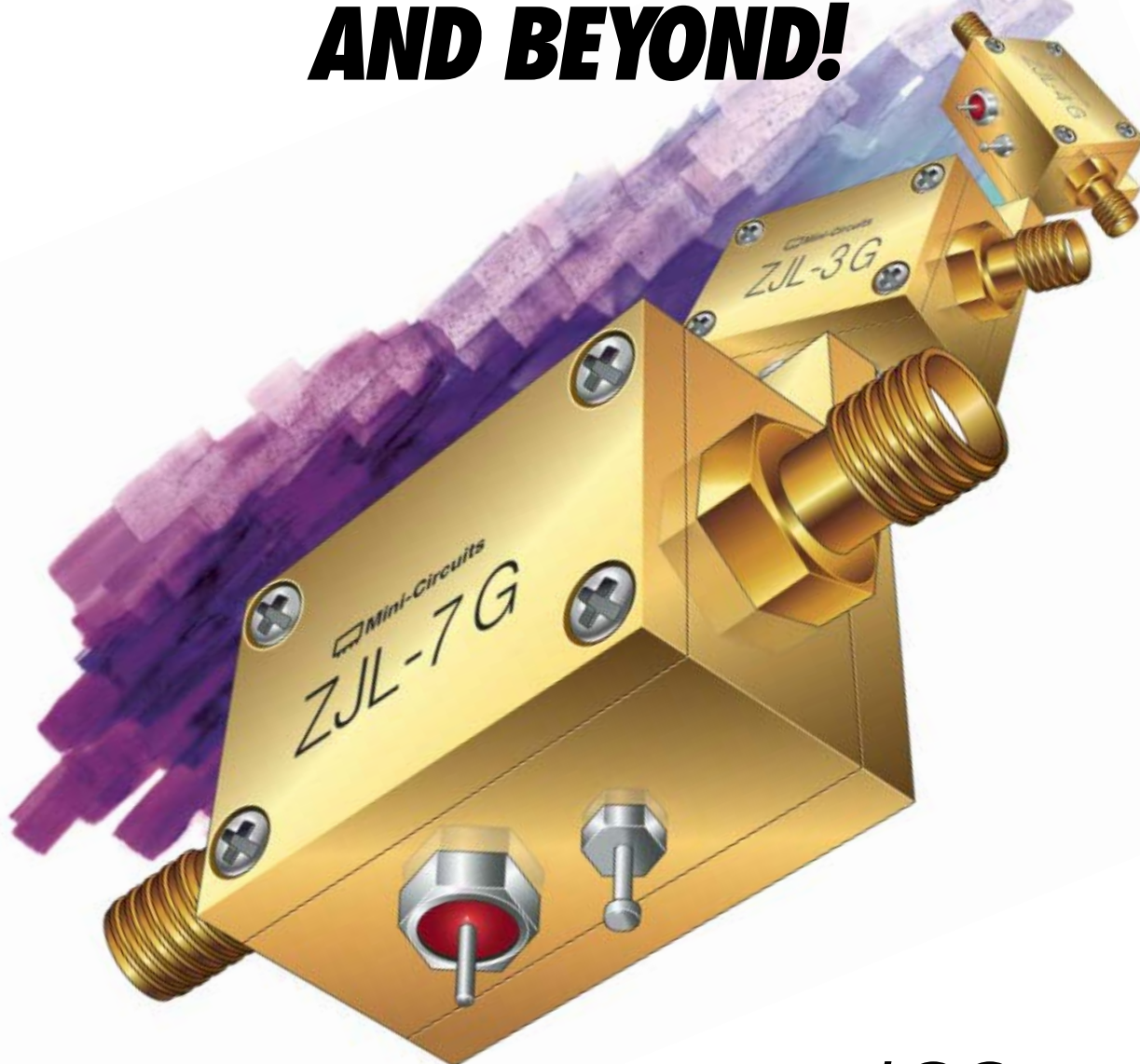
**Weinschel Associates**  
Broadband RF/Microwave Solutions

19212 Orbit Drive  
Gaithersburg, MD 20879  
Voice: 877.948.8342  
Fax: 301.963.8640  
RF@WeinschelAssociates.com

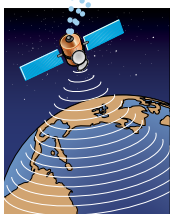
www.WeinschelAssociates.com



# THE GLOBAL SOLUTION... AND BEYOND!



## 10 MHz to 7 GHz AMPLIFIERS from **\$99<sup>95</sup>** (1-9 qty.)



From amateur radio to cellular to satellite applications, with medium output power up to 17 dBm, Mini-Circuits versatile ZJL and ZKL connectorized amplifiers offer the broad range of choices designers demand for achieving high system performance goals. Ultra-wideband models deliver **gain ranging from 9 to 40 dB** and IP3 up to +32 dBm. But beyond the performance and reliability built into these miniature 12V amplifiers lies another important feature, the low price...from only \$99.95! Call now for fast delivery.

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

### SPECIFICATIONS

Model	Freq. (MHz)	Gain (typ) Midband (dB)	Flat (±dB)	Max. P <sub>out</sub> 1 (dBm)	Dynamic Range (Typ @2 GHz <sup>2</sup> ) NF(dB) IP3(dBm)	Price \$ea. (1-9)
ZJL-5G	20-5000	9.0	±0.55	15.0	8.5 32.0	80 129.95
ZJL-7G	20-7000	10.0	±1.0	8.0	5.0 24.0	50 99.95
ZJL-4G	20-4000	12.4	±0.25	13.5	5.5 30.5	75 129.95
ZJL-6G	20-6000	13.0	±1.6	9.0	4.5 24.0	50 114.95
ZJL-4HG	20-4000	17.0	±1.5	15.0	4.5 30.5	75 129.95
ZJL-3G	20-3000	19.0	±2.2	8.0	3.8 22.0	45 114.95
ZKL-2R7	10-2700	24.0	±0.7	13.0	5.0 30.0	120 149.95
ZKL-2R5	10-2500	30.0	±1.5	15.0	5.0 31.0	120 149.95
ZKL-2	10-2000	33.5	±1.0	15.0	4.0 31.0	120 149.95
ZKL-1R5	10-1500	40.0	±1.2	15.0	3.0 31.0	115 149.95

### NOTES:

1. Typical at 1 dB compression.
2. ZKL dynamic range specified at 1 GHz.
3. All units at 12V DC.



**Mini-Circuits®**  
ISO 9001 ISO 14001 CERTIFIED

**ALL NEW**  
**minicircuits.com**

P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661 For detailed performance specs & shopping online see Mini-Circuits web site



The Design Engineers Search Engine Provides ACTUAL Data Instantly From MINI-CIRCUITS At: [www.minicircuits.com](http://www.minicircuits.com)

**RF/IF MICROWAVE COMPONENTS**

232 Rev E

Visit <http://mwj.hotims.com/11713-87> or use RS# 87 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)

# EM ENABLES CLASSIC FILTER TECHNIQUE

**E**lectromagnetic (EM) tools are indispensable for simulating high frequency designs, but they are poorly suited for synthesizing filters that require the determination of multiple parameters. This article describes how to use EM simulation to aid a classic and under-utilized technique for filter design. The classic technique requires building prototypes of a few select resonators and plotting certain measured data. From these plots the filter dimensions are easily synthesized. Modern EM simulation breathes new life into this classic technique by eliminating the need to construct prototypes. This is particularly important when a process requires a long manufacturing cycle time. Unusual resonators such as compact planar, MEMS and multi-layer structures are increasingly used to solve challenging design requirements, but are poorly modeled by analytical formulas. The technique described here is particularly well suited for such structures.

## THE CLASSIC TECHNIQUE

The classic technique is also referred to as the general procedure, because it enables the design of bandpass filters of almost any type. This article emphasizes the application of EM

to the procedure. Puglia<sup>1</sup> gives a comprehensive description of the general procedure. For completeness, the procedure is briefly reviewed here.

Bandpass filters entail only three first principles:

1. the resonators must exist,
2. the resonators must couple to each other and
3. the structure must couple to the terminations.

The general procedure is based directly on these first principles. The designer selects a form of resonator. Essentially, the only restrictions are that the resonator realizability and some method of coupling must exist. Next, data is acquired that relates the degree of resonator coupling to a variable parameter. Finally, data is acquired that relates termination coupling to a variable parameter. From this data, the filter is synthesized using simple analytical expressions.

Filter tables are usually published in the form of prototype values for a low pass filter

---

RANDY RHEA  
*Susina LLC*



# More Gigs Galore.

1S1G4A 1 Watt 0.8-4.2 GHz	35S4G8 35 Watt 4-8 GHz	540S1G4 540 Watt 0.8-4.2 GHz	40T26G40A 40 Watt 26.5-40 GHz	200T4G8 200 Watt 4-8 GHz	1000TP1G2 1000 Watt Pulse 1-2.5 GHz	2000TP8G12 2000 Watt Pulse 8.2-12.4 GHz
1S4G11 1 Watt 4-10.6 GHz	40S4G11 40 Watt 4-10.6 GHz	600S1G3 590 Watt 0.8-3.0 GHz	50T4G18 50 Watt 4.2-18 GHz	200T8G18A 200 Watt 7.5-18 GHz	1000TP2G8 1000 Watt Pulse 2.5-7.5 GHz	2000TP8G18 2000 Watt Pulse 7.5-18 GHz
5S1G4 6.5 Watt 0.8-4.2 GHz	50S1G4A 50 Watt 0.8-4.2 GHz	700S1G4 700 Watt 0.8-4.2 GHz	70T26G40 70 Watt 26.5-40 GHz	250T1G3 250 Watt 1-2.5 GHz	1000TP8G18 1000 Watt Pulse 7.5-18 GHz	4000TP1G2 4000 Watt Pulse 1 - 2 GHz
5S4G11 5 Watt 4-10.6 GHz	60S4G8 60 Watt 4-8 GHz	800S1G3 800 Watt 0.8-3.0 GHz	70T18G26 75 Watt 18-26.5 GHz	250T8G18 250 Watt 7.5-18 GHz	1000TP1G3* 1000/500 Watt Pulse 1.15-3.1 GHz	4000TP2G4 4000 Watt Pulse 2-4 GHz
5S10G20 5 Watt 10-20 GHz	80S4G11 80 Watt 4-10.6 GHz	10ST1G18A 10 Watt 0.8-18 GHz	120T40G40 40 Watt 40-45 GHz	300T2G8 300 Watt 2.5-7.5 GHz	1500T1G3A 1500 Watt 1-2.5 GHz	4000TP4G8 4000 Watt Pulse 4-8 GHz
10S1G4A 13 Watt 0.8-4.2 GHz	100S1G4 100 Watt 0.8-4.2 GHz	20ST1G18A 20 Watt 0.8-18 GHz	125T18G26 125 Watt 18-26.5 GHz	500T1G2 500 Watt 1-2.5 GHz	1500T2G8A 1500 Watt 2.5-7.5 GHz	4000TP8G12 4000 Watt Pulse 8-12 GHz
10S4G11 10 Watt 4-10.6 GHz	120S1G3 120 Watt 0.8-3.0 GHz	35ST1G18 35 Watt 0.8-18 GHz	125T26G40 125 Watt 26.5-40 GHz	500T2G8 500 Watt 2.5-7.5 GHz	1500T8G18 1500 Watt 7.5-18 GHz	4000TP12G18 4000 Watt Pulse 12-18 GHz
15S1G3 15 Watt 0.8-3.0 GHz	120S4G8 120 Watt 4-8 GHz	50ST1G18 50 Watt 0.8-18 GHz	125T40G45 125 Watt 40-45 GHz	500T8G18 500 Watt 7.5-18 GHz	2000T1G3 2000 Watt 1-2.5 GHz	
15S4G8 15 Watt 4-8 GHz	200S1G4A 200 Watt 0.8-4.2 GHz	15T4G18A 15 Watt 4.2-18 GHz	200T1G2 200 Watt 1-2 GHz	750TP1G3/200T 750/500 Watt Pulse 1.15-3.1 GHz	2000T2G8 2000 Watt 2.5-7.5 GHz	
20S4G11 20 Watt 4-10.6 GHz	240S1G3A 240 Watt 0.8-3.0 GHz	20T4G18A 20 Watt 4.2-18 GHz	200T1G3A 200 Watt 0.8-2.8 GHz	1000T1G2B 1000 Watt 1-2.5 GHz	2000T8G18 2000 Watt 7.5-18 GHz	
25S1G4A 25 Watt 0.8-4.2 GHz	400S1G4 400 Watt 0.8-4.2 GHz	40T4G18 40 Watt 4.2-18 GHz	200T2G4 200 Watt 2-4 GHz	1000T2G8B 1000 Watt 2.5-7.5 GHz	2000TP1G2A 1700 Watt Pulse 1-2.5 GHz	
30S1G3 30 Watt 0.8-3.0 GHz	450S1G3 450 Watt 0.8-3.0 GHz	40T18G26A 40 Watt 18-26.5 GHz	200T2G8A 200 Watt 2.5-7.5 GHz	1000T8G18B 1000 Watt 7.5-18 GHz	2000TP2G8B 2000 Watt Pulse 2.5-7.5 GHz	

## From 0.8 GHz To 45 GHz, And Everything In Between For EMC & Wireless Testing.

When EMC and Wireless testing is your gig, you need choices. AR has microwave amplifiers from 0.8 - 45 GHz and everything in between. Solid State to 800 watts or TWTAs to 4000 watts. Another example of AR Infinite Solutions.

AR products supply a multitude of RF solutions to companies around the world. Our limitless support network reaches the far corners of the world. And, everything we sell is backed by the best comprehensive warranty in the industry.

So when you're looking for just the right microwave amplifier for your total testing needs, remember... AR has a wide world of gigs.

To learn more, visit [www.ar-worldwide.com](http://www.ar-worldwide.com) or call 215.723.8181.

\*1.15-1.45 and 2.7-3.1 GHz for radar simulation.

ISO 9001:2000  
Certified



### rf/microwave instrumentation

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

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

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

Visit <http://mwj.hotims.com/11713-23> or use RS# 23 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)

Copyright© 2007 AR. The orange stripe on AR products is Reg. U.S. Pat. & TM. Off.

TABLE I

 LOW PASS PROTOTYPE VALUES  
 FOR A 0.1 dB PASSBAND RIPPLE CHEBYCHEV FOR ORDER N = 2 TO 9

N	g(0)	g(1)	g(2)	g(3)	g(4)	g(5)	g(6)	g(7)	g(8)	g(9)	g(N+1)
2	1	0.843	0.622								1.335
3	1	1.032	1/147	1.032							1.000
4	1	1.109	1.306	1.770	0.818						1.335
5	1	1.147	1.371	1.975	1.371	1.147					1.000
6	1	1.168	1.404	2.056	1.517	1.903	0.862				1.335
7	1	1.181	1.423	2.097	1.573	2.097	1.423	1.181			1.000
8	1	1.190	1.435	2.120	1.601	2.170	1.564	1.944	0.878		1.335
9	1	1.196	1.443	2.135	1.617	2.205	1.617	2.135	1.443	1.196	1.000

with 1 radian cut-off frequency and a source impedance of 1  $\Omega$ . An example for 0.1 dB passband ripple Chebyshev filters of orders 2 through 9 is given in **Table 1**. Many authors, including Puglia,<sup>1</sup> provide simple formula for finding Chebyshev prototype values for other passband ripple and order criteria.  $g_0$  is the normalized source termination and  $g_{N+1}$  is the normalized load termination. Notice that for odd-order Chebyshev  $g_0 = g_{N+1}$ . For even-order,  $g_{N+1}$  increases for increasing passband ripple. There are N reactive values for an Nth order prototype.

The general procedure utilizes k and q values rather than low pass prototype values. k values relate to resonator couplings and q values relate to end-resonator loaded Qs. k and q values are easily derived from low pass prototype values.

$$k_{n,n+1} = \frac{1}{\sqrt{g_n \cdot g_{n+1}}} \text{ for } n = 1 \text{ to } (N-1) \quad (1)$$

$$q_1 = g_0 \cdot g_1 \quad (2)$$

$$q_N = g_N \cdot g_{N+1} \text{ for } N \text{ odd} \quad (3)$$

$$q_N = \frac{g_N}{g_{N+1}} \text{ for } N \text{ even} \quad (4)$$

As an example, the Chebyshev table with  $N = 5$ ,  $q_1 = q_5 = 1.147$ , then  $k_{12} = k_{45} = 0.797$  and  $k_{23} = k_{34} = 0.608$ .

These k and q values are normalized by the filter fractional bandwidth, bw.

$$bw = \frac{f_{\text{upper}} - f_{\text{lower}}}{f_0} \quad (5)$$

where

$f_{\text{upper}}$  = passband upper cut-off frequency

$f_{\text{lower}}$  = passband lower cut-off frequency

and

$$f_0 = \frac{f_{\text{upper}} + f_{\text{lower}}}{2} \quad (6)$$

Then the actual filter couplings and loaded Qs are

$$K_{n,n+1} = bw \cdot k_{n,n+1} \quad (7)$$

$$Q_1 = \frac{q_1}{bw} \quad (8)$$

$$Q_N = \frac{q_N}{bw} \quad (9)$$

Notice that the capitalized symbols refer to actual couplings and loadings while noncapitalized symbols refer to normalized values.

### DETERMINING A STRUCTURE'S K VALUES

Consider the pair of resonators shown in **Figure 1**. The red areas are the microstrip metal, the blue areas are the via pads on the ground plane and the gray lines are the EM simulation grid. Each grid square is 15 mils on a side. The microstrip resonators are 90 mils wide and 240 mils long on a 31-mil thick PTFE-fiberglass substrate. The resonators are grounded with via holes at the bottom and are loaded with capacitors  $C_1$  and  $C_2$  at the top, thus forming a conventional combline. This metal layout pattern is simulated using the EMPOWER electromagnetic simula-

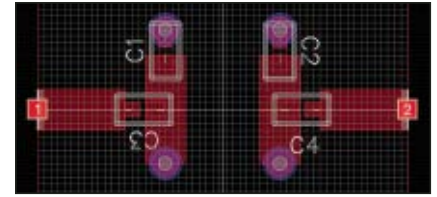


Fig. 1 Layout of combline microstrip resonators used for EM simulation.

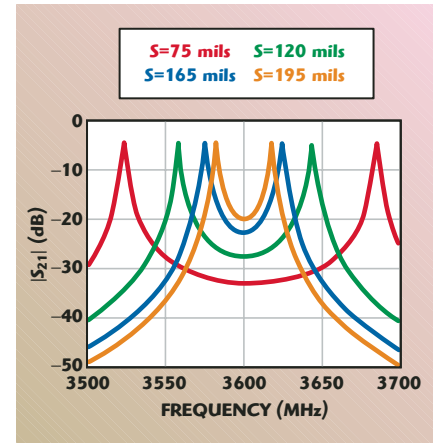


Fig. 2  $S_{21}$  response of coupled combline resonators with variable edge-to-edge spacing S.

tor in the GENESYS software suite.<sup>2</sup> Test ports 1 and 2 are very loosely coupled to the resonators through input and output lines and very small capacitors  $C_3$  and  $C_4$ . The edge-to-edge resonator spacing is 11 grid squares or 165 mils.

The frequency domain responses of this system are shown in **Figure 2** for edge-to-edge spacings of 195, 165, 120 and 75 mils.  $C_1$  and  $C_2$  are tuned to center the response at the desired filter center frequency, in this case 3600 MHz. Two response peaks are observed when the loading coupling is very loose. The coupling coefficient of this system is given by

$$K = \frac{f_{\text{upper}} - f_{\text{lower}}}{f_0} \quad (10)$$

For the spacing of 165 mils,  $f_{\text{upper}} = 3624.8$  MHz and  $f_{\text{lower}} = 3575.2$  MHz, so  $K = 0.0138$ .

The general procedure involves plotting this data, as illustrated in **Figure 3**. The green curve is obtained by EM simulation, while the blue curve is the result of circuit theory simulation. The red curve is the difference, in percent, between these data. A feature of the general procedure is that K is typically a monotonic function of the variable parameter,



# 10MHz to 65GHz Components



Directional Couplers



Power Dividers



90°/180° Hybrids



Antenna Beamformers



QPSK Modulators

***Achieving Perfection***



[www.etiworld.com](http://www.etiworld.com)  
[sales@etiworld.com](mailto:sales@etiworld.com)

50 Intervale Road, Boonton, NJ 07005, USA Tel: 973.394.1719 Fax: 973.394.1710

Visit <http://mwj.hotims.com/11713-49> or use RS# 49 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)

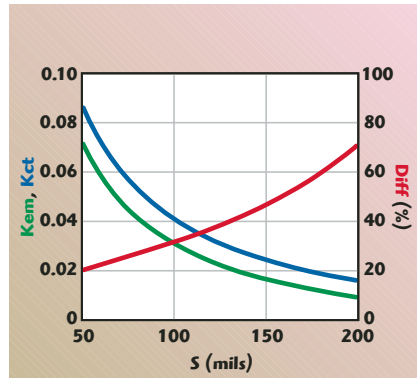


Fig. 3 Coupling coefficient  $K$  versus edge-to-edge spacing  $S$ .

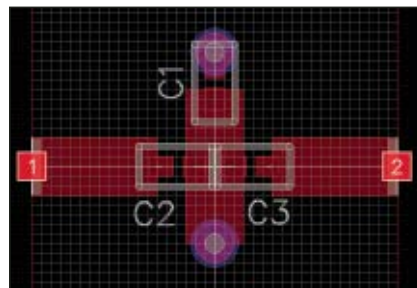


Fig. 4 Layout of a microstrip combine resonator used for EM simulation of the double-loaded  $Q$  vs. coupling capacitance.

and a smooth curve is easily drawn through a small number of data points. Here the data has been extrapolated to 50 and 200 mils. A plot of the coupling coefficient  $K$  for any spacing between these limits is now created.

### DETERMINING A STRUCTURE'S $Q$ VALUES

Consider the resonator shown in **Figure 4**. The resonator is grounded with a via at the bottom and is loaded with capacitors  $C_1$  at the top. It is a single resonator identical to the coupled resonators. Test ports 1 and 2 are coupled to the resonators through input and output lines and capacitors  $C_2$  and  $C_3$  that control the loaded  $Q$  of each end resonator in the final filter. A frequency domain response of this system is shown in **Figure 5**, where the values of  $C_2$  and  $C_3$  are 0.3 pF.  $C_1$  is tuned to center the response at the desired filter center frequency each time a different value is tried for the coupling capacitors. The singly terminated loaded  $Q$  is given by

$$Q = \frac{2f_0}{f_{\text{upper}} - f_{\text{lower}}} \quad (11)$$

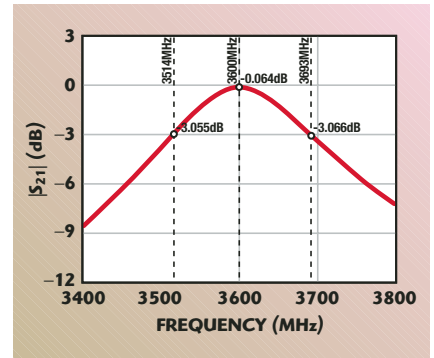


Fig. 5 Response of a doubly-loaded resonator with coupling capacitors of 0.3 pF.

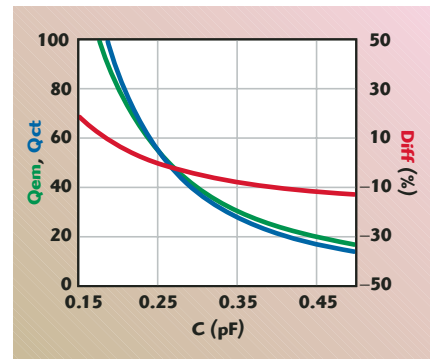


Fig. 6 Singly-loaded  $Q$  as a function of the coupling capacitor  $C$ .

In this case  $f_{\text{upper}} = 3693$  MHz and  $f_{\text{lower}} = 3514$  MHz, so  $Q = 40.2$ .

The general procedure involves repeating this data for a few different values of coupling capacitance. The  $Q$  was computed by EM simulation for capacitance values of 0.2, 0.3 and 0.45 pF. As was the case with  $K$ , the  $Q$  is typically a monotonic function of the variable parameter and a smooth curve is easily drawn through a small number of data points. **Figure 6** shows the data extrapolated to capacitor values of 0.15 to 0.5 pF. The  $Q$  from EM simulation is shown in green, while the one obtained by circuit theory simulation is shown in blue. Their difference in percent is shown in red. A plot of the resonator loaded  $Q$  for any capacitance value between these limits is now available.

### DESIGNING THE FILTER WITH $K$ AND $Q$ DATA

The plots of coupling coefficient and loaded  $Q$  contain sufficient data to design on this substrate a 3600 MHz combline filter with any bandwidth, any order and any transfer approximation shape, provided only that the required spacings and capacitor coupling values fall within the given

**Prewell**

**RF Amplifier**

InGaP HBT MMIC Amplifier

High Reliability

High Linearity Performance

**Application**

Gain Blocks

Mobile Infrastructure

Cellular, PCS, WCDMA, GSM

WLAN, DMB, CATV, WiBro, WiMAX

P/N	Bandwidth (GHz)	Test Freq. = 2950MHz	Device Bias
PW 110	DC-1	26 19 33 1.8	4.7 68

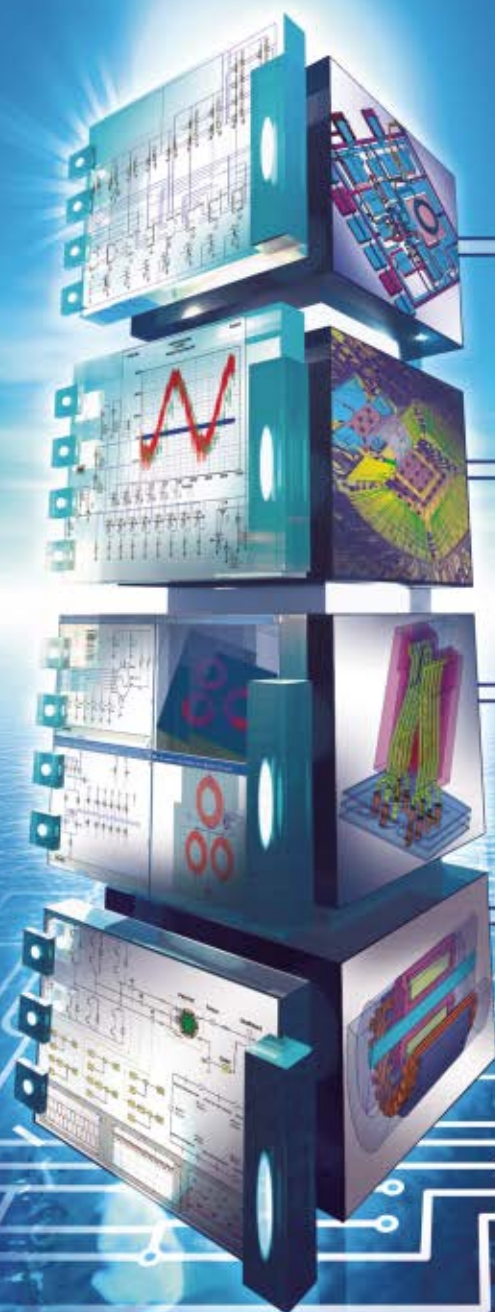
P/N	Bandwidth (GHz)	Test Freq. = 930MHz	Device Bias
PW 210	DC-3	21 16 30 3.1	4.7 45
PW 250	DC-3	18.5 16 30 3.3	4.7 45
PW 350	DC-3	16.5 17.5 33 3.3	4.8 58
PW 370	DC-3	14.5 17.5 33 3.6	4.8 58
PW 410	DC-3	20.5 19 35 3.4	4.9 70
PW 450	DC-3	18 19 35 3.7	4.9 70
PW 470	DC-3	16 19 35 3.5	5.0 70
PW 510	DC-3	20.5 20 38 3.4	5.4 85
PW 550	DC-3	18.2 20 38 3.5	5.35 85
PW 570	DC-3	16.2 20 38 3.6	5.4 85

P/N	Bandwidth (GHz)	Test Freq. = 1.9GHz	Device Bias
PH 230	1.5-3	17 22.5 38 3.2	5 85
PH 430	1.5-3	16.5 25 41 3.2	5 155
PH 435	1.5-3	16.5 26 42 3.2	5 150
PH 460	1-3	15 22.5 41 3.5	5 150
PH 530-25	1-3	13.5 30 45 3.9	5 260
PH 530-58	1-3	15.5 29.5 46 3.8	5 260

**Prewell Corporation**

#602, Megavally, 799, Gwangyang-dong, Dongan-gu, Anyang-si, Gyeonggi-do, Korea  
Tel : +82-31-420-8362 / Fax : +82-31-420-8369  
E-mail : sales@prewell.com  
www.prewell.com / www.prewell.com.cn





**HIGH-PERFORMANCE  
IC DESIGN & VERIFICATION**

**HIGH-PERFORMANCE  
SIGNAL & POWER INTEGRITY**

**HIGH-PERFORMANCE  
RF & MICROWAVE DESIGN**

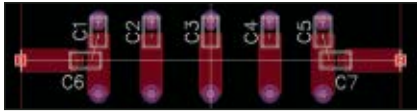
**HIGH-PERFORMANCE  
EM SYSTEMS DESIGN**

ANSOFT.COM

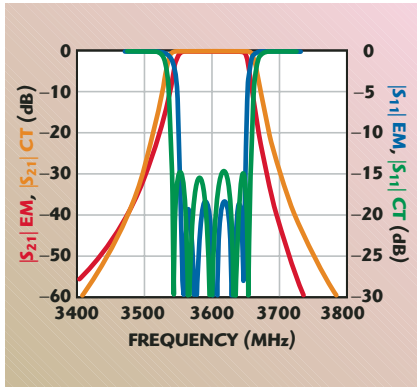
**SIMULATION SOFTWARE  
FOR HIGH-PERFORMANCE ELECTRONIC DESIGN**

Visit <http://mwj.hotims.com/11713-20> or use RS# 20 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)

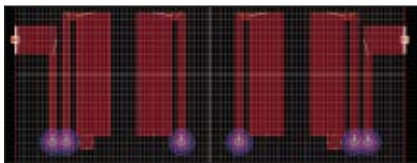




▲ Fig. 7 Layout of the final 3600 MHz combline bandpass filter.



▲ Fig. 8 Combline filter S-parameters computed by EM simulation and from circuit theory.



▲ Fig. 9 Layout of a four-section, 1700 MHz stepped-impedance resonator (SIR) bandpass filter.

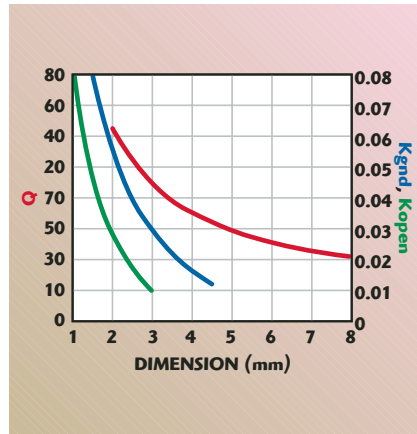
ranges. Consider, for example, a filter with the following parameters:

$$\begin{aligned} f_0 &= 3600 \text{ MHz} \\ \text{BW} &= 100 \text{ MHz} \\ N &= 5 \\ \text{Shape} &= \text{Chebyshev} \\ A_r &= 0.1 \text{ dB} \end{aligned}$$

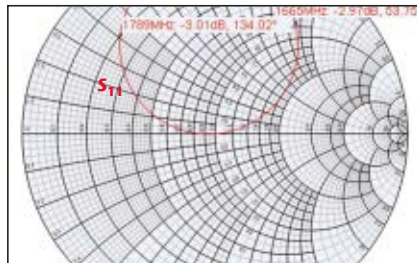
From Equations 1 through 9, it is found that  $Q_1 = Q_N = 1.147/0.0278 = 41.29$ . From the green trace in the plot of  $Q$  vs.  $C$ , the required input and output coupling capacitors are shown to be approximately 0.28 pF. From the same equations,  $K_{1,2} = K_{4,5} = 0.797 \times 0.0278 = 0.0222$  and  $K_{2,3} = K_{3,4} = 0.608 \times 0.0278 = 0.0169$ . From the green trace of the plot of coupling coefficient vs. spacing, the spacing between resonator 1 and 2, and 4 and 5, is approximately 120 mils, and the spacing between 2 and 3, and 3 and 4, is 150 mils.

## RESULTS USING THE GENERAL PROCEDURE

The layout of the final 3600 MHz combline bandpass filter is shown in **Figure 7**, with the dimensions given above. The EM and circuit theory



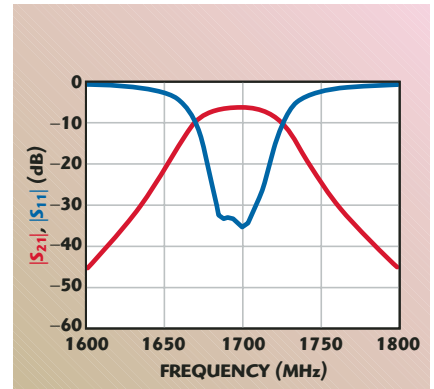
▲ Fig. 10 Loaded  $Q$  versus line length and coupling coefficients for adjacent lines.



▲ Fig. 11 Smith chart plot for measuring the end-resonator loaded  $Q$  vs. length of the coupling line.

computed responses are given in **Figure 8**. After EM simulation of the metal pattern, the loading capacitors C1 through C5 were optimized for the best response. The input and output coupling capacitors were fixed at the computed value of 0.28 pF. From the EM simulation, the resulting bandwidth is approximately 92 MHz, 8 percent lower than the desired 100 MHz, and the return loss is approximately 18 dB, 2 dB worse than desired. For comparison purposes, the circuit theory results show a bandwidth of approximately 116 MHz, 16 percent wider than desired and a return loss of only 15 dB, 5 dB worse than desired. Considering again the plot of coupling coefficient vs. spacing, the red trace is the percentage error of the circuit theory coupling with respect to the EM coupling.

Notice that, with a spacing of 50 mils the error is 25 percent, while with a spacing of 195 mils the error is 68 percent. This confirms the known phenomena in edge-coupled filters that a bandwidth error increases with narrow bandwidth filters. With wide-band filters the error is often unnoticed while with narrow filters the error can be extreme.



▲ Fig. 12 Transmission and return loss for the 1700 MHz SIR bandpass filter.

There is another important lesson here. The failure of the circuit theory accuracy is obvious, yet there are only two resonators. This means that the error is not attributable to coupling between non-adjacent resonators, as is often believed.

The source of the circuit theory bandwidth error is evanescent modes. The effects of these modes are naturally considered by EM simulation but they are difficult to simulate using circuit theory, because their effect depends on the orientation and loading of the lines, the filter bandwidth and the substrate properties. The error increases with thicker substrates. Interestingly, inter-digital filters are far less susceptible to evanescent modes.

The design of filters, using EM simulation to find  $K$  and  $Q$  values, is more accurate than the design using circuit theory synthesis and simulation techniques. The simplicity of the math used to design this combline filter results naturally because the general procedure relies directly on the three first principles.

## SECOND EXAMPLE

The layout of a four-section, 1672 to 1728 MHz bandpass filter is given in **Figure 9**, using a unique stepped-impedance resonator (SIR).<sup>3,4</sup> SIR technology shortens the required physical length of the resonators by increasing the inductance of high current sections of transmission lines and/or increasing the capacitance of high voltage sections. These quarter-wavelength 1700 MHz SIR resonators are 18.5 mm long on a 1.28 mm thick Rogers 3006 substrate with a relative dielectric constant of 6.15. The narrow sections of line are 0.5



# TINY CERAMIC LOW & HIGH PASS FILTERS

80 to 13000 MHz... Immediate Delivery



from **99¢** ea. qty. 1000

Measuring only 0.12"x0.06", these tiny hermetically sealed filters cover 80 to 13000 MHz. Utilizing our advanced **Low Temperature Co-fired Ceramic (LTCC) technology**, their superior thermal stability, high reliability and very low cost make them a must for your system requirements.

## HIGH PASS FILTERS (HFCN)

Model	Passband MHz	Stopband MHz (Loss >20 dB) Min.	Price \$ ea. Qty. 10	DESIGNER'S KITS (5 of each model)	
				K1	K2
HFCN-650+	710-2490	480	1.99	•	•
HFCN-740+	780-2800	550	1.99	•	•
HFCN-880+	950-3200	640	1.99	•	•
HFCN-1200+	1220-4600	910	1.99	•	•
HFCN-1300+	1400-5000	930	1.99	•	•
HFCN-1320+	1400-5000	1060	1.99	•	•
HFCN-1500+	1600-5500	1250	1.99	•	•
HFCN-1600+	1650-5000	1290	1.99	•	•
HFCN-1760+	1900-5500	1230	1.99	•	•
HFCN-1810+	1950-4750	1480	1.99	•	•
HFCN-1910+	2000-5200	1400	1.99	•	•
HFCN-2000+	2260-6250	1530	1.99	•	•
HFCN-2100+	2200-6000	1530	1.99	•	•
HFCN-2275+	2450-7000	1770	1.99	•	•
HFCN-2700+	2650-6500	1800	1.99	•	•
▲ HFCN-2700A+	2900-8700	2150	2.99		•
▲ HFCN-3100+	3400-9900	2450	2.99		•
▲ HFCN-3500+	3900-9800	2800	2.99		•
▲ HFCN-3800+	4250-10000	3200	2.49		•
▲ HFCN-4400+	5000-10100	3500	2.99		•
▲ HFCN-4600+	5000-11000	3800	2.99		•
▲ HFCN-5050+	5500-10000	4200	2.99		•
▲ HFCN-5500+	6000-11500	4500	2.99		•
▲ HFCN-7150+	7900-11000	6150	2.99		•
▲ HFCN-8400+	9000-13000	6000	2.99		•

Total number of units in kit: 40 50

HFCN Models: -3800+, -5500+, -8400+ Patent Pending

7 Designer's Kits Available (see table):  
Order kits by prefix (K1, K2, etc.)  
Followed by -LFCN+ or -HFCN+  
Example: K1-LFCN+



HFCN+ & LFCN+ ▲HFCN+

## LOW PASS FILTERS (LFCN)

Model	Passband MHz	Stopband MHz (Loss >20 dB) Min.	Price \$ ea. Qty. 10	DESIGNER'S KITS (5 of each model)				
				K1	K2	K3	K4	K5
LFCN-80+	DC-80	200	3.99					
LFCN-95+	DC-95	230	3.99					
LFCN-105+	DC-105	250	3.99					
LFCN-120+	DC-120	280	3.99					
LFCN-160+	DC-160	330	2.99					
LFCN-180+	DC-180	370	2.99					
LFCN-190+	DC-190	400	2.99					
LFCN-225+	DC-225	460	2.99					
LFCN-320+	DC-320	560	2.99					
LFCN-400+	DC-400	660	2.99					
LFCN-490+	DC-490	800	2.99					
LFCN-530+	DC-530	820	2.99					
LFCN-575+	DC-575	900	2.99					
LFCN-630+	DC-630	1000	2.99					
LFCN-800+	DC-800	1400	1.99					
LFCN-900+	DC-850	1275	1.99					
LFCN-1000+	DC-1000	1550	1.99					
LFCN-1200+	DC-1200	1865	1.99					
LFCN-1325+	DC-1325	2100	1.99					
LFCN-1400+	DC-1400	2015	2.99					
LFCN-1450+	DC-1450	2025	2.99					
LFCN-1500+	DC-1500	2100	2.99					
LFCN-1525+	DC-1525	2040	2.99					
LFCN-1575+	DC-1575	2175	2.99					
LFCN-1700+	DC-1700	2375	1.99					
LFCN-1800+	DC-1800	2425	2.99					
LFCN-2000+	DC-2000	3000	1.99					
LFCN-2250+	DC-2200	2900	1.99					
LFCN-2400+	DC-2400	3600	1.99					
LFCN-2500+	DC-2500	3675	1.99					
LFCN-2600+	DC-2600	3750	1.99					
LFCN-2750+	DC-2750	4000	1.99					
LFCN-2850+	DC-2800	4000	1.99					
LFCN-3000+	DC-3000	4550	1.99					
LFCN-3800+	DC-3900	6000	2.99					
LFCN-4400+	DC-4400	6700	2.99					
LFCN-5000+	DC-5000	6850	1.99					
LFCN-5500+	DC-5500	7200	1.99					
LFCN-5850+	DC-5850	7600	1.99					
LFCN-6000+	DC-6000	8500	1.99					
LFCN-6400+	DC-5400	8300	1.99					
LFCN-6700+	DC-6700	9300	1.99					
LFCN-7200+	DC-7200	9500	1.99					

Total number of units in kit: 35 60 55 90 65

LFCN Models: U.S. Patent 6,943,646 except LFCN-800+, -1325+, -2000+ & -2400+.

**Mini-Circuits®**  
ISO 9001 ISO 14001 CERTIFIED

**ALL NEW**  
**minicircuits.com**

P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661 For detailed performance specs & shopping online see Mini-Circuits web site



The Design Engineers Search Engine Provides ACTUAL Data Instantly From MINI-CIRCUITS At: [www.minicircuits.com](http://www.minicircuits.com)

**RF/IF & MICROWAVE COMPONENTS**

418 RevC

Visit <http://mwj.hotims.com/11713-88> or use RS# 88 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)

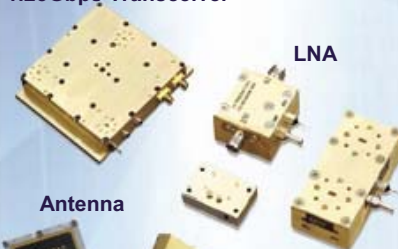
## Millimeter-Wave Point to Point Radiolink



- 70GHz E-Band
- 60GHz V-Band
- GbE/ Fast Ethernet
- LC/SC Interface
- 1ft, 2ft Antenna

## Millimeter-Wave Components

### 1.25Gbps Transceiver



LNA

Antenna

### Power Amplifiers



### Other Components

- Oscillator
- Mixer
- Diplexer
- Filter
- Transitions/Adaptor
- Attenuator

ISO9001 Certified  
RoHS Compliant



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

Tel) +82-52-288-7550

Fax) +82-52-288-7551

[sales@comotech.com](mailto:sales@comotech.com)

mm wide and the wide sections are 2.5 mm. Conventional, 1.5 mm wide, unstepped quarter wave 1700 MHz resonators on this substrate are 20 mm long. Folding also conserves space. The grid cells are  $0.25 \times 0.5$  mm. This structure is poorly modeled using circuit theory transmission line models. However, it is a classic candidate for design using the general procedure, with EM simulation to find resonator couplings and end-resonator loaded Qs. Plotted in **Figure 10** are the couplings and loaded Qs determined by EMPOWER. Notice that this SIR filter has two types of resonator couplings. Resonators one and two have lines that are open-ended adjacent to each other. The resonator coupling for this configuration is plotted in green, with the independent horizontal axis being edge-to-edge resonator spacing in millimeters. Resonators two and three have via grounded lines adjacent to each other. This coupling is plotted in blue. Plotted in red is the end resonator, singly loaded, Q vs. length of coupling line from the bottom edge of the input line to the centerline of the via. The left/right asymmetry of the SIR resonator precludes a doubly terminated measurement of the loaded Q, so an alternative method is used. For the EM simulation, a resonator is singly loaded and the resistivity of the metal is increased until the effective parallel loss resistance loads the resonator to a degree equal to the load termination. This occurs when the input return passes through the center of the Smith chart, as shown in **Figure 11**. The frequencies of the 3.01 dB return loss are then used in Equation 11 to find the singly terminated end-resonator loaded Q. For simulated coupling line lengths varying from two to eight millimeters, the required resistivity varies from 4.5 to 120. For the figure, a coupling line length of 5 mm and a resistivity of 75 were used. The input and output termination coupled-line transformers have the effect of slightly increasing the frequency of the end resonators. This was compensated empirically by adding small areas of metal to the end resonators, while examining the EM simulated response. The final SIR filter transmission and input return loss responses, computed by EMPOWER, are given in **Fig-**

**ure 12**. This filter occupies only about 40 percent of the space required by a conventional inter-digital structure. The general procedure and EM simulation are effective tool mates for quick and accurate design of filters with structures that are difficult to model analytically. ■

## References

1. K.V. Puglia, "A General Design Procedure for Bandpass Filters Derived from Low Pass Prototype Elements," *Microwave Journal*, Part I, Vol. 43, No. 12, December 2000, pp. 22-38; Part II, Vol. 44, No. 1, January 2001, pp. 114-134.
2. EMPOWER Manual, Agilent Technologies Inc.
3. S. Yamashita and M. Makimoto, "Miniaturized Coaxial Resonator Partially Loaded with High Dielectric-constant Microwave Ceramics," *Transactions on Microwave Theory and Techniques*, Part I, Vol. 31, No. 9, September 1983, pp. 697-703.
4. R. Rhea, *HF Filter Design and Computer Simulation*, Noble Publishing, Raleigh, NC, pp. 116-121.



**Randall Rhea** is a graduate of the University of Illinois (1969) and Arizona State University (1973). His thesis was construction of an earth station that monitored Apollo 16 & 17 Unified S-band signals from the moon. He worked briefly at

the Boeing Co. and Goodyear Aerospace and for 14 years at Scientific-Atlanta, where he became principal engineer. He founded Eagleware Corp. in 1985, recently acquired by Agilent Technologies, and Noble Publishing in 1994, recently acquired by SciTech Publishing. He has authored numerous technical papers, tutorial CDs and the books *Oscillator Design and Computer Simulation* and *HF Filter Design and Computer Simulation*. He has taught oscillator and filter design techniques to over 1000 engineers through full-day seminars at trade shows, the Georgia Institute of Technology and corporations. His hobbies include antiques, historical properties, astronomy and amateur radio (N4HI). He and his wife Marilyn have two adult children and reside near Thomasville, GA.

Visit [www.mwjjournal.com](http://www.mwjjournal.com) to read "Technology Enables New Components," Randy Rhea's Cover Feature that appeared in the November 2006 issue of *Microwave Journal*.



# EM Research, Inc.

The Ultimate Source for Miniature Frequency Synthesizers

## PHASE-LOCKED OSCILLATORS, FREQUENCY SYNTHESIZERS

### *Featuring SLX Series Synthesizer*

#### **Product Features:**

- 0.5" Square Package
- Complete Synthesizer
- Buffered Output (+ 7 dBm)
- Low Power (3.3 Vdc)
- Fixed Frequency Available



#### **General Characteristics:**

- Frequency Range: 50 – 4200 MHz
- Step Size: 25 KHz – 10 MHz
- Bandwidth ( $f_c = 1$  GHz): Up to 50%
- External Frequency Reference: 5 – 125 MHz
- Surface-Mount Package 0.50" x 0.50" x 0.15"  
(12.7 mm x 12.7 mm x 3.8 mm)

### **QUALITY • CONSISTENCY • PERFORMANCE**

- *Cutting-edge performance, ultra low phase noise and jitter.*
- *Custom designs available to meet your specific applications.*
- *High volume and short-run capabilities.*
- *We ARE your signal source solution!*

Visit <http://mwj.hotims.com/11713-43> or use RS# 43 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)

EM Research, Inc. • P.O. Box 10430, Reno, NV 89510-0430 • 1301 Corporate Blvd., Reno, NV 89502  
TEL: (775) 345-2411 • FAX: (775) 345-1030 • [www.emresearch.com](http://www.emresearch.com) • email: [sales@emresearch.com](mailto:sales@emresearch.com)

# CONCEPT AND METHOD OF HIGH EFFICIENCY IN A PRECISION KA-BAND SUBMINIATURE COAXIAL CONNECTOR

*This article presents the design approach and test results of a Ka-band narrow flange receptacle (NFR), subminiature version A (SMA) connector based on transmission line theory, involving multi-step impedances and air-layer characteristics to increase its maximum frequency of operation. In order to increase its frequency performance, the connector is designed with a dual outward form (a hook structure), a thick outer conductor wall and a very thin inner pin. The return loss increment due to the hook and multi air-layer structures is minimized to 2 and 1.5 dB, respectively. A VSWR of less than 1.2 is obtained from DC to 30 GHz and the connector performance is stable from room temperature to 120°C.*

During the late 1950s and early 1960s, 7 mm coaxial transmission lines with standard SMA connectors were only used at frequencies between 10 and 12 GHz. In the mid-1960s, the US Department of Commerce established the Joint Industry Research Committee for the Standardization of Miniature Precision Coaxial Connectors (JIRF/SMPCC). The result of that effort yielded a voluntary product standard in 1972.<sup>1,2</sup> The air transmission line size was reduced to 3.5 mm to extend the mode-free operation of that line to 36 GHz. With increasing demand for high speed data transmission rates, the operating frequencies of commercial communication systems are currently increasing to achieve wider bandwidth.<sup>3</sup> Consequently, the development of microwave products was undertaken in the United States, Europe and

Asia. Korea also developed microwave amplifiers, oscillators and mixers. In this article, a Ka-band connector is designed on the basis of transmission line theory and then fabricated. In order to meet the Ka-band operating frequency range, a multi-step impedance technique, utilizing air layers, is applied. Moreover, for commercial purposes, the connector must be able to operate at high temperature in order that the hook structure and step transition satisfy military (MIL) specifications.

---

JAE-HO YOON, WON-YONG CHO,  
AH-RAH KOH, SEUNG-JUN LEE,  
BHANU SHRESTHA, GARY P. KENNEDY  
AND NAM-YOUNG KIM  
*Kwangwoon University  
Seoul, Korea*





## Full selection of laminates and prepreg for RF/Microwave and High Speed Digital applications.

### Dk AND Df VALUES AT 10 GHz\*

- IS640-280 = Dk 2.80, Df 0.0025
- IS640-300 = Dk 3.00, Df 0.0032
- IS640-320 = Dk 3.20, Df 0.0032
- IS640-325 = Dk 3.25, Df 0.0032
- IS640-333 = Dk 3.33, Df 0.0035
- IS640-338 = Dk 3.38, Df 0.0035
- IS640-345 = Dk 3.45, Df 0.0035

\* All are available in 0.020", 0.030" and 0.060" thicknesses.

IS640 laminate and prepreg material is a unique formulation for the RF/Microwave and High Speed Digital markets. IS640 exhibits stable electrical properties over a broad frequency range of 2 to 20 GHz. Produced with stringent thickness and electrical tolerances, IS640 provides designers with consistent line impedance.

IS640 is available in multilayer core thicknesses (0.0025" - 0.018") and thicker core (0.020", 0.030" and 0.060") for RF and Microwave applications. Standard panel sizes are available, providing a complete materials package solution.

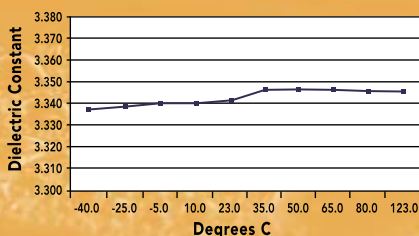
### IS640 MULTILAYER AVAILABILITY

PREPREG GLASS STYLES		PREPREG GLASS STYLES	PRESSED THICKNESS NOMINAL
0.0025	0.0080	106	0.0030"
0.0030	0.0100	1080	0.0040"
0.0040	0.0120	2113	0.0043"
0.0050	0.0140	3070	0.0048"
0.0060	0.0160	2116	0.0054"
0.0066	0.0180	1652	0.0060"

### IS640 PRODUCT STRENGTHS

- Superior Signal Integrity - stable Dk Df 2 - 20 GHz
- Customized Dk on 0.020", 0.030" and 0.060" thicknesses, Dk available = 2.80, 3.00, 3.20, 3.25, 3.33, 3.38 and 3.45
- Utilizes Standard E-glass
- Full compliment of multilayer cores from 0.0025" to 0.018"
- 6 glass styles available for prepreg
- No ceramic filler in the base resin
- Good drilling and routing performance
- Thermal coefficient of Dk, dielectric constant, = 55 ppm/°C from - 40°C to 125°C
- Thermal coefficient of Df, loss tangent, = 6 ppm/°C from - 40°C to 125°C
- Very good power handling results
- Compatible with Isola FR406, IS410, 370HR, IS415, FR408 and IS620 for hybrid applications

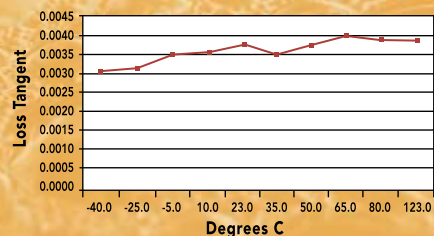
#### TCK DK



IS640-338 55 ppm/deg.C

Epoxy based systems are at 300 to 400 ppm/deg C level

#### TCK LOSS TANGENT



IS640-338 6 ppm/deg.C

Low TCK - Df ppm level very good for Power Handling

The data, while believed to be accurate and based on analytical methods considered to be reliable, is for information purposes only. Any sales of these materials will be governed by the terms and conditions of the agreement under which they are sold.

\* Isola utilizes the IPC-TM650-2.5.5.5 Stripline Resonator to test material with thickness of 0.030 and above as a means of determining a nominal value for dielectric constant and loss tangent test frequency is set at 10 GHz. Please note that for laminate dielectric thickness below .030 the test method that is utilized to determine the Dk and Df values is referred to as the Bereskin Stripline Resonator method. The Bereskin Stripline Resonator test method lends itself to the test and measurement of Dk and Df values of thinner dielectric laminate materials as those that would fall below .030. In the event we are requested to test the Dk and Df of a dielectric laminate that is below .030 per the IPC-TM650-2.5.5.5 test method we would employ a building block stack method to construct the test specimens in order to arrive at a laminate dielectric thickness that would be sufficient for the test to be conducted accurately. The effect of air gaps between the dielectric test specimens would then be back calculated out of the equation to provide for a more accurate result. Departures from these test methods and/or frequency may produce different values. Isola ensures the consistency and repeatability of the property sets in the product that we produce, however we encourage prospective users to conduct a thorough evaluation with appropriate modeling software during the design process to determine the value sets that are best suited for his/her application.

Isola Corp. 3100 West Ray Rd., Suite 301, Chandler, AZ 85226, (800) 845-2904, [www.isola-group.com](http://www.isola-group.com)

Visit <http://mwj.hotims.com/11713-60> or use RS# 60 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)

**isola**

## IMPEDANCE OF THE COAXIAL LINE

The common structure of a connector is similar to a coaxial line, as shown in **Figure 1**. A coaxial line propagates in a TEM mode and is characterized by an inner (a) and outer (b) radius. The primary parameters may be rigorously derived for a coaxial line that is uniformly filled with a dielectric material. The dielectric material has a relative permittivity  $\epsilon_r$  with respect to the free space value,  $\epsilon_0 = 8.854 \times 10^{-12} \text{ Fm}^{-1}$ . The coaxial line supports radial electric fields and circumferential magnetic fields, with a longitudinal current flow in the conductors.

For the purpose of understanding the impedance characteristics of the air line section of precision coaxial connectors, a lumped constant circuit representation of a low loss coaxial line is a convenient starting point. The general equation for the low loss coaxial line characteristic impedance is<sup>3</sup>

$$Z_0' = \sqrt{\frac{R + j\omega L}{G + j\omega C}} \quad (1)$$

where

$Z_0'$  = characteristic impedance

$R$  = intrinsic resistance (of the conductor) per unit length

$G$  = dielectric conductance per unit length

$L$  = inductance per unit length

$C$  = capacitance per unit length

Considering the special case where  $R$  and  $G$  are both equal to zero, Equation 1 reduces to

$$Z_0' = \sqrt{\frac{L}{C}} \quad (2)$$

At microwave frequencies, the inductance per unit length is very nearly equal to the external inductance per unit length and the capacitance per unit length can be calculated using<sup>2,3</sup>

$$L = \frac{\mu}{2\pi} \ln \frac{b}{a} \quad C = \frac{2\pi\epsilon}{\ln \frac{b}{a}} \quad (3)$$

These inductance and capacitance values depend on the ratio of the outer to inner conductor radii of the coaxial cable,  $b/a$ .  $\mu$  is the permeability of the non-magnetic material and  $\epsilon$

is the dielectric constant of the insulator.

Also, the effective resistance per unit length ( $R$ ) of the coaxial line is given by<sup>4-6</sup>

$$R = \frac{R_s}{2\pi} \left( \frac{1}{a} + \frac{1}{b} \right) \quad R_s = 1 / \sigma \delta \quad (4)$$

where

$R_s$  = surface resistance of the coaxial line

$\sigma$  = metal conductivity of the coaxial line

$\delta$  = skin depth

For impedance matching to the measurement equipment, the coaxial line should have a characteristic impedance<sup>3-6</sup>

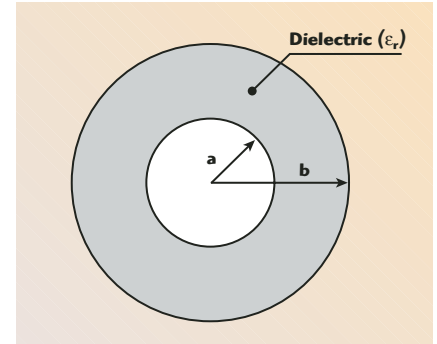
$$Z_0 = 60 \sqrt{\frac{\mu}{\epsilon}} \ln \frac{b}{a} \text{ [ohms]} \quad (5)$$

## DESIGN OF A KA-BAND NARROW FLANGE SMA CONNECTOR

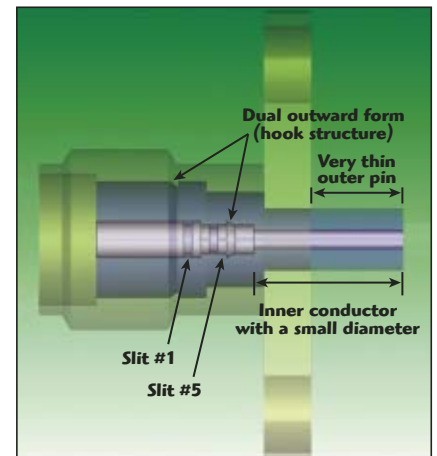
Subminiature coaxial connectors are commonly used in low power applications at higher microwave frequencies, particularly in the Ku-, K- and Ka-bands. In this article, the Ka-band SMA connector is designed using a Teflon-filled 50  $\Omega$  coaxial line. The structure of the Ka-band SMA connector is shown in **Figure 2**. This SMA connector consists of a central conductor, a dielectric and the body.<sup>4</sup> The SMA connector is designed to operate in the Ka-band and is capable of providing a much higher operating frequency, free of higher orders, using arbitrary surface discontinuities inside the connector, as shown in **Figure 3**. In addition, adding an air layer and a step transition to the connector enhances its high frequency performance.

The connector used in the measuring equipment uses an air-layer structure. Although the mechanical strength of the connector is

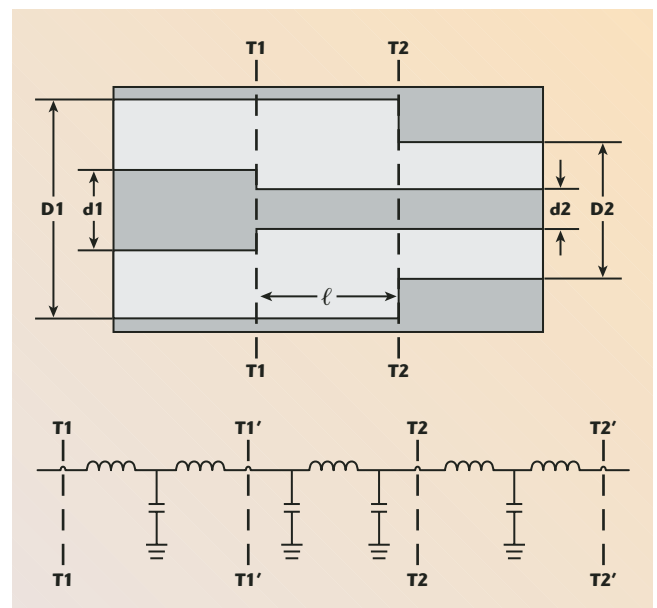
weak, it is better than having a dielectric layer structure at high temperature, since the rigid plastic supporting the center pin is very thin. This problem was solved by using an air layer inside the PTFE dielectric and fixing the center pin. Thus, the narrow



▲ Fig. 1 Cross-section of a coaxial line.



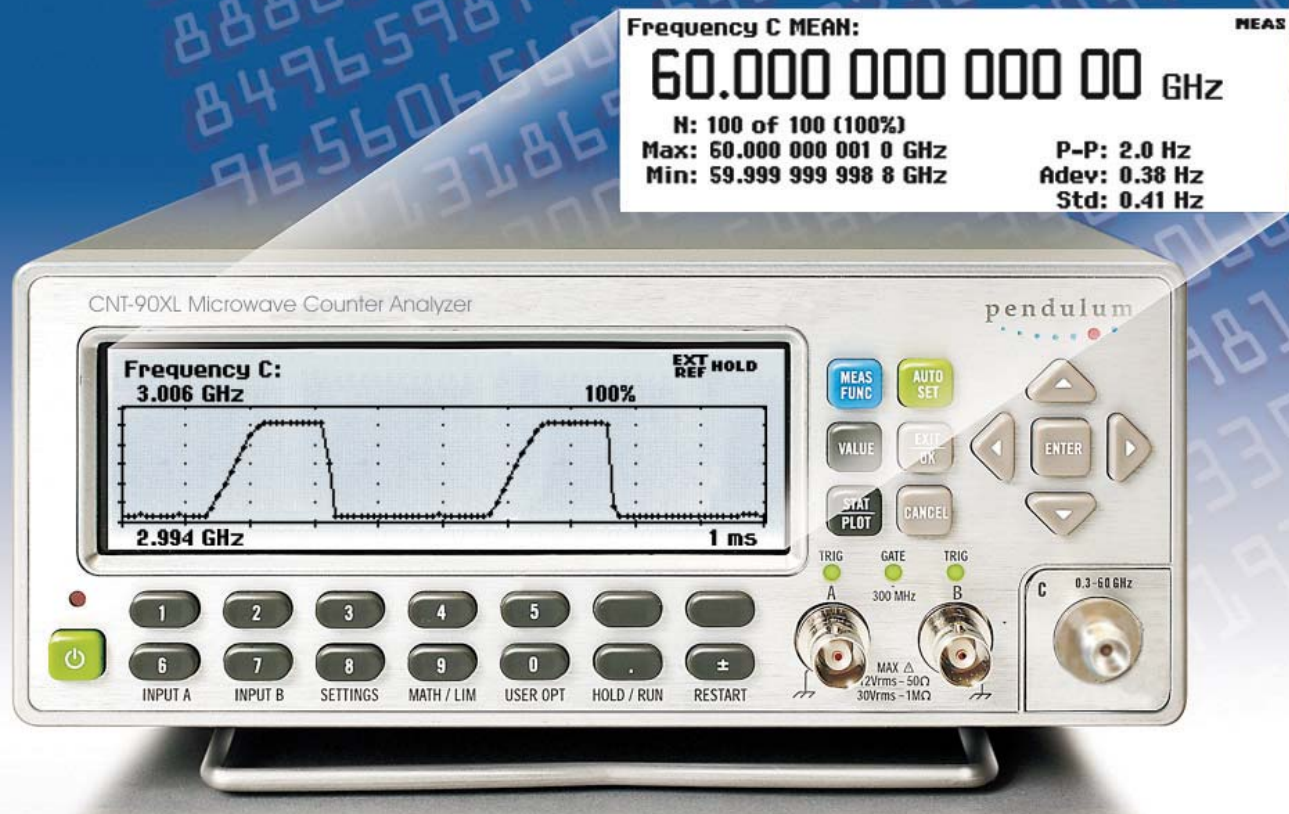
▲ Fig. 2 Cross-sectional view of the Ka-band SMA connector.



▲ Fig. 3 Equivalent circuit of a coaxial line compensated with the length  $\ell$  of the discontinuity.



# TRADE-IN your old MICROWAVE COUNTER



Get up to **\$5000** off when buying a  
**CNT-90XL** Microwave Counter/Analyzer

Please visit [www.pendulum-instruments.com/tradein.php](http://www.pendulum-instruments.com/tradein.php)

#### ULTRAHIGH RANGE, SPEED & RESOLUTION

- 27, 40, 46 or 60 GHz frequency range
- 250k meas. / sec. of frequency or power

#### VERSATILITY

- Frequency or power, CW or burst to 60 GHz
- All Timer / Counter functions to 300 MHz

#### FAST ANALYSIS

- Modulation domain analysis to 60 GHz
- View FM or AM on graphical display
- Frequency or power stability, settling or drift

#### AFFORDABLE

- The world's best Timer / Counter included!

#### Pendulum Instruments

- Experts in Time & Frequency Calibration, Measurement and Analysis  
Phone: +1 510-428-9488 (US), +46 8 598 510 55 (Int.)  
[www.pendulum-instruments.com](http://www.pendulum-instruments.com)

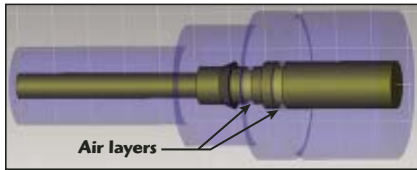
pendulum  
Incorporating XL Microwave

flange SMA connector has a good Ka-band frequency performance, due to

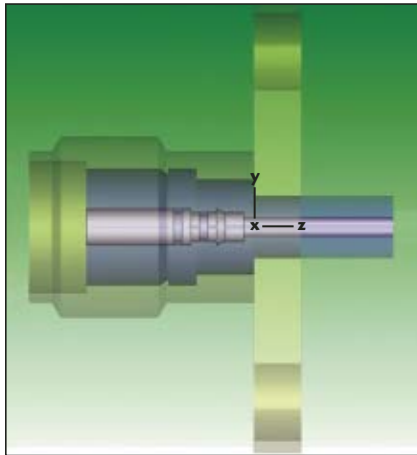
the multi-air and multi-step layers. Furthermore, for commercial pur-

poses, this connector is designed to have a guaranteed operating temperature up to 120°C. Four mechanical structures were applied in the design of the connector. First, a dual structure having a main body and a cover was used in order to avoid separation of the dielectric from the connector. Second, the hook structure in the center conductor is used to prevent separation between the dielectric and the inner conductor. Third, a thick outer conductor wall is used. This also provides great strength to ensure reliability in repeat matings. Finally, a very thin inner pin was used to obtain high frequency performance, which is a result of the high impedance line section.

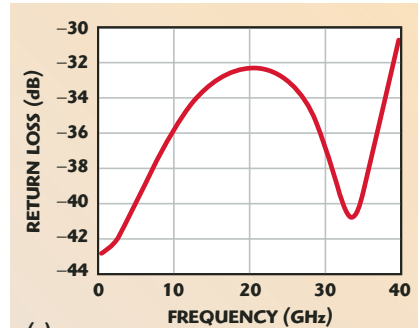
When the stepped-discontinuity structure is added, the inductance per unit length of the transmission line is decreased and the capacitance per unit length is increased. The higher order cut-off frequency was also increased as a result of the discontinuity. To avoid the problem of having an infinite VSWR, the arbitrary length between T1 and T2 should be as long as possible. The length  $l$  of the discontinuity in the transmission line is a very important parameter controlling the VSWR characteristics of the connector, as it is a factor in deciding the discontinuity size for 50  $\Omega$  matching.<sup>4</sup>



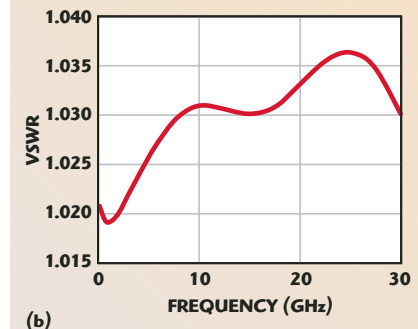
▲ Fig. 4 Structure of the inner conductor of the Ka-band SMA connector.



▲ Fig. 5 Inner structure of the Ka-band SMA connector.

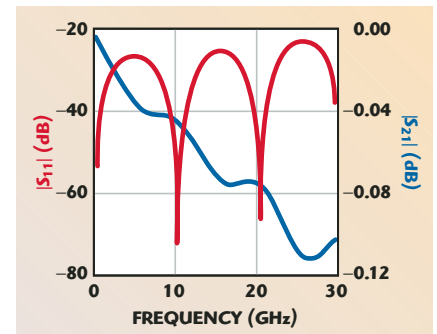


(a)

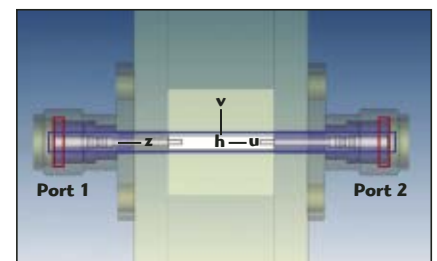


(b)

▲ Fig. 6 Simulated return loss (a) and VSWR (b) of the Ka-band SMA connector.



▲ Fig. 7 Simulation results for the microstrip line used in the measurements.



▲ Fig. 8 Test fixture for the simulation and measurement of the Ka-band SMA connector.

# Ultra Low Phase Noise

## 1 MHz to 18 GHz



▶ **Blue Tops RF Modules**



▶ **Synthesizers & Systems**



▶ **Military & Space**



▶ **Crystal Oscillators**



**Wenzel Associates, Inc.**  
"Quietly the Best"



▶ **Testing Services**



**CROVEN CRYSTALS**  
Wenzel International, Inc.



▶ **Crystals**

**Wenzel Associates, Inc.**  
(512) 835-2038  
Austin, Texas  
[www.wenzel.com](http://www.wenzel.com)

**Croven Crystals**  
(905) 668-3324  
Whiteby, Ontario, Canada  
[www.croven crystals.com](http://www.croven crystals.com)



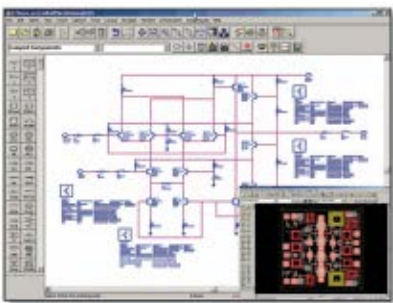


Handwritten equations on a napkin, including  $|R_1 + Z_{in}|^2 = \frac{|V_2(j\omega)|^2}{R_2}$ ,  $\left| \frac{V_2(j\omega)}{j\omega} \right|^2 = |T(j\omega)|^2 = \frac{R_2 R_{in}}{|R_1 + Z_{in}|^2}$ , and  $|T(j\omega)|^2 = 1 - 4 \frac{R_1}{R_2} |T(j\omega)|^2$ .

# A team of absolute value

Agilent EEsof EDA has the most RF software developers

With hundreds of RF software developers and partners, Agilent works the high frequency EDA equation like no other company.



Eagleware-Elanix is now part of Agilent EEsof EDA.

Our 25-year experience in high-frequency design began with Agilent RF engineers creating design software for their own use. The result has been the absolutely broadest selection of capabilities to meet both technical and budget needs of high-frequency designers. And as our team grows you can expect upgrades and new technologies proportional to our size – all focused on helping you tackle the latest design challenges and communication standards.

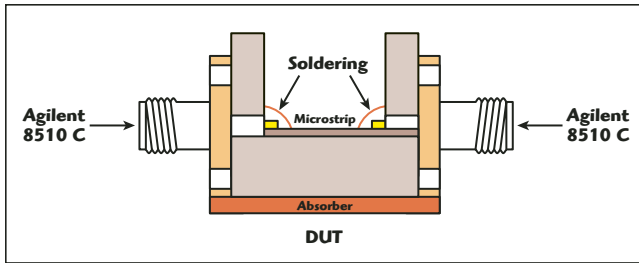
Now the Agilent EEsof EDA team has grown larger with the addition of Eagleware-Elanix and its own team of experts. Combine this with technical support that consistently ranks the best in the high-frequency EDA industry – and you can be confident that you're with the right team.

Let the world's largest team of RF EDA experts help you find the right solution for your needs and budget. Visit [www.agilent.com/find/eesof-innovations](http://www.agilent.com/find/eesof-innovations) for details

[www.agilent.com/find/eesof-innovations](http://www.agilent.com/find/eesof-innovations)



**Agilent Technologies**



▲ Fig. 9 Test fixture for the Ka-band SMA connector.

## SIMULATION RESULTS

In this article, the degradation in RF performance of the connector is minimized by simulating the multi-air and hooked structure using a 3D simulator from a Computer Simulation Technology (CST) tool based on the finite element method (FEM). The inner conductor, shown in **Figure 4**, was fabricated with two air layers to enhance the high frequency performance of the connector. **Figure 5** shows the inner structure of the Ka-band NFR SMA connector. Generally, when the coaxial line uses an air dielectric, the mechanical strength of the connector is weak. To solve this problem, a PTFE dielectric was used. As shown in **Figure 6**, the simulated return loss and VSWR increase as the frequency increases, but they are less than  $-32$  and  $1.04$  dB, respectively, in the frequency range from DC to 30

GHz. **Figure 7** shows the simulation results for the microstrip line used in the measurements. The microstrip line was 10 mm long and 1.3 mm wide, made on a Teflon PCB for high frequency performance. **Figure 8** shows a cross-sectional view of the test fixture used for the simulation and measurement of the Ka-band SMA connector using a microstrip line. The interface between the inner conductor and the Teflon dielectric is in accordance with MIL-STD-348. Furthermore, its performance is better than for similar RF connectors, matching the military standards MIL-PRF-39012 and MIL-C-83517, thereby enabling it to be treated as a microwave component.

## MEASUREMENT RESULTS

**Figure 9** shows the test fixture used to measure the Ka-band SMA connector. It uses a microstrip line

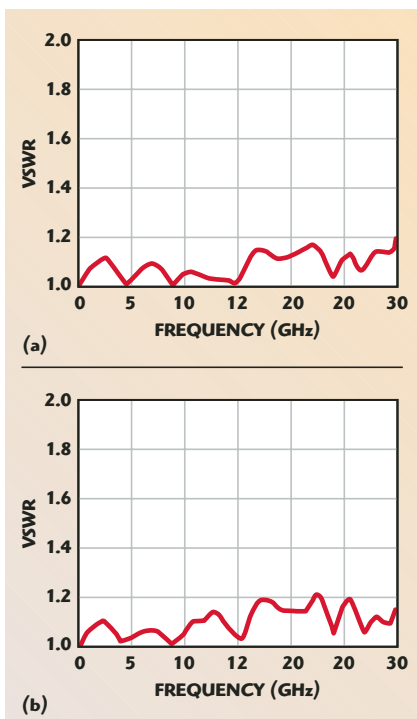
with a width of 1.3 mm and a length of 10 mm. The dimensions of the microstrip line were optimized after testing. The measurement was performed using a network analyzer (HP 8510C). **Figure 10** shows the measured VSWR as a function of frequency at room temperature and after being subjected to  $120^{\circ}\text{C}$  for an hour. The VSWR near 30 GHz is 1.19; therefore, the connector is expected to be useful up to 30 GHz. Furthermore, after subjecting the connector to a temperature of  $120^{\circ}\text{C}$  for one hour, the measurement was performed again to qualify it for use as a commercial product. Very little difference in VSWR was recorded between the two tests. Therefore, its RF performance has been shown to be stable with temperature. **Figure 11** shows photographs of the test fixture and of the fabricated connector.

## CONCLUSION

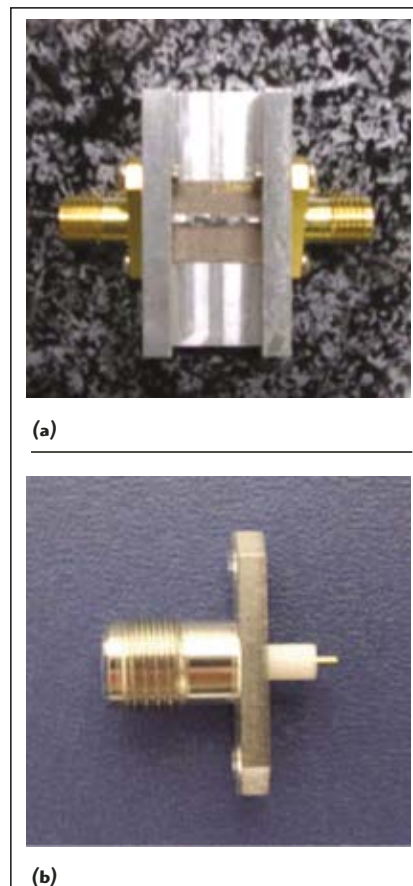
In this article, a reliable miniature SMA connector for use at Ka-band was designed and fabricated using the characteristic impedance of a coaxial line, a discontinuous transmission line, and the characteristics of dielectric bead-air line interfaces. The VSWR is less than 1.2 from DC to 30 GHz and was realized by adopting a slit construction and by optimizing the conductor pattern on a PCB. Its reliability is confirmed by electrical and environmental tests. The use of this SMA connector is possible in Ka-band RF module or system applications. ■

## ACKNOWLEDGMENTS

This research was supported by the Ministry of Information and Communication (MIC), Korea, under the Information Technology Research Center (ITRC) support program supervised by the Institute of Information Technology Assessment (IITA) (IITA-2005-(C1090-0502-0034)), by a research grant from Kwangwoon University in 2006, by the Realistic 3D-IT Research Program of Kwangwoon University under the National Fund from the Ministry of Education and Human Resources Development (2005), and has been performed through the Support Project of Mission Telecom Co. (MTC), Dongjin-TI Co. and A&P Technology Co.



▲ Fig. 10 Measured VSWR of the Ka-band SMA connector (a) at room temperature and (b) after one hour at  $120^{\circ}\text{C}$ .



▲ Fig. 11 The test fixture (a) and the fabricated Ka-band SMA connector (b).



# S. M. ELECTRONICS

**ATTENUATORS 0-50GHZ OVER 40,000 IN STOCK**

					
SA50 \$288.00 2.4MM 50GHZ	SA40 \$132.00 2.92MM 40GHZ	SA26B \$75.00 SMA 27GHZ	SA18E \$30.50 SMA 18 GHZ	SA18H \$30.50 SMA 18 GHZ	SA6H \$22.00 SMA 6GHZ
					
SA3 \$18.00 SMA 3GHZ BRASS	SA18S5W \$47.00 SMA 18GHZ 5W	SA6S5W \$43.00 SMA 6GHZ 5W	SA6S10W \$88.00 SMA 6GHZ 10W	SA18S10W \$122.00 SMA 18GHZ 10W	SA3T \$29.00 TNC 3GHZ 2W
					
SA18N \$47.00 N 18GHZ	SA3NS \$26.00 N 3GHZ	SA6N5WA \$45.00 N 6GHZ 5W	SA18N10W \$123.00 N 18GHZ 10W	SA3N50 \$217.00 N 3GHZ 50W	SA3N100 \$319.00 N 3GHZ 100W

**TERMINATIONS 0-50GHZ OVER 30,000 IN STOCK**

					
ST5035 \$290.00 2.4MM 50GHZ	ST4010 \$125.00 2.92MM 40GHZ	ST2650 \$27.50 SMA 27GHZ	ST1819 \$10.50 SMA 18GHZ	ST1850 \$22.00 SMA 18GHZ 2W	STN1811 \$23.00 N 18GHZ

**DC BLOCKS, EQUALIZERS, ADAPTERS, COUPLERS, CABLES**

					
SD3238 \$47.00 DC BLOCK SMA 5KHZ-23GHZ	SD3074 \$51.00 DC BLOCK N .01-18 GHZ	EQUALIZERS 1-18 GHZ	SM3244 \$189 2.92 F/F > 550 ADAPTER TYPES	SMC4030 \$89 COUPLER 800-2500MHZ 6-30DB	CABLES SMA, N, 2.92 OVER 30,000 IN STOCK



Visit <http://mwj.hotims.com/11713-123> or use RS# 123 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)

FAST DELIVERY!

**WWW.SMELECTRONICS.US 1-800-715-4396**

460 S HIGHWAY 5 FAIRVIEW, TX 75069 1-800-715-4396 FAX: 972-984-1218 EMAIL: SALES@SMELECTRONICS.US

## References

1. H.Y. Yoo and J.H. Yoon, "A High Durability Ka-band Spark-plug SMA Connector," *Digest of the 2004 Microwave and Propagation Fall Conference in KEES of the IEEE MTT/AP/EMC Korea Chapter*, Vol. 14, No. 1, November 2004, pp. 119-122.
2. A.E. Sanderson, "A New High Precision Method for the Measurement of the VSWR of Coaxial Connectors," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 9, No. 6, November 1961, pp. 524-528.
3. P.A. Rizzi, *Microwave Engineering Passive Circuits*, Prentice Hall, Upper Saddle River, NJ, 1988.
4. N.J. Sladek, "Fundamental Considerations in the Design and Application of High Precision Coaxial Connectors," *IRE International Convention Record*, Vol. 13, Part 5, March 1965, pp. 182-189.
5. T.E. MacKenzie, "Recent Advances in the Design of Precision Coaxial Standards and Components," *IRE International Convention Record*, Vol. 13, Part 5, March 1965, pp. 190-198.
6. B.O. Weinschel, "Standardization of Precision Coaxial Connectors," *Proceedings of the IEEE*, Vol. 55, No. 6, June 1967, pp. 923-932.



**Jae-Ho Yoon** received his BS degree in electronic materials of engineering from Kwangwoon University, Korea, in 2004. He was an exchange student in the 2<sup>nd</sup> IT Global Wireless Communication Course at the University of California San Diego (UCSD) from February to August 2004. He is currently pursuing his MS degree. His research interests include RFIC/MMIC harmonic noise frequency filtering VCOs, mixers, LNAs and CDMA wireless systems design.



**Won-Yong Cho** received his BS degree in electronics engineering from Kwangwoon University, Korea, in 2006. He is pursuing his MS degree and works at the RFIC Center at Kwangwoon University as a 3D RF tool education teaching assistant.



**Ah-Rah Koh** received her BS degree in electronics engineering from Kwangwoon University, Korea, in 2005. She is currently pursuing her MS degree and works at the RFIC Center at Kwangwoon University as an MMIC tool education teaching assistant. Her research interests include RFIC/MMIC VCOs, LNAs and CDMA wireless system design.



**Bhanu Shrestha** received his BS and MS degrees in electronic engineering from Kwangwoon University, Korea, in 1999 and 2004, respectively. His research interests include RFIC/MMIC/RFID circuits and system design.



**Gary P. Kennedy** received his BSc degree in applied physics from Liverpool John Moores University in 1988 and his PhD degree in solid-state physics/micro-electronics from the University of Liverpool in 1993. After completing his studies, he worked as a researcher and research fellow at the University of Liverpool and Southampton, respectively. In January 2000, he began working as a reliability engineer at the European Semiconductor Manufacturing Ltd., UK. He is currently a research professor in the ITRC RFIC Center of Kwangwoon University, Korea. His research interests include SiGe RFIC.



**Nam-Young Kim** received his BS degree in electronic engineering from Kwangwoon University, Korea, in 1987, and his MS and PhD degrees from the State University of New York at Buffalo in 1991 to 1994, respectively. He was a research scientist of CEEM at SUNY, Buffalo, in 1994. Since September 1994, he has been a professor in the department of electronic engineering at Kwangwoon University, Korea. He received M.Div and DCE degrees in 2001 and 2005, respectively. He has been director of the RFIC Education and Research Center since March 1998. His research interests include semiconductor device modeling, ASIC, RFIC and MMIC design.

## Fixed and Adjustable Gain Equalizers Operate 26 - 40 GHz

### Ka Band Equalizers



An ISO 9001 Certified Company



Visit: [www.aeroflex-inmet.com](http://www.aeroflex-inmet.com)

Focused development in the Ka Band range has yielded both fixed negative slope and parabolic gain equalizers. Available designs offer up to 10 dB of Delta Slope. Visit our web site and complete the Equalizer Questionnaire to learn how these units can perform in your application.

Aeroflex / Inmet  
Ann Arbor, Michigan  
Call 734-426-5553 or  
[sales@eroflex-inmet.com](mailto:sales@eroflex-inmet.com)





# 2 W & 5 W DC to 18 GHz ATTENUATORS

**IN STOCK**



**\$29.95**  
from ea. (1-49)

Rugged Stainless Steel Construction, High Repeatability, Miniature Size, Low Cost, and Off-The-Shelf Availability are some of the features that make Mini-Circuits "BW" family of precision fixed attenuators stand above the crowd! This extremely broad band DC to 18 GHz series is available in 5 watt Type-N and 2&5 watt SMA coaxial designs, each containing 15 models with nominal attenuation values from 1 to 40 dB. Built tough to handle 125 watts maximum peak power, these high performance attenuators exhibit excellent temperature stability, 1.15:1 VSWR typical, and cover a wealth of applications. So contact Mini-Circuits today, and capture this next generation of performance and value! *Mini-Circuits...we're redefining what VALUE is all about!*

**Now Available! Adapters** (Prices: qty. 1-49)



Type-N to SMA  
DC-18 GHz \$22.95 ea.



SMA to SMA  
DC-18 GHz from \$4.95 ea.



QUICK CONNECT SMA  
DC-18 GHz from \$4.95 ea.



SMA to BNC  
DC-2 GHz \$3.95 ea.



Type-N to Type-N  
DC-6 GHz \$9.95 ea.

MODELS (Add Prefix BW-)			Attenuation (dB)	
2 W SMA	5 W SMA	5 W Type-N	Nominal	Accuracy*
\$29.95	\$44.95	\$54.95		
S1W2	S1W5	N1W5	1	±0.40
S2W2	S2W5	N2W5	2	±0.40
S3W2	S3W5	N3W5	3	±0.40
S4W2	S4W5	N4W5	4	±0.40
S5W2	S5W5	N5W5	5	±0.40
S6W2	S6W5	N6W5	6	±0.40
S7W2	S7W5	N7W5	7	-0.4, +0.9
S8W2	S8W5	N8W5	8	±0.60
S9W2	S9W5	N9W5	9	-0.4, +0.8
S10W2	S10W5	N10W5	10	±0.60
S12W2	S12W5	N12W5	12	±0.60
S15W2	S15W5	N15W5	15	±0.60
S20W2	S20W5	N20W5	20	-0.5, +0.8
S30W2	S30W5	N30W5	30	±0.85
S40W2	S40W5	N40W5	40	-0.5, +1.5

\*At 25°C includes frequency and power variations.



To order Attenuators as RoHS, add + to base model No. Example: BW-S1W2+  
Adapters available as RoHS, see web site.

**Mini-Circuits®**  
ISO 9001 ISO 14001 CERTIFIED

**ALL NEW**  
**minicircuits.com**

P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661 For detailed performance specs & shopping online see Mini-Circuits web site



The Design Engineers Search Engine Provides ACTUAL Data Instantly From MINI-CIRCUITS At: [www.minicircuits.com](http://www.minicircuits.com)

**RF/IF MICROWAVE COMPONENTS**

331 Rev J

Visit <http://mwj.hotims.com/11713-89> or use RS# 89 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)



# A LOW NOISE PHEMT DEVICE

Pseudomorphic high electron mobility transistor (PHEMT) low noise amplifiers (LNA) are capable of operating at higher frequencies than LNA devices manufactured using other technologies. They also offer higher gain at the lower frequencies. The other key performance parameter of a LNA is the noise figure. In order to optimise the noise figure the DC power consumption of the device must be minimized.

Therefore, having offered the FPD750 in a SOT343 package, Filtronic has added a smaller, low cost LNA with lower DC power consumption—the FPD6836SOT343—to the PHEMT family. This device is usable from frequencies of 900 MHz (cellular) to 3.5 GHz (for WiMAX applications) and even as high as 5.8 GHz. It can be biased as low as 3 V, 20 mA and thus produces low noise. The noise figure ranges from 0.3 dB at 900 MHz to 0.9 dB at 5.8 GHz.

The FPD6836 family is offered in chip form and in two different package styles. The FPD6836P70 uses a P70 high frequency package with usable gain up to 18 GHz, while the FPD6836SOT343 is more cost effective and produces respectable gain beyond 6 GHz. It is this device that is the subject of this article. **Figure 1** il-

lustrates its measured gain and noise figure performance. The measurements were taken on a noise figure measurement system using electronic tuners to present the device input with a reflection coefficient optimized for noise figure.

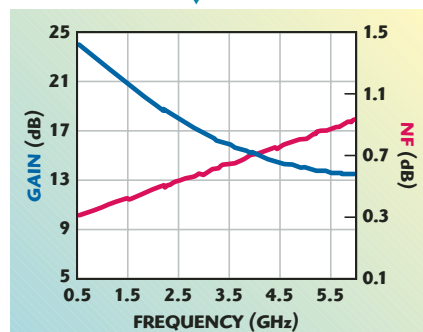
The gain plot is the associated gain of the device at the minimum noise figure. The curves show a noise figure of 0.5 dB at 1.85 GHz and 0.65 dB at 3.5 GHz with associated gain of above 19 and 16 dB, respectively. The part is biased at 3 V with a quiescent current of 50 mA. The gain is so stable at low bias that this can be reduced to 20 mA for even lower noise figure performance.

## REFERENCE DESIGNS

Two reference designs using the FPD6836SOT343 are presented. The first is aimed at the 1.85 GHz cellular band and the second at the 3.5 GHz WiMAX band. Both designs are realised on low cost PC boards with minimal components.

**Figure 2** is the schematic of the circuit design at 1.85 GHz. The FPD6836SOT343 is reactively matched on the input and the output with a series chip inductor and a shunt capaci-

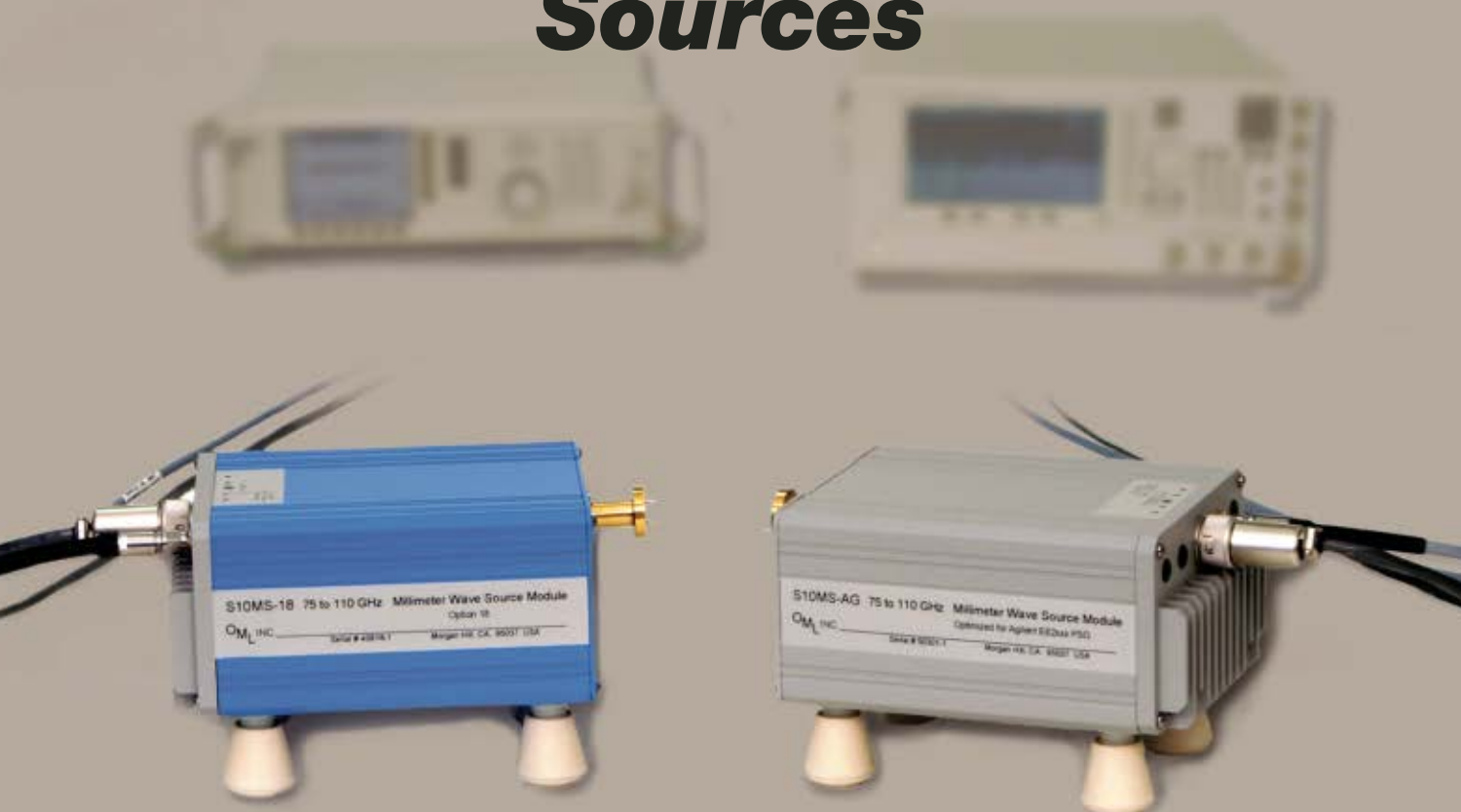
Fig. 1 The tuned gain and minimum noise figure frequency response of the FPD6836SOT343. ▼



FILTRONIC COMPOUND  
SEMICONDUCTORS LTD.  
Newton Aycliffe, UK



# Wideband Millimeter Wave Sources



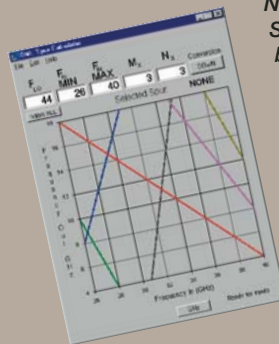
*Extend the frequency coverage of your synthesizer to produce high quality signals above 50 GHz. OML Source Modules cover the full waveguide band from WR-15 to through WR-03, providing contiguous coverage from 50 GHz to 325 GHz.*

*Compatible with all current microwave synthesizers, these modules have been optimized for use with the current Agilent and Anritsu families of high performance synthesizers.*

*These Source Modules display good spurious performance and replicate the host synthesizer's frequency accuracy, stability and phase noise (20 log n degradation).*

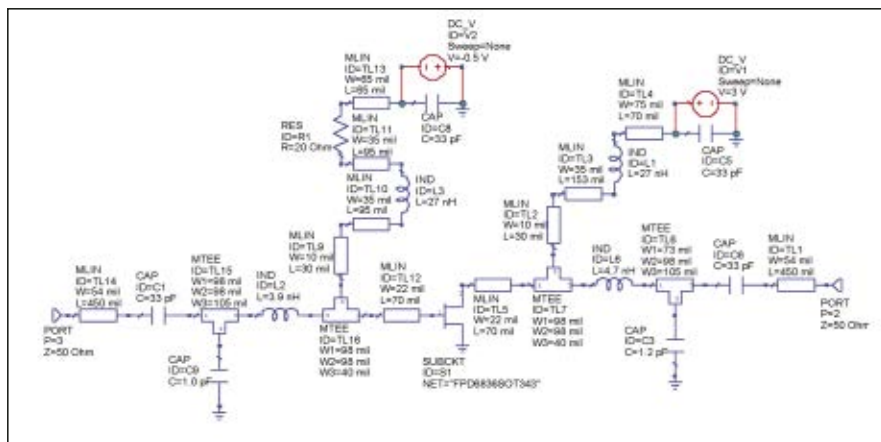
*For design discussion and detailed specifications, consult the Source Module section of the OML website at [www.omlinc.com](http://www.omlinc.com)*

**OML** INC.

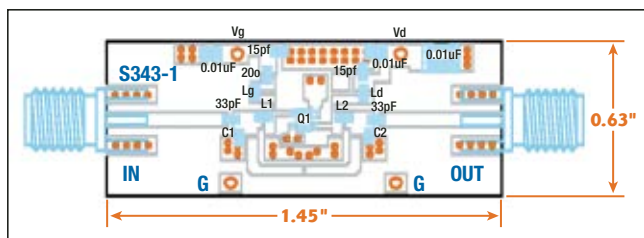


Now available free at the OML Web Site is the Windows™ compatible, block converter "Spurious Product Prediction Program" illustrated to the left. With this program, engineers can examine their block converter designs for harmful spurious responses.

Also contained on the Web Site are complete specifications for all OML millimeter wave frequency extension products as well as technical papers addressing many of the more common millimeter wave testing problems. Contained in these papers are many useful millimeter wave charts and graphs not found elsewhere.



▲ Fig. 2 FPD6836SOT343 1.85 GHz evaluation board schematic.



▲ Fig. 4 1.85 GHz evaluation board layout.

tor tuned for minimum noise figure and maximum gain. The device input and output reflection coefficients can be calculated as

$$\Gamma_{in} = \Gamma_{opt}^* \quad (1)$$

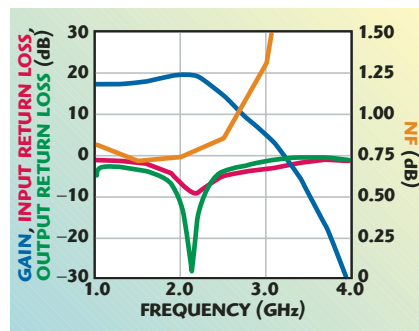
$$\Gamma_{out} = S_{22} + S_{12}S_{21}\Gamma_{opt} \quad (2)$$

$$1 - S_{11}\Gamma_{opt}$$

$\Gamma_{opt}$  at 1.85 GHz is obtained from the device's data sheet table, which is posted on the company's web site. DC blocking capacitors, RF choke inductors and a 20  $\Omega$  gate resistor form the core of the circuit. Additional capacitors are used on the DC supply lines for power supply stability.

GHz and has a gain of 19 dB and a noise figure of 0.7 dB at 1.85 GHz. Output third-order modulation measurements made using two CW tones spaced 5 MHz apart at an output power level of 4 dBm per tone show an output IP3 of 34 dBm. Higher output power levels are achievable with the same OIP3 performance, which show the good dynamic range of the device. The P1dB of the reference design is 14.5 dBm. **Figure 4** shows the layout of the PCB.

The size of the circuit (excluding the SMA connectors' ground pads and unused lines) is less than 0.5"  $\times$  0.5". The board material is low cost FR-4 with a dielectric thickness of 30 mm. The physical dimensions of the



▲ Fig. 3 1.85 GHz evaluation board gain, return loss and noise figure.

microstrip lines can be obtained from the schematic in Figure 2. Critical component values are given along with vendor information in **Table 1**.

**Figure 5** shows the schematic of the design for 3.5 GHz. The FPD6836SOT343 is reactively matched on the input with a series chip inductor and a shunt capacitor tuned for minimum noise figure. The output is matched with a series capacitor and a shunt inductor for maximum gain. The device input and output reflection coefficients can be calculated using Equations 1 and 2.

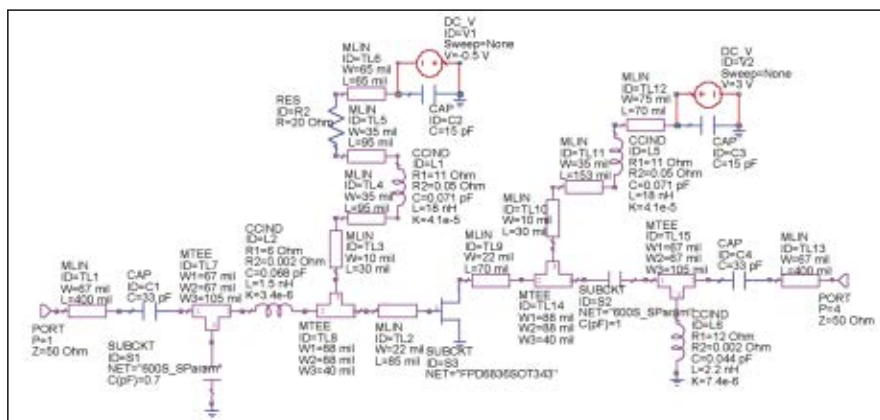
$\Gamma_{opt}$  at 3.5 GHz is extrapolated from the device's data sheet table. DC blocking capacitors, RF choke inductors and a 20  $\Omega$  gate resistor form the core of the circuit. Additional capacitors are used on the supply to ensure power supply stability.

The measured RF performance of the design is shown in **Figure 6**, where the gain, input and output return loss and noise figure are plotted. This circuit covers the 3.4 to 3.6 GHz band and has a gain of 15 dB and noise figure of 0.85 dB at 3.5 GHz. OIP3 measurements (made with two CW tones at 4 dBm per tone 5 MHz apart) gives an output IP3 of 33 dBm.

TABLE I

1.85 GHz CRITICAL COMPONENT VALUES AND VENDOR INFORMATION

Component	Value	Vendor
Lg	27nH	TOKO (LL1608)
Ld	27nH	TOKO (LL1608)
L1	3.9nH	TOKO (LL1005)
L2	4.7nH	TOKO (LL1005)
C1	1.0pF	ATC (600S)
C2	1.2pF	ATC (600S)
Eval board material	30 mil thick FR4 1/2 Ounce Cu	



▲ Fig. 5 FPD6836SOT343 3.5 GHz evaluation board schematic.





## Inspired Wireless Solutions From Filtronic Compound Semiconductors

Filtronic Compound Semiconductor products meet the needs of both current and emerging wireless markets. Products are manufactured using 6" high performance pHEMT technology and are available in die form or packaged in industry standard outlines. Filtronic's range of DFN and SOT343 packaged discrete devices are high frequency low noise parts eminently suitable for:

- the complete 2-11 GHz WIMAX Band
- the 2.4 and 4.9-5.8 GHz WLAN Band
- the new 4.9 GHz Public Safety Band
- all current Cellular Infrastructure Bands



Part Number		Typical 2 GHz Performance				Typical 12 GHz Performance			VDS (Vdc)	IDSS (mA)
	Gain (dB)	P-1 (dBm)	IP3 (dBm)	NF (dB)	Gain (dB)	P-1 (dBm)	IP3 (dBm)	NF (dB)		
FPD1500DFN	18	27	42	1.2	7*	27	40	N/A	5	465
FPD750DFN	20	24	38	0.3	11.5*	24	38	N/A	5	230
FPD750SOT343	18	20	38	0.3	8*	20	38	N/A	3.3	230
FPD6836SOT343	20	20	32	0.5	9*	19	32	1.2	3	105

Samples and eval boards available. Contact your local Filtronic Representative or Richardson Electronics for samples, eval boards, and pricing.

Filtronic is a world leader in the design and manufacture of RF, microwave and millimeter wave components and subsystems. Filtronic offers a broad range of products used in wireless communications infrastructure equipment, point-to-point communications and electronic defense systems.



[www.rfwireless.rell.com](http://www.rfwireless.rell.com)

These and other Filtronic Products are available through our Authorized Distributor, Richardson Electronics.




Filtronic Compound Semiconductors, Ltd.

Heighington Lane Business Park, Newton Aycliffe, Co. Durham, DL5 6JW, United Kingdom

Main Phone: +44 (0)1325 301111; Main Fax: +44 (0)1325 306177

US Sales: Phone: 408.850.5740 / Fax: 831.621.8074 / [www.filtronic.com](http://www.filtronic.com)



So you've used  
the same design  
tools for years.  
Or has it been  
the other way  
around?



Why struggle to create great designs with vintage tools? A recent EDA survey indicated that you-know-who finished near the bottom of leading EDA vendors in customer satisfaction. Life is short. There's a better design path that's been empirically proven: Microwave Office.™ Thousands of users have already discovered that superior layout technology, great technical support and faster simulations lead to shorter design cycles and first pass success. Stop beating your head against the monitor. Download a 30-day trial today and break the habit.



[appwave.com](http://appwave.com)



# **FREE**

## **Product Information**

Now Available Online  
at

# **Info Zone**

The new Web-based  
product information system

from



*Just visit*

**mwjournal.com/info**

**and enter the RS number from  
the ad or editorial item**

**or**

**request information by company  
name or product category**

**It's Easy**

**It's Fast**

**It's FREE**

## **GET IN THE ZONE!**



**Receive the  
most current**

Industry News  
New Product Information  
Market Analysis  
Industry Events

with

**Microwave  
FLASH**

And

**Microwave  
ADVISOR**

The weekly eNewsletters from  
The Editors of



*Subscribe today at:*

[www.mwjjournal.com/activate](http://www.mwjjournal.com/activate)

And join our 37,000 subscribers  
Who already receive the latest  
industry info!



# Need QPL Trimmers?

Voltronics Corporation Maintains 60 active parts that are currently QPL.



Voltronics can supply commercial parts to replace difficult to obtain QPL Trimmers. Additional testing can be performed on a variety of standard and special trimmers to meet your specific needs.

*For additional information, quotes or samples please contact:*

**Voltronics**   
CORPORATION

*The Trimmer Capacitor Company*

A **DOVER** COMPANY

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

100 Ford Road, Denville, NJ 07834  
973.586.8585 • Fax: 973.586.3404  
e-mail: [info@voltronicscorp.com](mailto:info@voltronicscorp.com)

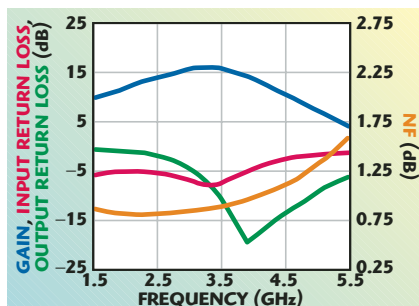
Visit <http://mwj.hotims.com/11713-153> or use RS# 153 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)

Again, the good dynamic range allows higher output power levels with the same OIP3 performance. P1dB for this design is 14 dBm. Note that both reference designs are not optimized for P1dB since it has been observed

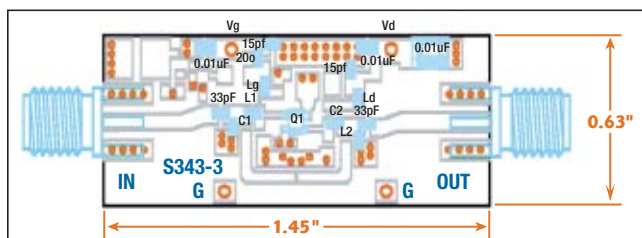
that a gain matched output tends to enhance the linearity of the part.

**Figure 7** shows the layout of the PCB. Again, the components occupy an area excluding the SMA connectors of less than  $0.5" \times 0.5"$ . The board is composed of 30 mm thick Rogers 4003 material. This low loss dielectric avoids high line losses, which would degrade the noise figure at these frequencies had FR-4 material been used. The dimensions of the microstrip lines are given in **Figure 5**. Critical component values are given along with vendor information in **Table 2**.

The FPD6836SOT343 can also be used as a  $50\ \Omega$  gain block with no matching at the input and the output of the part at all. At 1.85 GHz the device has a typical noise figure of 0.9 dB, a small-signal gain (SSG) of 18 dB and P1dB of 18.5 dB when matched into  $50\ \Omega$  with no matching components.



▲ Fig. 6 3.5 GHz evaluation board gain, return loss and noise figure.



▲ Fig. 7 3.5 GHz evaluation board layout.

**TABLE II**  
**3.5 GHz CRITICAL COMPONENT**  
**VALUES AND VENDOR INFORMATION**

Component	Value	Vendor
Lg	18nH	Coil Craft (0603CS)
Ld	18nH	Coil Craft (0603CS)
L1	1.0nH	Coil Craft (0402CS)
L2	2.2nH	Coil Craft (0402CS)
C1	0.7pF	ATC (600S)
C2	1.0pF	ATC (600S)
Eval board material	Rogers 4003 30 mil Thick 1/2 Ounce Cu	

## STABILITY AND RELIABILITY

The low noise PHEMT device also exhibits very good temperature stability. The maximum variations over temperature for P1dB, SSG and IM3 have been calculated from measured data for three critical parameters:

$$\begin{aligned}\Delta P1dB &= 0.9\text{ dB} \\ \Delta SSG &= 0.6\text{ dB} \\ \Delta IM3 &= 2\text{ dB}\end{aligned}$$

The measurements were obtained with the device biased at 3.0 V and 50 mA on a 1.85 GHz evaluation board similar to the reference design previously explained. These were taken at temperature intervals from  $-40^\circ\text{C}$  to  $+85^\circ\text{C}$ . The process used for fabrication allows a maximum operating channel temperature of  $150^\circ\text{C}$ , at which the MTTF is calculated as  $7.0 \times 10^6$  hours.

## CONCLUSION

The FPD6836SOT343 is a versatile device that can be used as a matched low noise amplifier with very low DC power consumption. It can also be used as a low cost gain block with no matching for applications where noise figure is non-critical. Applications for this part exist for a frequency range of up to 6 GHz. PCS/cellular base stations (800 MHz to 2.4 GHz), WLL and WLAN systems (2.6, 3.5 and 5.8 GHz) are some examples of the wide range of applications for which the device can be used.

**Filtronic Compound Semiconductors Ltd.,**  
**Newton Aycliffe, UK,**  
**+44 1325 301111,**  
**www.filtronic.com.**

RS No. 301

**Tiger Micro-Electronics Institute**

**Ferrite Components for Military and Commercial Applications**

Tiger's ferrite components include: drop-in, connectorized and waveguide isolators, circulators with high performance at economical price, frequency range from 0.04 up to 18 GHz.

**HOT PRODUCTS:**

Model Number	Frequency	IL (dB)	Iso (dB)	VSWR In/out	Power For. Ret. (W)
TGG601	13.75-14.5 GHz	0.4	23	1.2:1	10W
TGG601B	7.7-8.5 GHz	0.3	22	1.17:1	10W
TGG401	3.4-4.2 GHz	0.3	23	1.15:1	10W
TG2H216	380-400MHz	0.5	55	1.15	100W
TGH9013	225-400MHz	0.8	18	1.40	10-100W

**VISIT US**  
At [www.tiger-mw.com](http://www.tiger-mw.com)  
Hi-Tech Incubation Park, Nan Yan Xian,  
Email: [business@tiger-mw.com](mailto:business@tiger-mw.com)  
Add: 5th Floor, Building #1,  
Tianfu Road, Chengdu, China, 610041  
Tel: +86-28-66070208  
Fax: +86-28-66070496





*Shown with optional equipment.*

## *Bring Wireless Products to Market Quickly, Our AMS 8050 System Is the Solution!*

### **Test As You Design**

ETS-Lindgren presents the AMS 8050 Antenna Measurement System: a compact antenna lab for making fast, over-the-air (OTA) performance measurements of small wireless devices and mobile handsets. It's perfect for research and development, design qualification, production sampling, and pre-certification measurement. It's everything you need to beat the competition to market.

### **TRP, TIS and More**

Small in size but big on performance, the AMS 8050 System lets you measure 3-D spherical pattern and 2-D pattern-cut measurements, and perform tests to determine quantities such as total radiated power (TRP), effective isotropic radiated power (EIRP), total isotropic sensitivity (TIS), effective isotropic sensitivity (EIS), near-horizon partial radiated power (NHPRP), and near-horizon partial isotropic sensitivity (NHPIS).

### **Know Before You Go**

If you're using an outside test house for certification testing, our system can help you go fully prepared. OTA measurements made in the AMS 8050 have demonstrated good correlation to measurements made in larger, fully compliant chambers. Use the AMS 8050 System to make tests during product development, and you'll be able to identify and correct problems before leaving your lab.

### **Built by Experts**

The AMS 8050 System is designed and built by people who know something about OTA wireless testing – ETS-Lindgren. We were the first lab authorized by the CTIA to perform certification testing per their OTA performance test plan. And our OTA test systems are used in 75% of CTIA Authorized Test Labs (CATL) worldwide. Click on our website for more information.

*Enabling Your Success*



An ESCO Technologies Company

[www.ets-lindgren.com](http://www.ets-lindgren.com)

Company offices: USA +512.531.6400, Finland +358.2.8383300, Japan +81.3.3813.7100, China +86(10)8273.0877  
Additional locations in the US, UK, Finland, France, Singapore, Japan and China  
Representatives and Distributors Worldwide

© 2006 ETS-Lindgren

Visit <http://mwj.hotims.com/11713-50> or use RS# 50 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)



# AN LTCC MIXER FOR INSTRUMENTATION AND MILITARY APPLICATIONS

Test instrumentation may need to accommodate signals having a wide-percentage frequency bandwidth. For ease of processing such RF signals, the input can be upconverted in order to reduce the percentage bandwidth. To facilitate upconversion ahead of higher frequency receivers, Mini-Circuits has developed a high performance passive mixer that allows original-equipment manufacturers (OEM) to optimize receiver design. Such mixers are also useful in military applications.

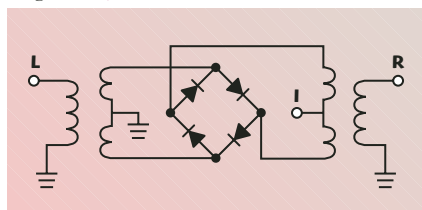
The company's model SIM-U742MH+ mixer is based on a combination of low temperature-cofired-ceramic (LTCC) technology, semiconductor technology and a highly manufacturable circuit layout. The patented combination<sup>1</sup> results in small size, high insensitivity to electrostatic discharge (ESD), excellent stability with temperature and is part of a growing family of SIM mixers.

Instrumentation and military transmitters need components, such as mixers and oscillators that provide stable performance

over time and under different environmental conditions, including temperature. The SIM-U742MH+ mixer is built on a LTCC substrate, ideally suited for designs with multi-layer circuits. In contrast to conventional planar circuit designs, in which all circuit elements are placed on one side of a single-layer printed circuit board, LTCC circuits can be designed and fabricated in three dimensions, even with embedded components between layers, to save space. The approach results in a mixer that measures just 0.2" × 0.18" × 0.08" (5.1 × 4.6 × 2.1 mm), which is smaller than some commercial semiconductor-based mixers. While the SIM-U742MH+ mixer incorporates semiconductors to accomplish its frequency-translation function, it is a passive design that operates without DC bias (compared to a standard integrated-circuit mixer which requires the application of constant DC bias).

The SIM-U742MH+ is a double-balanced mixer (see **Figure 1**) built around a reliable

Fig. 1 The SIM-U742MH+ double-balanced mixer block diagram. ▼



MINI-CIRCUITS  
Brooklyn, NY





40 42 44 46 48 50  
**GHz**

## High Quality. Higher Frequency.

Our new high performance series of RF, Microwave, and Millimeter-wave connectors can provide you with the benefit of legendary Delta quality over a broad spectrum of bandwidth requirements.

In addition to SMP and extended-frequency 26.5-GHz SMA connectors, we now offer ultra-precision SMAs with superb performance to 27 GHz, 2.92 mm (SMK) connectors to meet your SMA-compatible requirements to 40 GHz, and 2.4 mm production grade connectors that will satisfy your requirements all the way to 50 GHz.

Delta connectors are precision machined to measure up to your most demanding specifications. Our new product lines include cable plugs and jacks as well as field-replaceable receptacles for use with hermetic seals. The field-replaceable receptacles are available in all common mounting flange and pin size configurations.

Delta's new connectors are designed using state-of-the-art optimization tools and techniques. This focus on precision results in connectors with low VSWR, transmission loss, and RF leakage.

Call or visit our website to see how Delta Quality RF and Microwave connectors can help you meet your product performance goals—from DC to 50 GHz.



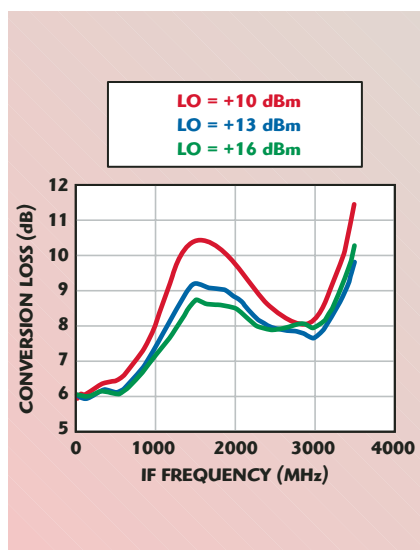
(978) 927-1060

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

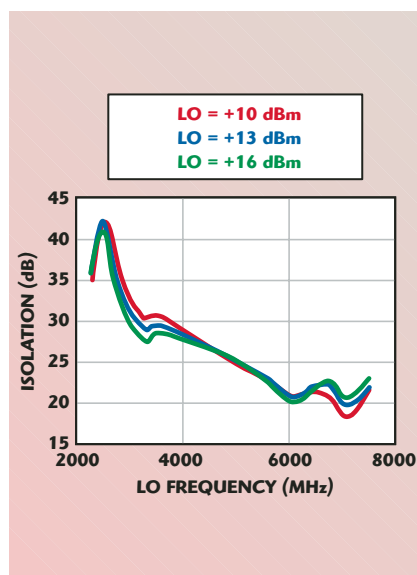


**TABLE 1**
**THE SIM-U742MH+ MIXER'S PERFORMANCE**

Parameter	
RF range (input) (MHz)	0.1–3300
IF range (output) (MHz)	2300–7400
LO range (input) (MHz)	2300–7400
LO power (nominal) (dBm)	+13
Conversion loss (typical) (dB)	8.0
LO-IF isolation (typical) (dB)	23
LO-to-RF isolation (typical) (dB)	17
Compression point (P1dB) (dBm)	+9
Operating temperature range (°C)	–40 to 85
Storage temperature range (°C)	–55 to 100
Size (in)	0.2 × 0.18 × 0.08
Case style	HV1195



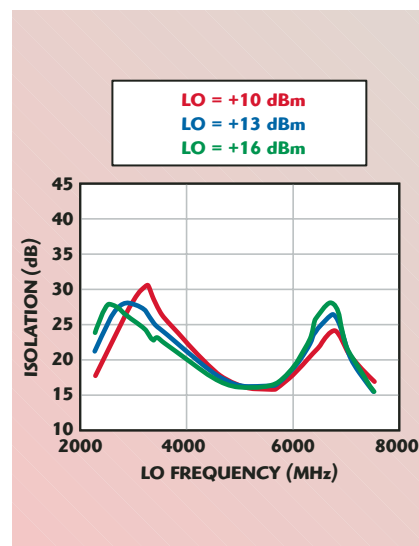
▲ Fig. 2 The SIM-U742MH+ mixer's conversion loss at an RF output of 4075 MHz.



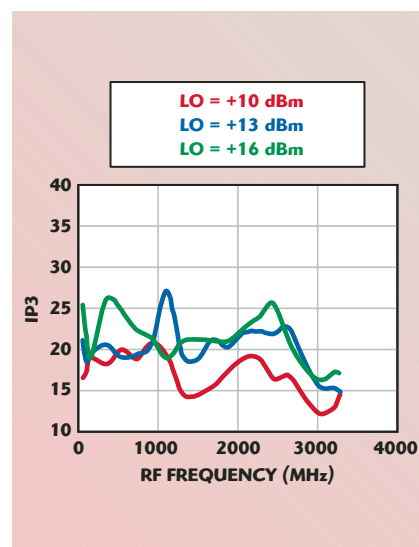
▲ Fig. 3 The mixer's LO-to-IF isolation.

diode quad. Except for the diodes, the entire structure is implemented in multiple layers of LTCC, which is inherently hermetic. By integrating components in LTCC, the mass of the mixer is minimized, making it extremely rugged in terms of withstanding mechanical shock and vibration. In fact, the entire mixer structure can withstand the environmental extremes usually associated with tough military components, regarding temperature, humidity, vibration and mechanical shock.

The mixer is RoHS-compliant, constructed without lead-based solder or other hazardous materials. It is also built to withstand severe ESD scenarios under conditions normally hazardous to monolithic semiconductor mixers. The SIM-U742MH+, like other members of the company's SIM mixer line, meets Class 1C ESD requirements: a level of 1000 V when tested per the Human Body Model (HBM), compared to standard semiconductor mixers which are typically rated as Class 1A, 250 V for HBM



▲ Fig. 4 The mixer's LO-to-RF isolation.



▲ Fig. 5 The measured input third-order intercept performance at 4075 MHz RF output.

testing. The SIM-U742MH+ mixer also meets Class M2 ESD requirements (testing at 100 V) according to the ESD Machine Model. **Table 1** summarizes the performance characteristics of the SIM-U742MH+ mixer.

## EVALUATING PERFORMANCE

The SIM-U742MH+ mixer accepts radio-frequency (RF) signals from near 0.1 to 3300 MHz and local-oscillator (LO) signals from 2300 to 7400 MHz and a nominal LO level of +13 dBm to produce IF output signals from 2300 to 7400 MHz. It performs the frequency upconversion with a typical conversion loss of 8.0 dB. The mixer's conversion loss increases with RF frequency. **Figure 2**



# ***Filters Duplexers Multiplexers***

**Commercial • Military • Wireless**



*Eastern Wireless TeleComm specializes in custom designed RF and Microwave filters and filter based products for Commercial, Wireless, Military, and Space applications.*

*With more than 35 years of design and manufacturing experience, we are able to incorporate the latest proven design techniques into our products, maximizing performance and repeatability.*

*EWT...the most cost effective solution for your filter requirements.*

- **Cavity**
- **Waveguide**
- **Surface Mount**
- **Lumped Element**
- **Custom Assemblies**
- **All Applications to 40 GHz**



**Eastern Wireless  
TeleComm, Inc.**  
[www.ewtfilters.com](http://www.ewtfilters.com)

Tel: 410.749.3800 Fax: 410.749.4852  
[sales@ewtfilters.com](mailto:sales@ewtfilters.com)

Visit <http://mwj.hotims.com/11713-40> or use RS# 40 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)



shows test results with LO drive levels of +10, +13 and +16 dBm. The variation of conversion loss with LO drive power is typically +1.0/-0.5 dB across the 3300 MHz measured bandwidth.

The LO-to-RF isolation of the SIM-U742MH+ mixer was evaluated at the three LO drive levels used in the conversion loss test, to understand the effect of variations in LO power on isolation. As **Figure 3** shows, the LO-to-IF isolation is high (typically 23 dB) and very well behaved at all three LO drive levels. Variation in isolation as a function of LO power is negligible.

Similarly, the LO-to-RF port isolation was also evaluated at the three LO drive levels. The SIM-U742MH+ mixer exhibited typically 17 dB isolation across an LO frequency range of 4100 to 7400 MHz (see **Figure 4**).

Since wide dynamic range is important in instrumentation applications, the input third-order intercept point (IIP3) of the SIM-U742MH+ mixer was also evaluated at the three

LO drive levels (+10, +13 and +16 dBm) and at an RF output range of 3900 to 4300 MHz. IP3 is consistently about +20 dBm up to 2.5 GHz and then derates to +15 dBm at 3.3 GHz (see **Figure 5**).

The LTCC double-balanced mixer features typical LO port return loss of 3.5 to 8.5 dB. The return loss measured at the RF port is 5.5 dB typical, while the return loss at the IF port is typically 17 dB.

The mixer supports conventional surface-mount applications, and can be supplied in tape-and-reel formats for use with automated assembly equipment. The RoHS-compliant mixer is designed to withstand high levels of ESD mishandling compared to more sensitive, and often larger, semiconductor mixers.

Mini-Circuits' LTCC mixers have been tested extensively and qualified for environmental conditions such as humidity, thermal shock and vibration. To evaluate the durability and reliability of the solder joints, 20 of the LTCC mixers were soldered onto

FR-4 PCB motherboards and thermally cycled (1000 cycles) over the operating temperature range of -40° to 85°C. The DC continuity was measured from the motherboard trace to the top of the LTCC board, with no failures found.

## CONCLUSION

The model SIM-U742MH+ high performance mixer leverages LTCC, semiconductor technology and patented circuit techniques to achieve high frequency low loss up-conversion for both instrumentation and military applications. Additional information on it and other SIM mixers may be obtained from the company's web site under the model series SIM.

## Reference

1. United States Patent No. 7,027,795 (2006).

**Mini-Circuits,**  
Brooklyn, NY (718) 934-4500,  
[www.minicircuits.com](http://www.minicircuits.com).

**RS No. 300**

# FIRST AID



## for RF Interference

### Tunable Filter Kit

- + 9 Filters from 2.5 to 18 GHz
- + Direct Frequency Readout
- + 3 dB Bandwidth: 50 MHz
- + 35 dB Bandwidth: 100 MHz
- + 50 dB Bandwidth: 150 MHz
- + Insertion Loss: 2.0 dB max.
- + Out of Band Rejection: 50 dB to 18 GHz
- + Power Handling: 50 watts



**Coleman Microwave Company**  
1-800-563-3449  
[www.colemanmw.com](http://www.colemanmw.com)



**IEEE MTT-S INTERNATIONAL  
MICROWAVE SYMPOSIUM**  
June 3-8, 2007  
Honolulu, Hawaii

**Microwave Week 2007:** The IMS 2007 technical sessions will run from Tuesday through Thursday of Microwave Week. Workshops will be held on Sunday, Monday and Friday. In addition to IMS 2007, a microwave exhibition, a historical exhibit, the RFIC Symposium ([www.rfic2007.org](http://www.rfic2007.org)) and the ARFTG Conference ([www.arftg.org](http://www.arftg.org)) will also be held in Honolulu, HI, during Microwave Week 2007. Following this will be the IEEE Antennas and Propagation Society International Symposium, also in Honolulu, HI, from June 9-15, 2007.

Visit [www.ims2007.org](http://www.ims2007.org)  
for more information

# High Power Caseless 90° Couplers

## Stock To 30 Day Delivery



**Fastest  
Delivery  
Available!**



FREQUENCY (MHz)	MODEL NUMBER	AVERAGE POWER (CW Watts)	AMPLITUDE BALANCE (±dB, Max.)	PHASE BALANCE (±Deg., Max.)	ISOLATION (dB Min./Typ.)	INSERTION LOSS (dB, Max.)	VSWR (Max.)
50 – 110	M-51-111-96W802	600	0.3	2.0	20/23	0.30	1.2:1
100 – 500	M-12-52-92W502	200	0.85	2.5	14/18	0.85	1.35:1
100 – 500	M-12-52-98WF502	800	0.8	2.0	18/20	0.30	1.2:1
120 – 230*	M-121-231-92W012	300	0.5	2.0	20/27	0.30	1.2:1
150 – 250	M-151-251-94W012	400	0.3	2.0	20/25	0.30	1.2:1
200 – 400*	M-22-42-92W102	250	0.5	2.0	20/25	0.30	1.2:1
200 – 400	M-22-42-95WB302	500	0.4	2.0	19/23	0.25	1.2:1
200 – 1000*	M-22-13-92WD502	250	0.75	3.0	20/23	0.50	1.3:1
250 – 500	M-251-52-92W102	250	0.5	2.0	20/25	0.30	1.2:1
300 – 500	M-32-52-92W102	250	0.4	2.0	20/23	0.25	1.2:1
300 – 950	M-32-951-92W102	250	0.6	2.0	20/23	0.25	1.25:1
400 – 550	M-42-551-92W102	250	0.2	2.0	20/25	0.20	1.2:1
400 – 700	M-42-72-92W012	250	0.5	2.0	20/25	0.30	1.2:1
400 – 1000*	M-42-13-92W102	250	0.6	2.0	18/20	0.25	1.2:1
400 – 1000	M-42-13-95WB302	500	0.6	2.0	20/23	0.20	1.2:1
400 – 1000	M-42-13-91KW402	1000	0.6	2.0	20/25	0.20	1.2:1
440 – 880	M-441-881-92W102	250	0.5	2.0	20/25	0.20	1.2:1
700 – 1400*	M-72-142-92W102	250	0.5	2.0	18/25	0.30	1.25:1
800 – 1600	M-82-162-92W102	250	0.5	2.0	20/23	0.25	1.2:1
800 – 1600	M-82-162-95WB302	500	0.5	2.0	20/25	0.20	1.25:1
800 – 1600	M-82-162-91KWB912	1000	0.5	2.0	20/25	0.20	1.3:1
800 – 2500*	M-82-252-92W122	200	0.6	4.0	18/20	0.40	1.25:1
800 – 4200	M-82-43-92W122	200	0.5	4.0	16/20	0.20	1.2:1
960 – 1220	M-961-1221-92W102	200	0.3	2.0	18/25	0.30	1.25:1
960 – 1220	M-961-1221-95WB302	500	0.4	2.0	20/23	0.20	1.2:1
1000 – 2000	M-13-23-92W102	200	0.5	3.0	18/24	0.30	1.25:1
1000 – 2000	M-13-23-95WB302	500	0.5	3.0	18/22	0.20	1.2:1
1200 – 1400	M-122-142-92W102	250	0.4	3.0	20/23	0.25	1.2:1
1200 – 1400	M-122-142-95WB302	500	0.4	2.0	20/25	0.20	1.2:1
1300 – 3000	M-132-33-92W102	200	0.6	3.0	18/23	0.25	1.2:1
1400 – 2400	M-142-242-92W102	200	0.5	3.0	16/20	0.25	1.2:1
1400 – 2800	M-142-282-92W102	200	0.5	3.0	16/20	0.25	1.2:1
1500 – 3000	M-152-33-92W102	200	0.6	3.0	18/22	0.25	1.25:1
1700 – 2500	M-172-252-92W102	200	0.4	3.0	20/23	0.25	1.2:1

\* Multiple packages are available on these models, please contact MITEQ. 180 degree and coaxial versions are available upon request

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



100 Davids Drive, Hauppauge, NY 11788  
(631) 436-7400 FAX: (631) 436-7430

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

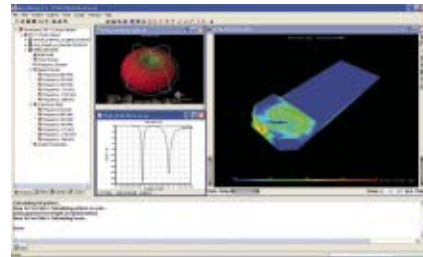




## EMC TEST SOFTWARE

The model SW1006 is the latest version of the company's radiated susceptibility, conducted immunity and pre-compliance emissions software. Model SW1006 automatically performs both calibration and immunity testing in full compliance with IEC 61000-4-3, 4-6, MIL-STD 461/462 RS103, CS114, RTCA/DO160 Section 20 specifications. The software also supplies the user with selectable test parameters and a "thresholding" mode for pre-compliance investigation of equipment susceptibility, as well as closed loop leveling. Pre-compliance emission testing can be done with the use of a spectrum analyzer and either a pre-amp or LISN. The SW1006 software is designed for use with the supplied NI PCI-GPIB interface card for instrument communication.

**AR Worldwide RF/Microwave Instrumentation,**  
Souderton, PA (215) 723-8181, [www.ar-worldwide.com](http://www.ar-worldwide.com).  
**RS No. 310**



## EM SIMULATION

The MicroStripes 3D EM simulation solution for RF/microwave and antenna design, which integrates with Applied Wave Research's Microwave Office® circuit design software, has reached version 7.5. It enables users to import any desired excitation waveform during the modeling process, run the simulation and evaluate the results without any additional post-processing. This makes it possible, for example, to simulate the effect of a lightning strike, electromagnetic pulse or electrostatic discharge on a system using a pre-computed, analytic or measured waveform. In version 7.5, ground planes can also be used for models without meshing all of the space between the system and ground plane. Version 7.5 also reduces the computational resources required to model ferrite tiles.

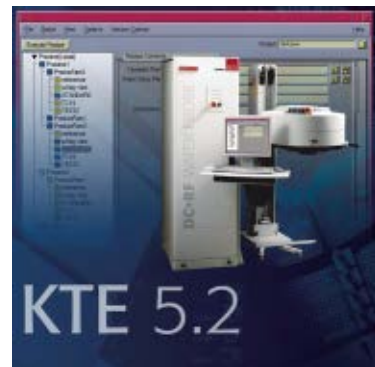
**Flomerics Ltd.,**  
Hampton Court, Surrey, UK +44 (0) 20 8487 3000,  
[www.flomerics.com](http://www.flomerics.com).  
**RS No. 311**



## PARAMETRIC PRODUCT SEARCH TOOL

The parametric product search tool is designed for the RF engineer to specify important product parameters and view the company's products that match a specific requirement in a specification-compliance format. Unlike conventional search engines that eliminate products that narrowly fall outside of specification, the parametric product search tool can show these products allowing the engineer to make intelligent design trade-off decisions to "fine tune" the requirement to specific needs. View this and other product software support tools including Product Cross Reference, PLL Phase Noise and Mixer Spur Chart Calculators on the company's site.

**Hittite Microwave Corp.,**  
Chelmsford, MA (978) 250-3343, [www.hittite.com](http://www.hittite.com).  
**RS No. 312**



## PARAMETRIC TEST SOFTWARE

The release of KTE V5.2 is the company's Interactive Test Environment software for the Series S600 Parametric Test System. KTE V5.2 provides a number of features that dramatically increase throughput for circuit materials testing, such as those requiring RF level frequencies, as well as incorporating improvements in parallel test routines used for lab and production applications. In addition, the KTE V5.2 software update offers significant improvements in ease of use that simplify testing. Keithley's KTE is a powerful wafer test development and execution environment that guides test engineers through the development of a test plan. Users can create individual electrical tests at the sub-site level by drawing on pre-defined libraries of test, then defining parameters and connections.

**Keithley Instruments Inc.,**  
Cleveland, OH (440) 248-0400, [www.keithley.com](http://www.keithley.com).  
**RS No. 314**



# Phase Shifters for every Application to 40GHz

**AEROFLEX**  
KDI-INTEGRATED PRODUCTS

## Specifications

Type: Varactor, PIN, MMIC, FET  
Frequency  
Power  
Phase shift range  
Switching speed  
Insertion Loss  
Phase Linearity  
Phase flatness  
Digital control  
Bit size  
Analog control  
Bias/control voltages  
Package size -,SM, Connector  
Mechanical / electronic adjust  
Loss vs phase change  
Price  
Unit-to- unit tracking  
Insertion phase  
Temperature and environment  
Hermetic  
Fixed phase offset module  
Thermal compensation  
Modular for integration

You prioritize the specifications;  
We'll design the Phase Shifter to fit the application:.

Our phase shifters cover the range from "MHz to 40 GHz" with PIN diode, varactor, or the latest MMIC or FET performance.

You can choose either analog, digital, or mechanical adjustment controls. You'll be able to select from our wide range of designs with any combination of specifications listed in surface mount or connector packages.

Or, you may want to integrate the phase shifter with an attenuator, Time Delay, or other microstrip circuit for a higher level assembly. The latest high performance radar phased arrays require the ultimate in phase and amplitude accuracy that is achieved with the optimum combination of specifications that Aeroflex provides.

Performance is guaranteed for all conditions and backed with our ISO 9001 verification testing.

For more information contact us at  
**973-887-5700 x500** or e-mail  
[sales@aeroflex-kdi.com](mailto:sales@aeroflex-kdi.com)

**AEROFLEX**  
A passion for performance.



## FILTER SYNTHESIS AND SELECTION TOOL

Filter Wizard<sup>SM</sup> has been enhanced to incorporate additional all-pole and elliptic bandreject solutions, including high-Q ceramic puck options. Filter Wizard accelerates user progress from specs to RFQ for RF and microwave filters spanning an ever-increasing range of response types, bandwidths and unloaded Q values from 500 kHz to 50 GHz.

**K&L Microwave Inc.,**  
Salisbury, MD (410) 749-2424, [www.klfilterwizard.com](http://www.klfilterwizard.com).  
**RS No. 313**



## MICROWAVE/RF ASSEMBLY BUILDER

The GORE<sup>TM</sup> microwave/RF assembly builder is an on-line interactive design guide that provides simple step-by-step instructions for configuring GORE microwave/RF cable assemblies. Gore's new microwave/RF configurator—available at [www.gore.com/rfcablebuilder](http://www.gore.com/rfcablebuilder)—simplifies the assembly design and configuration process enabling the user to build an assembly and submit an RFQ using the simple step-by-step configuration tool, with no registration required to access the process.

**W.L. Gore & Associates Inc.,**  
Elkton, MD (302) 292-5100, [www.gore.com](http://www.gore.com).  
**RS No. 315**

# ElectroMagneticCareers.com

Jobs for RF Engineers

# Microwave Journal

Looking for

an RF Engineer for your team?

an RF Engineering position?

Look no more!

**Employer:**

Post Your Engineering Positions

Post your open positions to those qualified engineers seeking the professional challenges you offer.

**Job-Seeking Engineer:**

Post Your Resume

Posting your resume or searching the posted positions can help you find the perfect job quickly and easily.

Antenna, Radar, SATCOM, Wireless Communications, Broadcast, Telemetry, EMC Compliance, Microwave Measurements ...

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





## In Pursuit of Excellence Through Engineering Since 1978

### Military and Industrial Products From 10 MHz to 40 GHz

#### SOLID STATE SWITCHES

- DC to 40 GHz
- SPST Through SP64T
- Sub-Octave Band and Octave Band
- Broadband and Ultra-Broadband
- With and Without Integral Drivers
- TTL, ECL, CMOS and RS422 Control Types
- Rectangular and Radial Mechanical Outlines
- Connectorized and Surface Mount
- High Speed, High Isolation and Low Loss Models
- Variable Rise Time and Other Specialty Switches



#### SOLID STATE VARIABLE ATTENUATORS

- 10 MHz to 18 GHz
- Up to 120dB Dynamic Range
- Sub-Octave, Octave and Broadband
- Non-Linear Current Control
- Linearized Analog Voltage Control
- Linearized Digitally Programmable Voltage Control
- Up to 12 Bit Digitally Controlled Resolution
- High Speed and Low Speed Models
- Switched Bit Attenuators

#### DETECTOR LOGARITHMIC VIDEO AMPLIFIERS

- 10 MHz to 40 GHz
- 45dB and 70dB Dynamic Ranges
- All Models are Truly DC-Coupled
- CW and Noise Immunity Models
- Very High Sensitivity Models
- Linear Detector Models
- Miniature Models Available
- Sub-Octave, Octave, Broadband and Ultra-Broadband
- Integrated SuperComponents and Sub-Systems Available



**American Microwave Corporation**

7311-G Grove Road • Frederick, Maryland 21704, USA

(301)662-4700 • FAX: (301)662-4938

[www.americanmicrowavecorp.com/amc](http://www.americanmicrowavecorp.com/amc)

Email: [sales@americanmicrowavecorp.com](mailto:sales@americanmicrowavecorp.com)

**ISO 9001 : 2000 Certified**  
**Screening to MIL-STD-883 Available for all Products**

Visit <http://mwj.hotims.com/11713-16> or use RS# 16 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)



FIVE DAYS ■ FOUR CONFERENCES ■ ONE EXHIBITION

# EXHIBIT AT...



## Europe's Premier Microwave, RF, Wireless and Radar Event

8-12 October 2007

ICM, Munich International Congress Centre,  
Munich, Germany

EuMW2007 will provide:

- 7000 sqm of gross exhibition space • 5000 key visitors from around the globe
- 1700 – 2000 conference delegates • In excess of 250 exhibitors

The exhibition will provide an invaluable platform to present the latest technological developments and a forum for discussion on industry, scientific and technical trends.

**Interested in Exhibiting?** Book Online at [www.eumweek.com](http://www.eumweek.com) or contact:

Richard Vaughan  
[Rvaughan@horizonhouse.co.uk](mailto:Rvaughan@horizonhouse.co.uk)  
Tel: +44 207 596 8742

Kristen Dednah  
[kdednah@mwjournal.com](mailto:kdednah@mwjournal.com)  
Tel: +1 781 769 9750

**37<sup>TH</sup> EUROPEAN MICROWAVE CONFERENCE 2007**  
The 37th European Microwave Conference

**WIRELESS TECHNOLOGY 2007**  
The European Conference on  
Wireless Technology

**EuRAD 2007**  
European Radar Conference

**EuMIC 2007**  
European Microwave Integrated Circuits Conference  
Formerly GAAS Symposium

Organised by:



**EuMA**  
European Microwave Association

Official Publication  
**Microwave Journal**

In co-operation with:



**GAAS®**

Visit <http://mwj.hotims.com/11713-51> or use RS# 51 at [www.mwjournal.com/info](http://www.mwjournal.com/info)



# A Tradition of Excellence Since 1989

## Military and Industrial Products From 10 MHz to 40 GHz

### LOG AMPLIFIERS

- Log IF and RF Amplifiers
- Successive Detection Log Video Amplifiers (SDLVA's)



### THRESHOLD DETECTORS

- Ultra Fast < 10ns Threshold Detectors
- TTL or ECL Output Logics are Available
- Internally or Externally Adjustable Threshold Levels

### PHASE SHIFTERS AND MODULATORS

- Analog and Digital High Speed Phase Shifters
- I&Q Vector Modulators/Detectors
- Ultra Fast < 10ns BiPhase Modulators

### LIMITERS AND DETECTORS

- Limiters
- Diode Detectors
- Limiter Detectors
- Directional Detectors
- Linear Amplifier Detectors



### PASSIVE AND ACTIVE COMPONENTS

- Power Dividers
- Hybrid Couplers
- Directional Couplers
- Dual Directional Couplers
- Pre-Scaler/Frequency Dividers
- Video Buffer Amplifiers
- High Speed Video Amplifiers
- RF Sinewave to TTL Converters
- High Speed TTL and ECL Converters
- Image Reject and Balanced Mixers
- Frequency and Polar Discriminators



### INTEGRATED ASSEMBLIES AND SUBSYSTEMS

- Frequency Synthesizers
- Monopulse Comparators
- IFM and Channelized Subsystems
- High Dynamic Range Receiver Front Ends
- Switched Bit Attenuator Array Assemblies
- Level, Scan and Pulse Modulation Modules
- High and Low Band Direction Finding Modules
- RF Oscillator Component Consolidation RF Subsystems
- Microwave Monitoring Receivers For CW and Pulsed Signals



**Planar Monolithics Industries, Inc.**

7311-G Grove Road • Frederick, Maryland 21704, USA

(301)631-1579 • Fax: (301) 662-2029

[www.planarmonolithics.com/pmi](http://www.planarmonolithics.com/pmi) • Email: [sales@planarmonolithics.com](mailto:sales@planarmonolithics.com)

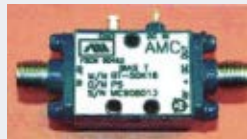
**ISO 9001 : 2000 Certified**  
**Screening to MIL-STD-883 Available for all Products**

Visit <http://mwj.hotims.com/11713-157> or use RS# 157 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)



## ■ Ultra Broadband Bias Tee

The model BT-50K18 Option PS is a miniature 50 kHz to 18 GHz bias tee, usable to 15 kHz.

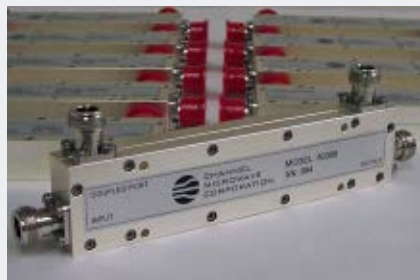


It has an insertion loss of 0.75 dB and a VSWR of 1.75 is typical. This model offers 60 dB RF/DC isolation between 10 MHz and 18 GHz. The phase of a transmitted signal is shifted less than  $\pm 7.5^\circ$ . The bias port has a series resistance of  $2.5 \Omega$  and will handle DC voltage of 15 V and current of 200 mA maximum. Size:  $0.8" \times 0.62" \times 0.4"$  with removable SMA connectors.

**American Microwave Corp.,**  
Frederick, MD (301) 662-4700,  
[www.americanmicrowavecorp.com](http://www.americanmicrowavecorp.com).

RS No. 216

## ■ Directional Couplers



These high performance directional couplers have 'Air-line' structures that offer low thru-line loss while maintaining high directivity. The couplers are available to cover the 100 MHz to 70 GHz frequency range in a variety of different configurations. The coupler can be supplied as a stand-alone component or as a section of an integrated assembly.

**Channel Microwave Corp.,**  
Camarillo, CA (805) 482-7280,  
[www.channelmicrowave.com](http://www.channelmicrowave.com).

RS No. 217

## ■ Waterproof QMA Connector

This connector is claimed to be the first waterproof QMA connector optimized for applications up to 6 GHz and a minimum of 100 cycles.



With an IP 68 waterproof rating it features the Quick-Lock locking mechanism, allows  $360^\circ$  rotation and small dimensions. It can be mated with QLF certified QMA connectors and is vibration resistant as SMA to MIL standard. It supports all radio frequency connections and has been designed for users who need fast and space-saving connections in outdoor applications such as wireless communications and transmission systems, portable radio systems, air traffic control and monitoring systems, and assemblies for mobile radio base stations.

**Huber + Suhner AG,**  
Herisau, Switzerland +41 (0) 71 353 4111,  
[www.hubersuhner.com](http://www.hubersuhner.com).

RS No. 220

## ■ High Power T/R Switch

The P/N M20-064 is a high power T/R switch that operates in a frequency range from 20 to 2500 MHz. These switches utilize the company's multi-octave technology that is compatible with the latest GaN and LDMOS solid-state amplifiers.



The switches are designed for both prototyping and high volume low cost production. This T/R switch is capable of handling up to 100 W, with an ultra low insertion loss of only 1 dB maximum and an output VSWR of  $< 1.42$ .

**Comtech PST, Hill Engineering Division,**  
Topsfield, MA (978) 887-5754,  
[www.comtechpst.com](http://www.comtechpst.com).

RS No. 218

## ■ Connectorized Double-balanced Mixer

The model HMC-C035 is a connectorized GaAs MMIC double-balanced mixer module that is ideal for use as an up-converter or down-converter in military EW/ECM, radar, microwave radio, space and test equipment applications from 23 to 37 GHz. This model is a general purpose, double-balanced mixer housed in a miniature, hermetic module. This mixer provides an input IP3 of +19 dBm, 35 dB of LO/RF and LO/IF suppression, and typical conversion loss of 9 dB.



**Hittite Microwave Corp.,**  
Chelmsford, MA (978) 250-3343,  
[www.hittite.com](http://www.hittite.com).

RS No. 219

## ■ High Isolation OMTs

This range of ortho-mode transducers (OMT) provides isolation better than 40 dB between the Tx and Rx ports, with 100 dB possible by integrating the OMT with an optional transmit rejection filter.



The OMTs are designed to be attached to the conical feed horn in a mobile SATCOM system, and their function is to separate Tx and Rx polarizations and frequencies. Spearheading the range is a Ku-band OMT, which is made from aluminum and measures 55.5 mm in length (excluding filter). It has a typical Rx bandwidth of 11 to 12.75 GHz and a typical Tx bandwidth of 13.75 to 14.50 GHz, with a maximum transmit power of 56 dBm. The range also includes a C-band OMT for use in commercial SATCOM systems and an X-band version for military applications.

**Link Microtek Ltd.,**  
Basingstoke, Hampshire, UK  
+44 (0)1256 355771,  
[www.linkmicrotek.com](http://www.linkmicrotek.com).

RS No. 221

## ■ Nine-channel Switched Filter

The model 9IFA-20/600-SR is a nine-channel switched filter band used in airborne counter-measure test set applications. Specifications include: nine channels with bandwidth ranging from 10 to 550 MHz; insertion loss of 5 dB; and VSWR of 2.0. This filter offers rejection of 60 dB to 10



GHz, TTL logic, switching speed of 250 ns and DC power of +5 V at 200 mA.

**Lorch Microwave,**  
Salisbury, MD (410) 860-5100,  
[www.lorch.com](http://www.lorch.com).

RS No. 222

## ■ Wireless Band Loads

The V-Line RF loads are optimized for excellent performance across all wireless bands.



Their rugged construction makes them ideal for both base station and in-building wireless systems. These wireless

band loads are available from stock, even in large quantities.

**MECA Electronics,**  
Denville, NJ (973) 625-0661,  
[www.e-meca.com](http://www.e-meca.com).

RS No. 223

## ■ High Pass Filters

Using a seven-section high pass filter design, the VHF series filters provide excellent passband



matching (typical VSWR is 1.5), flat passband response and a sharp transition band. The high pass filters deliver excellent sub-harmonic rejection of 850 to 13000 MHz. Built with solid stainless steel unibody construction and coated with a durable gold finish, these units feature SMA type connectors, can handle high power (up to 7 W at input) and are temperature stable from  $-55^\circ$  to  $100^\circ\text{C}$ . These filters are ideal for eliminating sub-harmonics and for DC blocking. Typical applications include transmitter/receiver filtering, repeaters and lab test setups. Price: in stock, from \$24.95 each (Qty. 1-9).

**Mini-Circuits,**  
Brooklyn, NY (718) 934-4500,  
[www.minicircuits.com](http://www.minicircuits.com).

RS No. 224

## ■ PCS Receive Filter

The part number 8C9-1880-X60N11 is a PCS receive band filter. This unit is centered at



1880 MHz with a flat passband of 60 MHz. Passband insertion loss comes in at

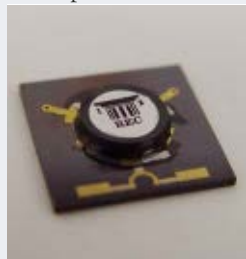
less than 0.8 dB, with a passband return loss of greater than 16 dB. The filter also has 60 dB of attenuation at 1930 to 1990 MHz. This unit sized at only 1.75" high x 2.75" wide x 5.5" long has Type N connectors, but can be fitted with most any RF connector.

**Reactel Inc.,**  
Gaithersburg, MD (301) 519-3660,  
[www.reactel.com](http://www.reactel.com).

**RS No. 225**

### WiFi Surface-mount Isolator

The model 2W6NB is a surface-mount microstrip isolator that is designed for WiFi



IEEE 802.11a wireless-local-area-network (WLAN) applications from 5.15 to 5.35 GHz. This model provides an excellent match between the antenna and the WLAN receiver circuitry. Occupying a footprint of only 12 x 12 mm for use in PCMCIA cards, the compact isolator achieves port-to-port isolation of 17 dB with an insertion loss of 0.4 dB. Price and availability: less than \$5.00 (1,000,000 qty.).

**Renaissance Electronics Corp.,**  
Harvard, MA (978) 772-7774,  
[www.rec-usa.com](http://www.rec-usa.com).

**RS No. 226**

### Waveguide Broadwall Coupler

This standard range of multi-hole broadwall directional couplers operates in the frequency range from 40 to 2.6 GHz in standard waveguide sizes. The electrical characteristics of high directivity and coupling flat-



ness are achieved by using a precise machined coupling hole pattern and a precision load in the secondary arm. Non-standard configurations or selected parameters are available on request.

**RLC Electronics Inc.,**  
Mount Kisco, NY (914) 241-1334,  
[www.rlcelectronics.com](http://www.rlcelectronics.com).

**RS No. 227**

### EDGE Radio

The Helios™ II-Plus EDGE radio provides a high level of integration and robust performance. The Helios II-Plus is ideal for manufacturers developing next-generation quad-band handsets incorporating advanced multimedia features such as DVB-H, FM radios, MP3 players, digital cam-



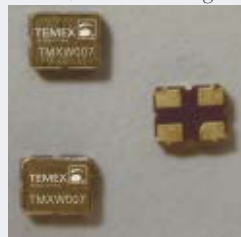
eras and Web browsing. Helios II-Plus reduces radio frequency (RF) board space by an additional 25 percent when compared to the company's previous Helios design. Skyworks' radio solution also interfaces with virtually any analog baseband and radically simplifies factory calibration, allowing OEMs to substantially increase production throughput. In addition, Helios II-Plus surpasses GSM and EDGE specifications under a variety of real-world conditions such as extreme temperature, low battery voltage and antenna mismatch. Most importantly, Helios II-Plus enables increased user talk times by exceeding transmitted radiated power (TRP) specifications for improved current consumption.

**Skyworks Solutions Inc.,**  
Woburn, MA (781) 376-3000,  
[www.skyworksinc.com](http://www.skyworksinc.com).

**RS No. 228**

### RF SAW Filter

The W007 is a RF SAW filter for GPS receivers, which is designed for marine navigation as well as automotive and leisure-industry applications. For GPS applications RF filters must be capable of combining a low insertion loss and high rejection and



the W007 offers excellent insertion loss/rejection trade-offs. The device has a minimum absolute attenuation of 40 dB at 1710 MHz. The filter center frequency is 1575.42 MHz with a bandwidth of 2.4 MHz, over a temperature range of -40° to +85°C. It is RoHS compliant and available in a lead-free SMD 2.5 x 2 x 0.9 mm package.

**TEMEX SAS,**  
Sophia-Antipolis, France  
+33 (0) 4 97 23 30 00, [www.temex.com](http://www.temex.com).

**RS No. 229**

### Cavity Filter

The model CFB7-800 is a cavity filter designed to address the interference mitigation requirements for the Public Safety and SMR markets. This filter features a passband of 794 to 806 MHz with an insertion loss of 1 dB. Isolation is specified at 90 dB at F<776 MHz and F>827



MHz. Connectors are SMA female. The design provides high "Q" and stable temperature performance in a small package. Applications include tower top amplifiers and in-building bi-directional amplifier configurations where component size is critical. Size: 2.25" x 3.063" x 7".

**Trilithic Inc.,**  
Indianapolis, IN (317) 895-3600,  
[www.trilithic.com](http://www.trilithic.com).

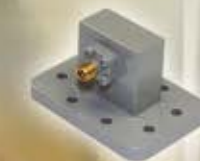
**RS No. 230**

## Microwave Components For Wireless Telecommunications, Military & Aerospace Industries

### Waveguide & Coaxial Couplers



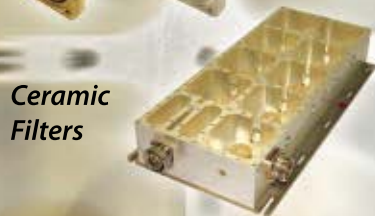
### Waveguide to Coaxial Adapters



### Waveguide Filters



### Ceramic Filters



### Diplexers



### Dual Mode Filters



# UBS

Unique Broadband Systems Ltd.

Toll Free 1-877-669-8533  
Email: [sales@uniquesys.com](mailto:sales@uniquesys.com)  
[www.uniquesys.com](http://www.uniquesys.com)



# N Stock

RF Connectors stocks one of the largest inventories of OEM N connectors in North America. We offer 30 types of bulkhead and panel mount N connectors, ready to ship. Most feature silver-plated bodies, PTFE dielectrics and gold contacts. Custom design is available.



**RF**  
connectors  
Division of RF Industries

(800)233-1728

(858)549-6340

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

Visit <http://mwj.hotims.com/11713-111>

## Come Join a Growing Company

Hittite Microwave Corporation is an innovative designer and manufacturer of analog and mixed-signal ICs, modules and subsystems for RF, microwave and millimeterwave applications covering DC to 110 GHz. Our RFIC/MMIC products are developed using state-of-the-art GaAs, GaN, InGaP/GaAs, InP, SOI, SiGe and BiCMOS semiconductor processes and support a wide variety of wireless/wired communications and sensor applications for Automotive, Broadband, Cellular Infrastructure, Fiber Optics, Microwave & Millimeterwave Communications, Military, Space and Test & Measurement markets.

*We have career opportunities for experienced:*

- Western Regional Sales Manager
- Sales Engineer • Product Engineer
- Applications Engineer • Marketing Engineer
- Program Manager
- Microwave Engineers & Managers
- Contracts Administrator
- MMIC Power Amplifier Designer
- RFIC/MMIC Design Engineer
- Microwave Device Modeling Engineer
- Mechanical Engineer • Engineering Test Technician

We offer an excellent and competitive benefits package. Please email your résumé indicating position of interest to:  
[hmcexec@hittite.com](mailto:hmcexec@hittite.com)

**Hittite**  
MICROWAVE CORPORATION

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

## NEW PRODUCTS

### AMPLIFIERS

#### ■ Pulsed Radar Amplifier

The model SSPA 3.1-3.5-1500-RM is a high power, pulsed RF amplifier that operates from 3.1 to 3.5 GHz in a rack-mounted configuration. It will also operate down to 3 GHz, if requested. This PA is ideal for S-band military radars. It is packaged in a 3u high, 19-inch rack-mounted enclosure. This amplifier has a typical peak output power of 2000 W at a 5 percent duty cycle with a 64  $\mu$ s pulse width. This amplifier offers a typical saturated gain of 55 dB with a typical power flatness of  $\pm 1$  dB.



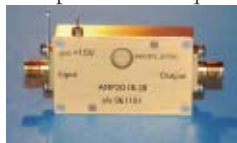
**Aethercomm Inc.,**

San Marcos, CA (760) 598-4340, [www.aethercomm.com](http://www.aethercomm.com).

**RS No. 231**

#### ■ High Performance Amplifiers

The model AMP2G18-28 is a broadband high performance amplifier that operates in a frequency range from 2 to 18 GHz with a nominal gain of 28 dB. Gain flatness is better than  $\pm 2$  dB with typical values of  $\pm 1.5$  dB. Noise figure is better than 4 dB with mid-band values of below 3 dB typical. This amplifier features a P1dB of at least +10 dBm and VSWR is typically better than 2.0. The AMP2G18-28 utilizes the latest in microwave semiconductor technology resulting in an integrated and economical high performance solution.



**Amplical Corp.,**

Verona, NJ (201) 919-2088, [www.amplical.com](http://www.amplical.com).

**RS No. 232**

#### ■ Ultra-low Noise Amplifiers

This new line of ultra-low noise JCA amplifiers has just been released. With over twenty new models available to cover many of the popular microwave frequency bands, narrowband models can be optimized for sub 0.5 dB noise figures over 100 to 200 MHz sub-bands, with broadband multi-octave noise figure performance under 1 dB maximum for C-band frequencies and below. Higher frequency models are available upon request.



**Endwave Defense Systems,**

Sunnyvale, CA (408) 522-3180, [www.endwave.com](http://www.endwave.com).

**RS No. 233**

#### ■ Detection Log Video Amplifier

The model SDLVA-61F-80-582987-004 option TBRK, MS is a matched set of successive detection log video amplifiers in a compact stacked configuration. This unit operates over 61.25 MHz  $\pm 250$  kHz and has been designed so that both modules share a common power terminal.



**Planar Monolithics Industries,**

Frederick, MD (301) 631-1579, [www.planarmonolithics.com](http://www.planarmonolithics.com).

**RS No. 234**

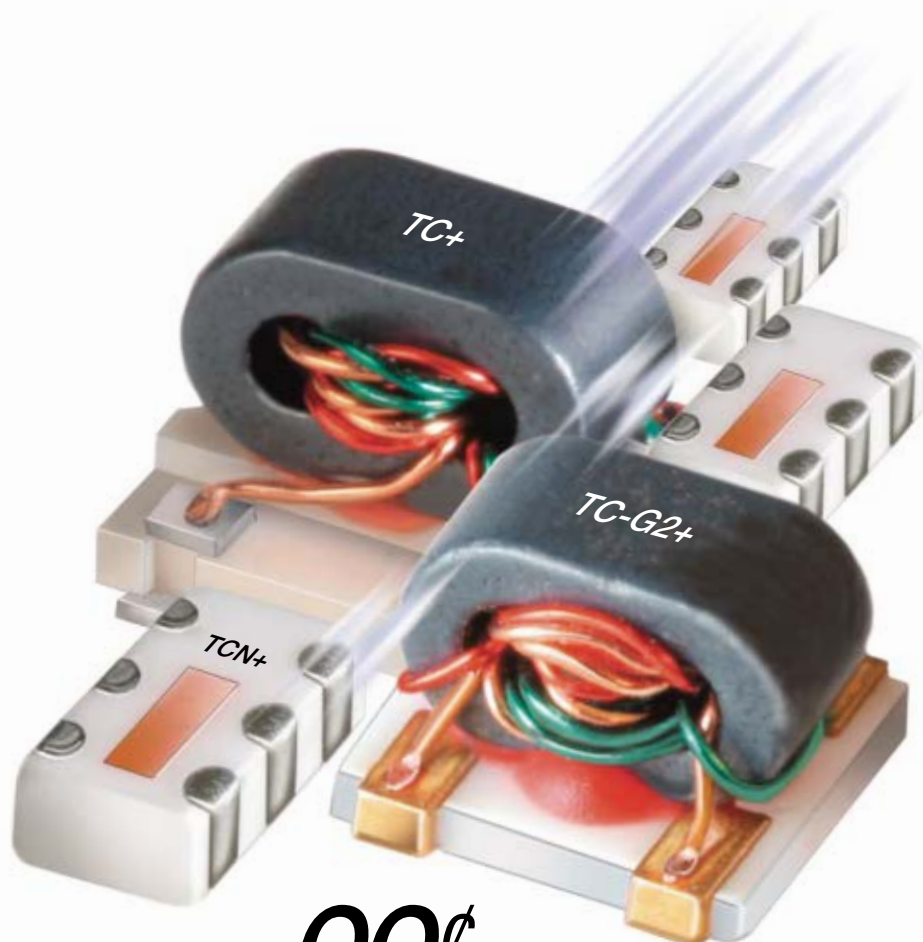
### ANTENNA

#### ■ Telemetry Antenna System

This lightweight segmented reflector antenna system is designed for telemetry applications with integral LNA. Operation is over a 10 percent bandwidth. This antenna system features a lightweight rugged segmented composite construction that breaks down into seven separate pieces for ease of transportation. This reflector antenna operates from 1.71 to 1.85 GHz and provides nominal gain of 23.5 dBi. Also available is an associated low directivity antenna and switch that allows



# TINY RF & MICROWAVE TRANSFORMERS



.3-3000MHz as low as **99¢** IN STOCK each (qty. 100)

Mini-Circuits wide selection of broadband transformers demonstrates excellent VSWR with impedance ratios from 1:1 up to 16:1, covering from 300KHz to 3GHz. To meet your demanding size, performance, and environmental requirements Mini-Circuits offers three package styles to accommodate your transformer Microwave & RF needs.

**TCN+** mini-packaged Low Temperature Co-fired Ceramic transformers deliver outstanding thermal stability high reliability, and permit fast high volume manufacturing.

**TC+** models have compact open case design, all-welded construction, and offer high-strength plastic base for low cost commercial applications.

**TC-G2+** ceramic base with gold plated terminations, for military and high reliability requirements.

These low cost transformers are the best price/performance buy in the business! For detailed specifications, full data, and Designer Kits see our Website.

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

 Available as RoHS compliant.

  
.12"x.06"

  
.15"x.15"

**Mini-Circuits®**  
ISO 9001 ISO 14001 CERTIFIED

**ALL NEW**  
**minicircuits.com**

P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661 For detailed performance specs & shopping online see Mini-Circuits web site



The Design Engineers Search Engine Provides ACTUAL Data Instantly From MINI-CIRCUITS At: [www.minicircuits.com](http://www.minicircuits.com)

**RF/IF MICROWAVE COMPONENTS**

377 RevK

Visit <http://mwj.hotims.com/11713-90> or use RS# 90 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)



selection between high and low directivity antennas for far/near communication links. Other models are also available for other frequency ranges and applications.

**Cobham Defense Electronic Systems,  
Nurad Division,  
Baltimore, MD (410) 542-1700,  
www.cobhamdes.com.**

RS No. 235

## INTEGRATED CIRCUIT

### Receiver and Transmitter Chipset



The GaAs MMIC, sub-harmonically pumped receiver and transmitter devices are identified as XR1006-QD and XU1002-QD, respectively. These chips integrate an image reject sub-harmonic anti-parallel diode mixer, an LO buffer amplifier and a low noise amplifier for the receiver, and an output amplifier for the transmitter. The image reject mixer eliminates the need for an image bandpass filter after the amplifier to remove thermal noise at the image frequency. Using 0.15 micron gate length GaAs PHEMT device model technology, these devices cover the 17 to 25 GHz frequency bands. The receiver offers a noise figure of 2.5 dB and 20 dB image rejection across the band.

**Mimix Broadband Inc.,  
Houston, TX (281) 988-4600,  
www.mimixbroadband.com.**

RS No. 236





**PUSH-ON  
SMA & N  
Adapters**

**K Adapters**

**Custom  
Connectors**

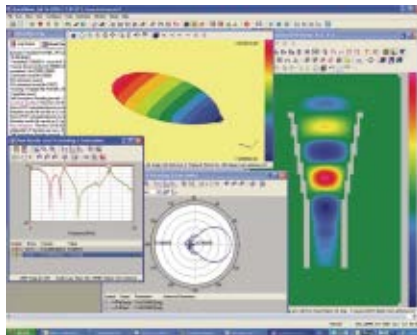
**Test Cable  
Assemblies**



**www.rftec.com**

## SOFTWARE

### EM Modeling Tool



Additions to the Concerto series 6 high frequency electromagnetic modeling tool include new and enhanced solvers, sophisticated model parameterization and an enhanced scripting capability. Component or system models can be imported from CAD programs, or created using a powerful, built-in, 3D geometric modeler. Users have a choice of three simulation methods to characterize performance. As standard, Concerto offers a 3D Finite Difference Time Domain simulator. A 2D FDTD simulator for axisymmetric geometry is available as is adaptive meshing. Depending on the application, users have two further simulation options—a Method of Moments tool and a new Finite Element Method tool.

**Vector Fields Ltd.,  
Kidlington, Oxford, UK  
+44 (0)1865 370151,  
www.vectorfields.com.**

RS No. 239

## SOURCES

### Customized Direct Synthesizers

The company now offers customized direct frequency synthesizers to meet the most exacting specifications.



The company has added the capability to produce variations of standard models with auxiliary outputs and fixed frequency/single frequency, among other options. With its modular architecture, the company can produce many "specials" to fit within 19" cabinets. The standard product line includes high quality, fast-switching, low noise synthesizers in 14 different ranges, with frequency ranges from 0.1 to 40 MHz to 1 to 6400 MHz with optional resolution ( $\mu$ Hz to kHz). Switching time runs from 1-20  $\mu$ s, depending on the digit (decade) switched.

**Programmed Test Sources Inc.,  
Littleton, MA (978) 486-3400,  
www.programmedtest.com.**

RS No. 241

### Multi-band Synthesizer



The MBS-500 multi-band frequency synthesizer is a wideband frequency source designed for use in RF test and measurement applications. This synthesizer operates in a frequency range from 100 to 500 MHz in a single unit. The MBS-500 features step size of 100 kHz, output power of +14 dBm and phase noise of less than -95 dBc/Hz at 10 kHz offset. Including its internal frequency reference, the MBS-500 is packaged in a 3.5" x 2.5" x 0.6" package with SMA output connector.

**EM Research Inc.,  
Reno, NV (775) 345-2411,  
www.emresearch.com.**

RS No. 240

### Surface-mount Synthesizer

The model FSFS315555-500 is a frequency synthesizer that tunes in 5 MHz steps and can



work with any external reference source from 10 to 250 MHz, specified for settling time of 50 microseconds or less to within 10 kHz of a new frequency.

Fast switching speed and low phase noise are often conflicting goals for a frequency synthesizer, but the new FSFS315555-500 miniature surface-mount frequency synthesizer provides outstanding performance for both parameters across a 2400 MHz tuning range from 3150 to 5550 MHz. The frequency synthesizer is programmed by means of a simple three-wire serial interface.

**Synergy Microwave Corp.,  
Paterson, NJ (973) 881-8800,  
www.synergymicrowave.com.**

RS No. 242

### L-band Frequency Synthesizer

The model SFS1680A-LF is an ultra-small smart synthesizer series that eliminates external programming.



This product is a new class of synthesizer for a high quality, fixed frequency stable signal source, and makes life simpler

for the system designer. The smart design takes care of locking every time the circuit is switched on or even every time it loses lock due to external factors. The design includes features like lock detect. SFS1680-LF delivers clean stable signal with reference spurious suppression better than -80 dBc and phase noise of -106 dBc/Hz at 10 kHz offset. Size: 0.60" x 0.60". Price: \$49.00/unit (5 pcs min). Delivery: three to five weeks.

**Z-Communications Inc.,  
San Diego, CA (858) 621-2700,  
www.zcomm.com.**

RS No. 243

**KR Electronics**  
[www.krfilters.com](http://www.krfilters.com)



**Custom & Standard Filters to 3 GHz**

Bandpass Anti-Aliasing Highpass Video Filters Diplexers Delay Equalized Surface Mount	Lowpass Notch Root Cosine Equalizers Linear Phase Absorptive
---------------------------------------------------------------------------------------------------------	-----------------------------------------------------------------------------

KR Electronics, Inc.  
Avenel, NJ  
[www.krfilters.com](http://www.krfilters.com)

sales@krfilters.com  
Phone 732.636.1900  
Fax 732.636.1982

RS 68

**SECTOR MICROWAVE INDUSTRIES, INC.**



\* DPDT  
\* TYPE N, SMA, BNC, TNC  
\* MANUAL OVERRIDE  
\* DC THROUGH 23 GHZ.

(631) 242-2300 FAX (631) 242-8158  
[www.sectormicrowave.com](http://www.sectormicrowave.com)

RS 125

**Laboratory (RF) MicroProbe Station**

**Extremely Low Cost**  
**< \$10,000 US**  
**DC/RF/Microwave Test**



A ultra compact, manually operated probe station for engineers, scientists and students. Measure Microwave, RF and IV parameters of Semiconductor Devices. Characterize MEMS, wireless, photonic and nanoelectronic components and assemblies.

- Benchtop Size (11") • 2" Vacuum chuck with pump • 1" X-Y-Z stage with z-lift
- 2 ea. 0.5" X-Y-Z probe positioners, includes 2 ea. 18 GHz probes & DC needles
- 10X/30X Stereo Zoom Trinocular Microscope • Fluorescent Illuminator
- Compatible with additional Magnetic Mount Positioners (optional)
- Compatible with industry standard microwave probes (optional)

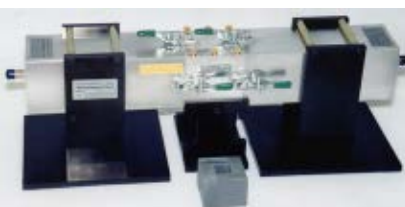
• Cost effective for research projects •

**J microTechnology**  
3744 NW Bluegrass Pl  
Portland, OR 97229  
(503) 614-9509  
(503) 531-9325 (FAX)  
[www.jmicrotechnology.com](http://www.jmicrotechnology.com)

**Research Performance / Student Price**

RS 63

**Square Coax Lines**  
Absorbers, Honeycomb, Solids  
Thin Shielding Materials

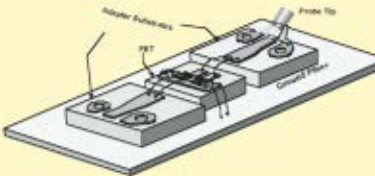


**Mu and Epsilon**  
Calibration Standards  
Quick Connect/Disconnect

**[www.damaskosinc.com](http://www.damaskosinc.com)**  
damaskos@aol.com  
(610)358-0200 fax(610)558-1019

RS 37

**ProbePoint™ CPW-μStrip Adapter Substrates**



- Precision CPW to μStrip Adapter Substrates
- Companion Calibration Substrates and Standards
- Standard & custom Carriers
- Accurate Electrical Data to Frequencies >50 GHz
- 5, 10, & 15 mil thickness
- Compatible with 40GHz+ probes
- Standard and Custom Calibration Standards

**J microTechnology**  
3744 NW Bluegrass Pl  
Portland, OR 97229  
(503) 614-9509  
(503) 531-9325 (FAX)  
[www.jmicrotechnology.com](http://www.jmicrotechnology.com)

**Test Tooling for the Unstable**

RS 64

**New and Used Electronic Test Equipment**  
**Buy / Sell / Trade**

Spectrum Analyzers  
Network Analyzers  
Telecommunications  
Oscilloscopes  
Power Supplies  
Signal Generators



ValueTronics sells new and used electronic test equipment and is interested in purchasing your surplus test equipment.

To buy or sell, please contact one of our knowledgeable sales engineers via phone or email or visit our web page.

**ValueTronics International, Inc.**  
Toll Free (US & Canada): 800-552-8258  
Phone: 847-468-8258  
Email: [snb@valuetronics.com](mailto:snb@valuetronics.com)

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

**Tektronix** **Agilent Technologies**  
**BK PRECISION** **ADVANTEST** **FLUKE**

RS 152

**DC-40 GHz Filters & Multiplexers**  
Broadband  
Suspended-Substrate  
Filters, Diplexers, Triplexers, Quadruplexers, Quintuplexers, Sextuplexers...



- Std. Crossovers: 1,2,4,8,12,18,26 GHz
- Non Std. Your Specs
- Other Lines: Switch Filter Banks

**ES Microwave, LLC**  
8031 Cessna Avenue, Gaithersburg, MD 20879  
P: 301-519-9407 F: 301-519-9418  
[www.esmicrowave.com](http://www.esmicrowave.com)

RS 48

**AST Advanced Switch Technology**

694 Fortune Cr  
Kingston, On  
K7P 2T3  
Canada  
Tel: 613 384 3939  
Fax: 613 384 5026  
E-mail: [info@astswitch.com](mailto:info@astswitch.com)



AST is the only company exclusively dedicated to the manufacturing of switches. Our commitment to quality and performance is unmatched in the industry.

If it's switches you're looking for, your only choice is AST.

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

RS 2

**Personal Probe Station**

**Very Low Cost High Function**



A compact full featured, modestly priced, manually operated probe station developed for engineers and scientists. Measure Microwave, RF and DC parameters of Semiconductor Devices, Packages and Assemblies with NIST traceability.

- Benchtop Size (<11") • Vacuum chuck • X-Y-Z stage
- X-Y-Z probe positioners • Top Plate Z-lift • Vacuum Accessory Manifold
- 6.5X-112.5X Stereo Zoom Microscope • Adjustable Halogen Illuminator
- Vacuum Accessories • Compatible with 40GHz+ probes
- Accessories for Thermal Chucks and Probe Cards
- Compatible with Magnetic Mount Positioners

• Test wafers, microstrip packages and surface mount components •

**J microTechnology**  
3744 NW Bluegrass Pl  
Portland, OR 97229  
(503) 614-9509  
(503) 531-9325 (FAX)  
[www.jmicrotechnology.com](http://www.jmicrotechnology.com)

**A Probe Station On Every Bench**

RS 65

187



# RF & HYPER

33<sup>rd</sup> EDITION

## EUROPE 2007

THE TRADE SHOW DEDICATED TO RADIOFREQUENCIES, MICROWAVES,  
WIRELESS, OPTICAL FIBRE AND THEIR APPLICATIONS

MARCH 27, 28 & 29, 2007

CNIT - PARIS LA DEFENSE

### AT THE HEART OF EMERGING MARKETS

Come and discover at the RF & Hyper Europe trade show the latest technological developments presented by more than 150 exhibitors who are experts in radiofrequencies, microwaves, and optical fibre.

You will find the latest innovations in active and passive components, modules, systems, simulation or design software, instrumentation and test for applications in telecommunications (Wifi, Wimax, 3G, Bluetooth, UWB, ZigBee...), satellite connections, avionics, military, safety, as well as the new developments in RFID systems.

### EVENTS 2007

ANTENNAS in the spotlight  
at the exhibition!

2 days of EMC conferences not to be  
missed.

After its success in 2006: a new edition  
of RF TECHNOLOGIES AND PACKAGING  
seminars.

To register as an exhibitor, request  
a badge or register for the conferences:

**www.RFHyper.com**

#### EXPOSIUM

1, rue du Parc - 92593 Levallois-Perret Cedex, France

Tel.: +33 (0)1 49 68 51 00 - Fax : +33 (0)1 49 68 54 18 - E-mail : RFHyper@exposium.fr

Visit <http://mwj.hotims.com/11713-110> or use RS# 110 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)

RF & Hyper Europe, an exhibition  
organized by EXPOSIUM

[www.exposium.fr](http://www.exposium.fr)



# Come to Boston Massachusetts...

*"The place where it all began"*

On Patriot's Day  
Monday April 16, 2007



Paul Revere's Midnight Ride



Battle on Lexington Green



Battle at North Bridge



Boston Red Sox Home Game



Boston Marathon



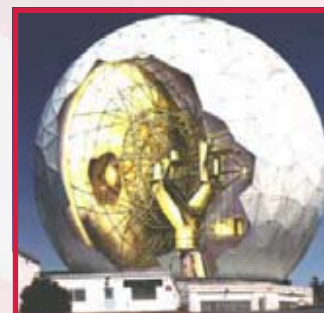
## IEEE Radar Conference

17-20 April 2007

The Westin Hotel, Waltham, MA

### Conference Highlights:

- Over 100 technical papers
- Topics covering all aspects of radar and radar systems
- Two days of short courses from leaders in the field
- Tour MIT Lincoln Laboratory's new 96GHz Haystack Radar in Westford
- Tour Raytheon's premier MMIC Foundry in Andover
- Military radar industry and commercial exhibitors



Haystack Upgrade, Westford, MA



Raytheon Foundry, Andover, MA



### Sponsored by

IEEE Aerospace & Electronic Systems Society,  
IEEE Boston Section

### Technical Cosponsors

IEEE Antennas and Propagation Society,  
IEEE Space Geoscience & Remote Sensing Society,  
IEEE Microwave Theory & Techniques Society,  
IEEE Signal Processing Society



[www.radar2007.org](http://www.radar2007.org)



To see one's work in print is the rightful reward of every creative engineer and scientist. The editors of *Microwave Journal* invite you to submit your technical manuscripts for consideration to be published in one of our upcoming issues. Technical articles, application notes and tutorial articles based on the monthly editorial themes are encouraged. Editorial themes include wireless, radar and antennas; RF components and systems; test, measurement and CAD; amplifiers and oscillators; semiconductor, MMICs and RFICs; satellite and mm-wave applications; communications and wireless applications; passive components; and control devices and modulation.

Design features should contain new and innovative technical ideas of practical use and interest to our predominantly engineering readers. Papers should be 14 to 16 double-spaced pages and contain 8 to 12 visual aids in the form of sketches, graphs, photographs or tables.

Papers should be submitted to the attention of the Technical Editor and will be reviewed promptly by our Editorial Review Board prior to acceptance. Articles outside of the monthly themes also will be encouraged.

### SEND ALL MATERIAL TO:

**Microwave Journal**  
685 Canton Street  
Norwood, MA 02062  
(781) 769-9750

Fax (781) 769-5037

e-mail:

fbashore@mwjournal.com



### APPLICATION NOTE

This application note, "Preamplifiers and System Noise Figure," is designed to assist engineers in learning how to improve the accuracy of their measurements by using a low noise amplifier in front of a spectrum analyzer to reduce the effective noise figure of RF and microwave test systems. This paper discusses applications and characteristics of Agilent's latest amplifier technology. Highlighted are Agilent's 87405C portable preamplifiers that provide exceptional gain of 25 dB and a probe-power bias connection.

**Agilent Technologies Inc.,**  
Palo Alto, CA (800) 829-4444,  
[www.agilent.com](http://www.agilent.com).

RS No. 200

### RELAY & SWITCH CATALOG

This product catalog features the company's reed relays and dry reed switches. The catalog includes detailed product information, electrical specifications and mechanical drawings for its full product line, including Coto's many new product series and configurations. The catalog also provides updated technical applications sections and color performance graphs.

**Coto Technology,**  
Warwick, RI (401) 943-2686,  
[www.cotorelay.com](http://www.cotorelay.com).

RS No. 201

### PRODUCT CATALOG

This catalog features the company's family of XpressO™ oscillators and outlines its new oscillator technology, which makes it possible for these XpressO configurable crystal oscillators to deliver more accurate performance over a wide range of parameters at a low cost. Advantages of these oscillators include frequencies that range from 1 MHz to 1.1 GHz, stabilities as tight as  $\pm 20$  ppm, and low jitter and phase noise.

**Fox Electronics,**  
Fort Myers, FL (888) 438-2369,  
[www.foxonline.com](http://www.foxonline.com).

RS No. 202

## NEW LITERATURE

### PRODUCT CATALOG

The 2007 test and measurement product catalog offers details and specifications on the company's general-purpose and sensitive sourcing and measurement products, DC switching, RF switching and measurement, data acquisition solutions, semiconductor test systems and optoelectronics test hardware. Arranged by major product type and application area, each section of the catalog contains a tutorial on test-system design and use with practical tips.

**Keithley Instruments Inc.,**  
Cleveland, OH (800) 688-9951,  
[www.keithley.com](http://www.keithley.com).

RS No. 203

### PRODUCT LITERATURE

This product literature features the company's new 18 GHz SCM Fiber Optic Link. The 18 GHz version is an addition to the company's successful SCM Fiber Optic Link product line.

The SCM links are "Plug and Play," requiring no external circuits. These links exhibit high dynamic range and low noise contribution. Typical applications include antenna remoting, LO remoting, Inter-Facility RF links, EMC test setups and scientific applications.

**MITEQ Inc.,**  
Hauppauge, NY (631) 436-7400,  
[www.miteq.com](http://www.miteq.com).

RS No. 204

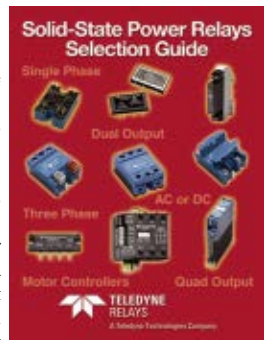
### SELECTION GUIDE

The solid-state power relays selection guide is designed for industrial applications and features 40 families of relays and motor controllers in a tabular format designed in an easy to use format to quickly assist engineers in choosing a product.

The 24-page digest provides detailed information about the AC and DC relays and motor controllers, with output up to 125A, 690Vac.

**Teledyne Relays,**  
Hawthorne, CA (800) 284-7007,  
[www.teledynereleys.com](http://www.teledynereleys.com).

RS No. 205



# The Idea Was... To Develop A High Performance, Rack Mount Synthesizer That Fits Your Budget & The Palm Of Your Hand.

## SPECIFICATIONS

### RF Output Frequency Range:

#### Output options:

Amplifier/Filter	350 - 1050 MHz
Divider Option	5.5 - 1050 MHz

### Bandwidth:

700 MHz

### Step Size: 1 Hz

### Internal Reference

#### Options:

<b>TCXO Specifications</b>	12.8 MHz
Temperature Stability	$\pm 1.5 \times 10^{-6}$
Aging first year	$\pm 2 \times 10^{-6}$
Operating Temp. Range	-10 to +60 °C

(With freq. adjustment through voltage control pin)

<b>OCXO Specifications</b>	13 MHz
Temperature Stability	$\pm 2.0 \times 10^{-6}$
Aging first year	$\pm 1 \times 10^{-7}$
Operating Temp. Range	-10 to +70 °C
Warm-Up Time:	10 min.

Additional Current Consumption	500 mA (warm-up)
After warm-up	200 mA (continuous)

### External Reference Input:

10, 12.8, 13, 19.44 MHz  
and multiples thereof  
VCC: +13 VDC ( $\pm 3$  V)

### Bias Voltage:

Supply Current: <800 mA @ 13 V

Bias Voltage Ripple: 100 mV p-p (Max)

RF Output Power: (w/amp. option) +10 dBm (Min)

When Unlocked:  $\leq 20$  dBm

Spurious Suppression: -65 dBc (Max)

### Harmonic Suppression:

Amplifier/Filter option	15 dBc (Min)
Divider option (Full range model)	8 dBc (Min)
(Octave band in divider range)	15 dBc (Min)

### Maximum Phase Noise

Offset	Frequency: 350 MHz (dBc/Hz)	Frequency: 1050 MHz (dBc/Hz)
100 Hz	-108	-100
1 kHz	-110	-102
10 kHz	-115	-110
100 kHz	-115	-115
1 MHz	-140	-140

### Switching Speed:

Per programming step:	$\leq 8$ mSec
After Turn-on	<1 Sec

### Output Impedance:

50 Ohms (Nom)

### Operating Temp. Range:

(See reference option)

### Storage Temp. Range:

-40 to +85 °C



## MTS3000DS series



### Features

- Over an octave bandwidth tuning
- Small step size resolution
- Outstanding spectral purity
- High spurious rejection
- Fast lock settling time
- Easy programmable format
- Internal Reference
- 3 HU 19" rack cassette
- 350-1050 MHz \*
- 1 Hz Resolution
- -110 dBc @ 10 kHz
- +13  $\pm 3$  V supply

- Also available as piggy back board -

Programming Interface: 3.3V SPI, 3.3V I2C, RS232  
or (Ethernet - special development requires NRE and longer leadtime)  
\* Available bandwidth up to 3:1 with frequencies ranging  
from 60 to 6500 MHz.



For additional information, contact Synergy's sales and application team.  
Phone: (973) 881-8800 Fax: (973) 881-8361 E-mail: sales@synergymwave.com  
Visit Our Web Site At [WWW.SYNERGYMWAVE.COM](http://WWW.SYNERGYMWAVE.COM)

Visit <http://mwj.hotims.com/11713-136> or  
use RS# 136 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)



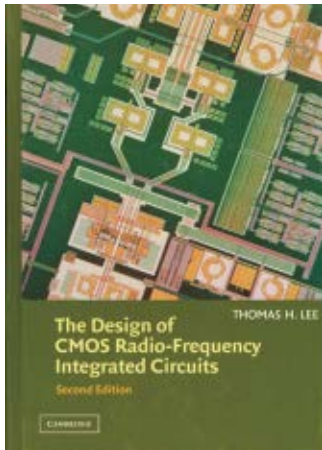


## ***The Design of CMOS Radio-frequency Integrated Circuits: Second Edition***

**Thomas H. Lee**

**Cambridge University Press • 815 pages; \$80**

**ISBN: 0-521-83539-9**



**To order this book, contact:**  
Cambridge University Press  
100 Brook Hill Drive  
West Nyack, NY 10994-2133  
(845) 353-7500

Since publication of the first edition of this book in 1998, RF CMOS has made a rapid transition to commercialization. Back then, the only notable examples of RF CMOS circuits were academic and industrial prototypes. Today, the situation is quite different, with many companies now manufacturing RF circuits using CMOS technology and with universities around the world teaching at least something about CMOS as an RF technology. This second edition now includes a chapter on the fundamentals of wireless systems. A few illustrative systems—such as IEEE 802.11 wireless LAN, second- and third-generation cellular technology and emerging technologies such as ultra-wideband (UWB)—are briefly examined. The chapter on passive RLC components now directly precedes a much-expanded chapter on passive IC components, rather than following it. The chapter on CMOS device physics has likewise been updated to reflect recent

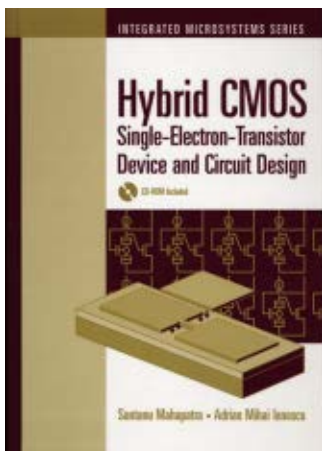
scaling trends. The related chapter on LNA design includes a detailed discussion of our much-improved understanding of MOS noise mechanisms at radio frequencies. In another rearrangement, the chapter on feedback now precedes that on power amplifiers in order to establish principles necessary for understanding several linearization methods. The chapter on power amplifiers has been greatly expanded to include much more on the subject of techniques for linearization and efficiency enhancement. The chapter on transceiver architectures now includes much more detailed coverage of the direct conversion architecture. Persistent, dedicated work by a host of determined engineers has overcome many of the daunting challenges that underlie the pessimism expressed in the first edition. Significant refinements, clarifications and corrections have been applied to nearly all the chapters, thanks to a wealth of ongoing research.

## ***Hybrid CMOS: Single-Electron-Transistor Device and Circuit Design***

**Santanu Mahapatra and Adrian Mihai Ionescu**

**Artech House • 229 pages; \$129, £78**

**ISBN: 1-59693-069-1**



**To order this book, contact:**  
Artech House  
685 Canton St.  
Norwood, MA 02062  
(781) 769-9750 ext. 4030; or  
46 Gillingham St.  
London SW1V 1HH, UK  
+44 (0) 207-8750

This book addresses, from an engineering perspective, the basic physics and the new designs and functionality that can be supported by single-electron devices. Rather than suggesting this new technology as a replacement solution for silicon CMOS, the authors foresee, with some concrete examples and arguments, the hybridization of single-electron devices and MOS transistors to address some of the great challenges associated with nanoscale integrated circuits. Chapter 1 introduces the reader to the CMOS scaling principles and limits, and the appearance of the single electronic field. Single-electron transistor (SET) and MOSFET devices are compared from the perspective of device operation and some of their complementary characteristics are highlighted. In Chapter 2, the state-of-the-art in the simulation of a single-electron device is reviewed, along with the related physics. It is shown that advanced single-electron circuit design re-

quires the development of compact models and one such successful model (MIB) is presented in detail and discussed. Chapter 3 discusses SET logic circuits and the MIB model is used to illustrate the circuit configurations with realistic simulations. Static currents in SET inverters and related power dissipation are estimated and analyzed. Chapter 4 deals with the concept of the hybridization of the SET and CMOS. It discusses co-simulation and co-design issues for hybrid circuits and proposes a CAD framework, including examples. Chapter 5 addresses the application of the SET for developing multiple valued logic and memory. It is demonstrated that single electronic implementation can outperform CMOS alternatives for such applications. Chapter 6 introduces the reader to the fabrication of SET devices with nanoscale features. Despite the fact that no industrial SET technology is available today, the reported progress in the field is very significant.

# Beam Lead Diodes

## Performance & Quality Designed for You

**AEROFLEX / METELICS'**  
Silicon and GaAs high performance microwave diodes for active imaginations.

### The AEROFLEX / METELICS Advantage

- ✓ Comprehensive line of microwave diodes including: PIN, Step Recovery, Schottky, Tunnel and Varactor diodes plus MIS/MOS capacitors.
- ✓ Industry's largest selection of package and screening options.
- ✓ Application specific solutions at catalog prices.

All of our Microwave diodes are available in industry standard packages for effortless, low-cost improvement of your present designs.

**Aeroflex / Metelics**

Phone: 408-737-8181

[sales@aeroflex-metelics.com](mailto:sales@aeroflex-metelics.com)

[www.aeroflex-metelics.com](http://www.aeroflex-metelics.com)

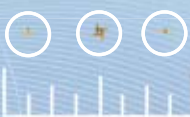


ISO 9001: 2000

**AEROFLEX**  
A passion for performance.

Microscopic  
Precision

Actual Size

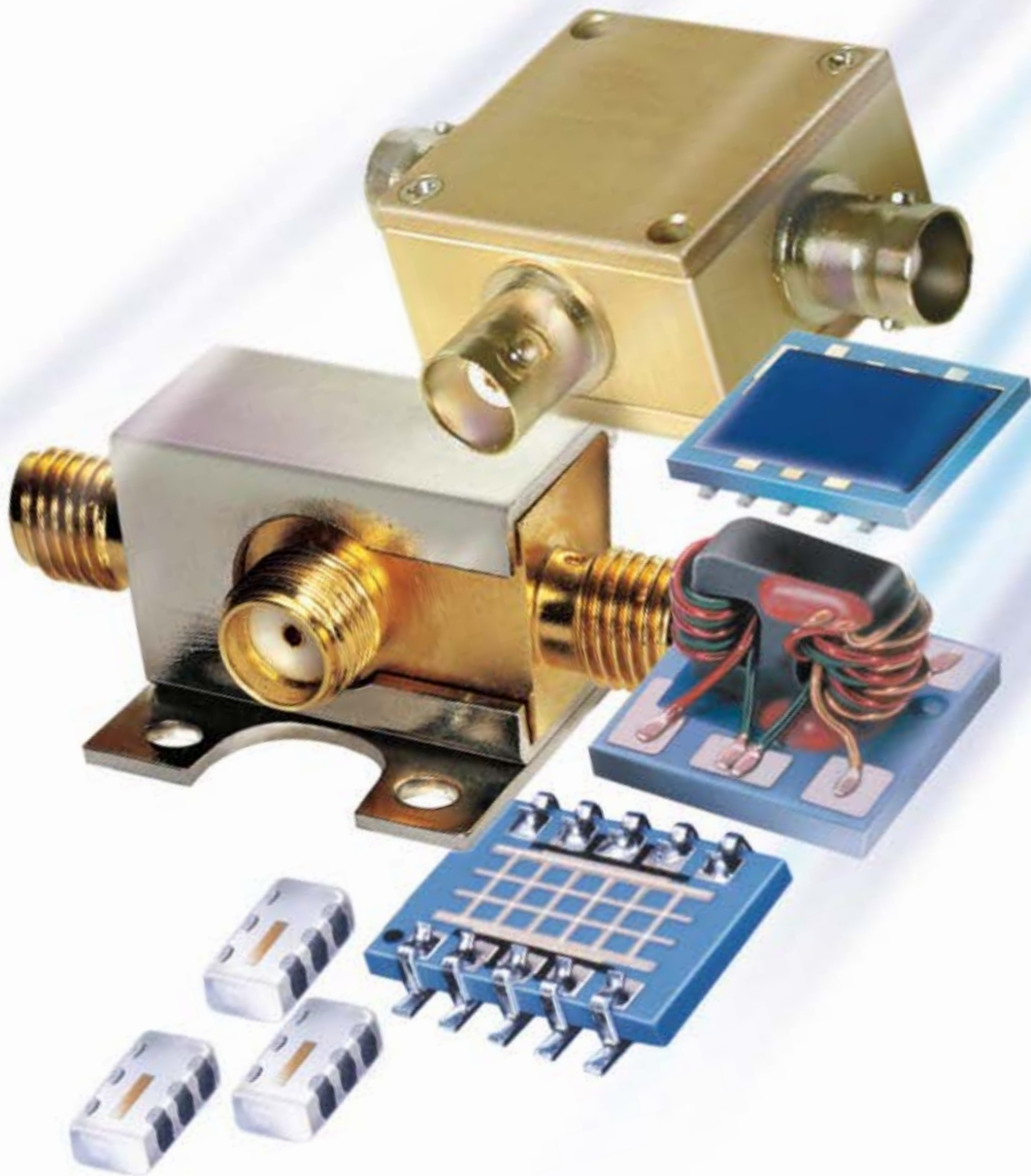


1 inch

Visit <http://mwj.hotims.com/11713-7> or use RS# 7 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)



RS No.	ADVERTISER	PAGE No.	PHONE	FAX	WEB ADDRESS
1	Advanced Control Components Inc. ....	99	732-460-0212	732-460-0214	http://mwj.hotims.com/11713-1
2	Advanced Switch Technology ....	187	613-384-3939	613-384-5026	http://mwj.hotims.com/11713-2
3	Aeroflex ....	39	516-694-6700	516-694-2562	http://mwj.hotims.com/11713-3
4	Aeroflex Plainview ....	135	800-645-8862		http://mwj.hotims.com/11713-4
5	Aeroflex/Inmet, Inc. ....	156	734-426-5553	734-426-5557	http://mwj.hotims.com/11713-5
6	Aeroflex/KDI-Integrated Products ....	177	973-887-5700 ext. 500	973-884-0445	http://mwj.hotims.com/11713-6
7	Aeroflex/Metelics, Inc. ....	193	408-737-8181	408-733-7645	http://mwj.hotims.com/11713-7
8	Aeroflex/Weinschel, Inc. ....	79	800-638-2048	301-846-9116	http://mwj.hotims.com/11713-8
9	Aethercomm ....	38	760-598-4340	760-598-4342	http://mwj.hotims.com/11713-9
10,11,12, 13,14	Agilent Technologies, Inc. ....	17,83,97, 119,153	800-829-4444	415-857-5518	http://mwj.hotims.com/11713-10
15	ALK Engineering ....	122	410-546-5573	410-860-9069	http://mwj.hotims.com/11713-15
16	American Microwave Corporation ....	179	301-662-4700	301-662-4938	http://mwj.hotims.com/11713-16
17	American Technical Ceramics ....	129	631-622-4700	631-622-4748	http://mwj.hotims.com/11713-17
18	AML Communications Inc. ....	65	805-388-1345	805-484-2191	http://mwj.hotims.com/11713-18
19	Anaren Microwave ....	117	800-411-6596	315-432-9121	http://mwj.hotims.com/11713-19
20	Ansoft Corporation ....	143	412-261-3200	412-471-9427	http://mwj.hotims.com/11713-20
21	Applied Wave Research, Inc. ....	162	310-726-3000		http://mwj.hotims.com/11713-21
22,23	AR Worldwide ....	58,139	215-723-8181	215-723-5688	http://mwj.hotims.com/11713-22
24	Artech House ....	126	800-225-9977	781-769-6334	http://mwj.hotims.com/11713-24
25	Avtech Electrosystems ....	126	888-670-8729	613-226-2802	http://mwj.hotims.com/11713-25
26	Barry Industries, Inc. ....	82	508-226-3350	508-226-3317	http://mwj.hotims.com/11713-26
27	Bird Technologies Group ....	90	866-695-4569		http://mwj.hotims.com/11713-27
28	Cernex, Inc. ....	15	408-541-9226	408-541-9229	http://mwj.hotims.com/11713-28
29	Ciao Wireless, Inc. ....	42	805-389-3224	805-389-3629	http://mwj.hotims.com/11713-29
30	Cobham Defense Electronic Systems .	22-23	978-557-2400	978-557-2800	http://mwj.hotims.com/11713-30
31	Coleman Microwave Company ....	174	800-563-3449	800-563-3450	http://mwj.hotims.com/11713-31
32	Comotech Corporation ....	146	+82-52-288-7550	+82-52-288-7551	http://mwj.hotims.com/11713-32
33	Compex Corporation ....	132	856-335-2277	856-335-7223	http://mwj.hotims.com/11713-33
34	CPI Beverly Microwave Division ....	28	978-922-6000	978-922-2736	http://mwj.hotims.com/11713-34
35	CST of America, Inc. ....	31	781-416-2782	781-576-5702	http://mwj.hotims.com/11713-35
36	CTIA Wireless 2007 ....	92	202-736-3664	202-785-0721	http://mwj.hotims.com/11713-36
37	Damaskos Inc. ....	187	610-358-0200	610-558-1019	http://mwj.hotims.com/11713-37
38	Delta Electronics Mfg. Corp. ....	171	978-927-1060	978-922-6430	http://mwj.hotims.com/11713-38
39	Dow-Key Microwave Corporation ....	6	805-650-0260	805-650-1734	http://mwj.hotims.com/11713-39
40	Eastern Wireless TeleComm, Inc. ....	173	410-749-3800	410-749-4852	http://mwj.hotims.com/11713-40
41	Electro Magnetic Careers ....	178			http://mwj.hotims.com/11713-41
42	Elisra Electronic Systems Ltd. (Microwave Division) ....	33	972(3)6175655	972(3)6175299	http://mwj.hotims.com/11713-42
43	EM Research, Inc. ....	147	775-345-2411	775-345-1030	http://mwj.hotims.com/11713-43
44	EMC Technology Inc. ....	19	772-286-9300	772-283-5286	http://mwj.hotims.com/11713-44
45	Emerson Network Power ....	127	800-247-8256		http://mwj.hotims.com/11713-45
46	Emhiser Micro-Tech ....	84	775-345-0461	775-345-1152	http://mwj.hotims.com/11713-46
47	Endwave Defense Systems ....	27	408-522-3180	408-522-3181	http://mwj.hotims.com/11713-47
48	ES Microwave, LLC ....	187	301-519-9407	301-519-9418	http://mwj.hotims.com/11713-48
49	ET Industries ....	141	973-394-1719	973-394-1710	http://mwj.hotims.com/11713-49
50	ETS-Lindgren ....	169	512-531-6400		http://mwj.hotims.com/11713-50
51	EuMW 2007 ....	180	+ 44 20 7596 8742	+ 44 20 7596 8749	http://mwj.hotims.com/11713-51
52	Filtron Compound Semiconductors, Ltd. ....	161	408-850-5740	831-621-8074	http://mwj.hotims.com/11713-52
53	Filtron Signal Solutions ....	131	603-459-1600	603-459-1605	http://mwj.hotims.com/11713-53
44	Florida RF Labs Inc. ....	19	800-544-5594		http://mwj.hotims.com/11713-44
54	G.T. Microwave Inc. ....	76	973-361-5700	973-361-5722	http://mwj.hotims.com/11713-54
55	GGB Industries, Inc. ....	3	239-643-4400	239-643-4403	http://mwj.hotims.com/11713-55
56	Herley New England ....	74	781-729-9450	781-729-9547	http://mwj.hotims.com/11713-56
57	Herrotek, Inc. ....	20	408-941-8399	408-941-8388	http://mwj.hotims.com/11713-57
	Hittite Microwave Corporation ....	184	978-250-3343	978-250-3373	www.hittite.com
58	Huber + Suhner AG ....	30	+41 (0)71 353 41 11	+41 (0)71 353 45 90	http://mwj.hotims.com/11713-58
	IEEE MTT-S International Microwave Symposium - Hawaii ....	114-115,174,197	781-769-9750	781-769-5037	www.ims2007.org
	IEEE Radar Conference 2007 ....	189			www.radar2007.org
59	Interad Ltd. ....	64	757-787-7610	757-787-7740	http://mwj.hotims.com/11713-59
60	Isola Corp. ....	149	800-845-2904		http://mwj.hotims.com/11713-60



## Directional/Bi-Directional **LTCC COUPLER FAMILY**



**IN STOCK** \$**169**  
From ea. Qty. 1000

Mini-Circuits LTCC coupler family offers versatile, low cost solutions for your **5 to 4200MHz** 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 & 75Ω directional and bi-directional couplers with coupling ranging from 6-22dB 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 65W. 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!**

**Mini-Circuits®**  
ISO 9001 ISO 14001 CERTIFIED

**ALL NEW**  
**minicircuits.com**

P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661 For detailed performance specs & shopping online see Mini-Circuits web site



The Design Engineers Search Engine Provides ACTUAL Data Instantly From MINI-CIRCUITS At: [www.minicircuits.com](http://www.minicircuits.com)

**RF/IF MICROWAVE COMPONENTS**

396 Rev D

Visit <http://mwj.hotims.com/11713-91> or use RS# 91 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)



RS No.	ADVERTISER	PAGE No.	PHONE	FAX	WEB ADDRESS
61	ITT Corporation	103	978-441-0200		<a href="http://mwj.hotims.com/11713-61">http://mwj.hotims.com/11713-61</a>
62	IWCE 2007	94	800-927-5007		<a href="http://mwj.hotims.com/11713-62">http://mwj.hotims.com/11713-62</a>
63,64,65	J microTechnology	187	503-614-9509	503-531-9325	<a href="http://mwj.hotims.com/11713-63">http://mwj.hotims.com/11713-63</a>
66	JFW Industries, Inc.	133	317-887-1340	317-881-6790	<a href="http://mwj.hotims.com/11713-66">http://mwj.hotims.com/11713-66</a>
67	K&L Microwave, Inc.	7	410-749-2424	443-260-2268	<a href="http://mwj.hotims.com/11713-67">http://mwj.hotims.com/11713-67</a>
68	KR Electronics, Inc.	187	732-636-1900	732-636-1982	<a href="http://mwj.hotims.com/11713-68">http://mwj.hotims.com/11713-68</a>
69	Locus Microwave, Inc.	122	814-466-6275	814-466-1104	<a href="http://mwj.hotims.com/11713-69">http://mwj.hotims.com/11713-69</a>
70	Lorch Microwave	45	800-780-2169	410-860-1949	<a href="http://mwj.hotims.com/11713-70">http://mwj.hotims.com/11713-70</a>
71	M/A-COM, Inc.	11	800-366-2266	978-442-5350	<a href="http://mwj.hotims.com/11713-71">http://mwj.hotims.com/11713-71</a>
72	Marki Microwave, Inc.	46	408-778-4200	408-778-4300	<a href="http://mwj.hotims.com/11713-72">http://mwj.hotims.com/11713-72</a>
73	Maury Microwave Corporation	9	909-987-4715	909-987-1112	<a href="http://mwj.hotims.com/11713-73">http://mwj.hotims.com/11713-73</a>
74	MECA Electronics, Inc.	88	973-625-0661	973-625-9277	<a href="http://mwj.hotims.com/11713-74">http://mwj.hotims.com/11713-74</a>
75	Micro Lambda Wireless, Inc.	105	510-770-9221		<a href="http://mwj.hotims.com/11713-75">http://mwj.hotims.com/11713-75</a>
76	Microwave Development Laboratories	89	781-292-6680/6684	781-453-8629	<a href="http://mwj.hotims.com/11713-76">http://mwj.hotims.com/11713-76</a>
	<i>Microwave Journal</i>	98,190,197	800-225-9977	781-769-5037	<a href="http://www.mwjjournal.com">www.mwjjournal.com</a>
77	Mimix Broadband, Inc.	COV 3	281-988-4600	281-988-4615	<a href="http://mwj.hotims.com/11713-77">http://mwj.hotims.com/11713-77</a>
78,79,80,	Mini-Circuits	4-5,18,35,			
81,82,83,		49,50,61,			
84,85,86,		75,100-101,121,			
87,88,89,		137,145,157,			
90,91		185,195	718-934-4500	718-332-4661	<a href="http://mwj.hotims.com/11713-78">http://mwj.hotims.com/11713-78</a>
92	Mini-Systems, Inc.	96	508-695-0203	508-695-6076	<a href="http://mwj.hotims.com/11713-92">http://mwj.hotims.com/11713-92</a>
93,94	MITEQ Inc.	40-41,175	631-436-7400	631-436-7430	<a href="http://mwj.hotims.com/11713-93">http://mwj.hotims.com/11713-93</a>
95	Modelithics, Inc.	64	888-359-6359	813-558-1102	<a href="http://mwj.hotims.com/11713-95">http://mwj.hotims.com/11713-95</a>
96	Narda Microwave-East, an L3 Communications Co.	8	631-231-1700	631-231-1711	<a href="http://mwj.hotims.com/11713-96">http://mwj.hotims.com/11713-96</a>
97	Networks International Corporation	34	913-685-3400	913-685-3732	<a href="http://mwj.hotims.com/11713-97">http://mwj.hotims.com/11713-97</a>
98	Noisecom	21	973-386-9696	973-386-9191	<a href="http://mwj.hotims.com/11713-98">http://mwj.hotims.com/11713-98</a>
99	OML Inc.	159	408-779-2698	408-778-0491	<a href="http://mwj.hotims.com/11713-99">http://mwj.hotims.com/11713-99</a>
100	Pascall Electronics Limited	62	+44(0) 1983 817300	+44(0) 1983 564708	<a href="http://mwj.hotims.com/11713-100">http://mwj.hotims.com/11713-100</a>
101	Pendulum Instruments	151	+46 8 598 510 55		<a href="http://mwj.hotims.com/11713-101">http://mwj.hotims.com/11713-101</a>
102	Phase One Microwave Inc.	60	916-784-9072	916-784-9074	<a href="http://mwj.hotims.com/11713-102">http://mwj.hotims.com/11713-102</a>
103	Picosecond Pulse Labs Inc.	73	303-209-8100	303-447-2236	<a href="http://mwj.hotims.com/11713-103">http://mwj.hotims.com/11713-103</a>
104	Planar Electronics Technology, Inc.	66-67	301-662-5019	301-662-1731	<a href="http://mwj.hotims.com/11713-104">http://mwj.hotims.com/11713-104</a>
157	Planar Monolithic Industries, Inc.	181	301-631-1579	301-662-2029	<a href="http://mwj.hotims.com/11713-157">http://mwj.hotims.com/11713-157</a>
105	Prewell Corporation	142	82-31-420-8362	82-31-420-8369	<a href="http://mwj.hotims.com/11713-105">http://mwj.hotims.com/11713-105</a>
106	Radio Research Instrument Co., Inc.	124	203-753-5840	203-754-2567	<a href="http://mwj.hotims.com/11713-106">http://mwj.hotims.com/11713-106</a>
107	Reactel, Incorporated	14	301-519-3660	301-519-2447	<a href="http://mwj.hotims.com/11713-107">http://mwj.hotims.com/11713-107</a>
108	REMEC Defense & Space	80	858-560-1301		<a href="http://mwj.hotims.com/11713-108">http://mwj.hotims.com/11713-108</a>
109	Renaissance Electronics Corporation	44	978-772-7774	978-772-7775	<a href="http://mwj.hotims.com/11713-109">http://mwj.hotims.com/11713-109</a>
110	RF & Hyper Europe 2007	188	33 (0)1 49 68 51 00	33 (0)1 49 68 54 18	<a href="http://mwj.hotims.com/11713-110">http://mwj.hotims.com/11713-110</a>
111	RF Connectors, Division of RF Industries	184	800-233-1728	858-549-6340	<a href="http://mwj.hotims.com/11713-111">http://mwj.hotims.com/11713-111</a>
112	RF Micro Devices	69	336-678-5570	336-931-7454	<a href="http://mwj.hotims.com/11713-112">http://mwj.hotims.com/11713-112</a>
113	RF TEC Mfg., Inc.	186	770-487-2187	770-486-9499	<a href="http://mwj.hotims.com/11713-113">http://mwj.hotims.com/11713-113</a>
114,115,116	RFHIC	106,108,110	82-31-250-5011	82-31-250-5088	<a href="http://mwj.hotims.com/11713-114">http://mwj.hotims.com/11713-114</a>
117	RFMW, Ltd.	113	877-367-7369	408-414-1461	<a href="http://mwj.hotims.com/11713-117">http://mwj.hotims.com/11713-117</a>
118	RLC Electronics, Inc.	25	914-241-1334	914-241-1753	<a href="http://mwj.hotims.com/11713-118">http://mwj.hotims.com/11713-118</a>
119	Rogers Corporation	111	480-961-1382	480-961-4533	<a href="http://mwj.hotims.com/11713-119">http://mwj.hotims.com/11713-119</a>
120	Rohde & Schwarz GmbH	59	+49-1805-124242	+49-89-412913777	<a href="http://mwj.hotims.com/11713-120">http://mwj.hotims.com/11713-120</a>
121	Rosenberger	107	+49-8684-18-0	+49-8684-18-499	<a href="http://mwj.hotims.com/11713-121">http://mwj.hotims.com/11713-121</a>
122	Roswin Inc.	120	+82-41-621-4450	+82-41-621-4451	<a href="http://mwj.hotims.com/11713-122">http://mwj.hotims.com/11713-122</a>
123	S.M. Electronics	155	800-715-4396	972-984-1218	<a href="http://mwj.hotims.com/11713-123">http://mwj.hotims.com/11713-123</a>
124	San-Tron Inc.	COV 2	978-356-1585	978-356-1573	<a href="http://mwj.hotims.com/11713-124">http://mwj.hotims.com/11713-124</a>
125	Sector Microwave Industries, Inc.	187	631-242-2300	631-242-8158	<a href="http://mwj.hotims.com/11713-125">http://mwj.hotims.com/11713-125</a>
126	Sirenza Microdevices	63	303-327-3030		<a href="http://mwj.hotims.com/11713-126">http://mwj.hotims.com/11713-126</a>
127	Skyworks Solutions, Inc.	53	781-376-3000		<a href="http://mwj.hotims.com/11713-127">http://mwj.hotims.com/11713-127</a>
128	Special Hermetic Products, Inc.	48	603-654-2002	603-654-2533	<a href="http://mwj.hotims.com/11713-128">http://mwj.hotims.com/11713-128</a>
129	Spectrum Elektrotechnik GmbH	85	+49-89-3548-040	+49-89-3548-0490	<a href="http://mwj.hotims.com/11713-129">http://mwj.hotims.com/11713-129</a>
130	State of the Art, Inc.	72	800-458-3401	814-355-2714	<a href="http://mwj.hotims.com/11713-130">http://mwj.hotims.com/11713-130</a>
131	Suss MicroTec AG	29	(+49) 35240/73-0		<a href="http://mwj.hotims.com/11713-131">http://mwj.hotims.com/11713-131</a>
132	SV Microwave, Inc.	71	561-840-1800	561-842-6277	<a href="http://mwj.hotims.com/11713-132">http://mwj.hotims.com/11713-132</a>
133	Symmetricom	36	978-232-1497		<a href="http://mwj.hotims.com/11713-133">http://mwj.hotims.com/11713-133</a>
134,135,136	Synergy Microwave Corporation	57,123,191	973-881-8800	973-881-8361	<a href="http://mwj.hotims.com/11713-134">http://mwj.hotims.com/11713-134</a>



# INTERNATIONAL MICROWAVE SYMPOSIUM HONOLULU, HAWAII IEEE MICROWAVE THEORY AND TECHNIQUES SOCIETY



**IEEE**

**JUNE 5-7, 2007**



**RESERVE BOOTH SPACE EARLY  
JOIN THESE COMPANIES THAT HAVE ALREADY  
RESERVED SPACE IN THE 2007 EXHIBITION**

A-Alpha Waveguide Co.  
Acceleware Inc.  
Actipass Co. Ltd.  
Advanced Control Components Inc.  
Aeroflex Inc.  
Aerowave Inc.  
Aethercomm Inc.  
Agilent Technologies  
Akon Inc.  
Allrizon-TG Communications Equ.  
American Microwave Corp.  
American Standard Circuits Inc.  
American Technical Ceramics  
Ametek HCC Industries  
Ametek Specialty Metal Products  
AML Communications Inc.  
AmpliTech Inc.  
Analog Devices Inc.  
Anaren Inc.  
Anritsu Co.  
Ansoft Corp.  
*Antenna Systems & Technology*  
Apollo Microwaves Ltd.  
Applied Thin-Film Products  
Applied Wave Research Inc.  
AR Worldwide  
ARA  
ARC Technologies Inc.  
Artech House  
ASB Inc.  
Assemblies Inc.  
Astrolab Inc.  
Auriga Measurement Systems  
Avnet Electronics Marketing  
Barry Industries Inc.  
Besser Associates Inc.  
Bird Technologies Group  
BL Microwave Ltd.  
Bliley Technologies Inc.  
Boonton Electronics  
Bowei Integrated Circuits Co. Ltd.  
Brush Ceramic Products  
C-MAC MicroTechnology  
Cadence Design Systems Inc.  
California Eastern Labs  
Cambridge University Press  
CAP Wireless Inc.  
Cascade Microtech  
Centellax Inc.  
Ceramic Products Group  
Cernex Inc.  
Chengdu AINFO Inc.  
Ciao Wireless Inc.  
Circuits Processing Technology  
Cobham DES  
Coining of America LLC  
COM DEV/CodeOne  
Commercial Microwave Technology  
Compex Corp.  
Component Distributors Inc.  
CoorsTek  
Corning Gilbert Inc.  
CPI Canada  
Cree Inc.  
CST of America Inc.  
CTT Inc.  
Cuming Microwave Corp.  
Custom Cable Assemblies Inc.

Custom Microwave Components  
dBm  
Delta Electronics Mfg Corp.  
Delta Microwave  
DeWeyl Tool Co.  
Diamond Antenna  
Dielectric Laboratories Inc.  
Dow Key Microwave  
Ducommun Technologies Inc.  
DuPont  
Dynawave Inc.  
e2v Technologies  
EADS NA Defense Test & Services  
Eagle Comtronics  
Elcom Technologies Inc.  
Electro Rent Corp.  
Electromagnetic Technologies Inds.  
Elisra Electronic Systems Ltd.  
EM Research Inc.  
EM Software & Systems (PTY) Ltd.  
EMAG Technologies Inc.  
EMC Technology Inc.  
Emerson & Cuming  
Emerson & Cuming Microwave Prod.  
Emerson Network Power Conn.  
Emhiser Micro-Tech  
Endwave Corp.  
Eudyna Devices Inc.  
European Microwave Week  
Excelcise Semiconductor Inc.  
F&K Delvotec Inc.  
Fairchild Semiconductor  
Farran Technology Ltd.  
The Ferrite Company Inc.  
Filtel Microwave Inc.  
Filtran Microcircuits Inc.  
Filtronic Compound Semicond.  
Filtronic Sage Laboratories Inc.  
Flexco Microwave Inc.  
Florida RF Labs Inc.  
Focus Microwaves Inc.  
Freescale Semiconductor  
Gaiser Tool Co.  
General Dynamics C4, VertexRSI  
Gerotron Communication GmbH  
GGB Industries Inc.  
Giga-tronics Inc.  
GigaLane Co. Ltd.  
Global Communication Semicond.  
WL Gore & Associates Inc.  
Gowanda Electronics  
Gryphics Inc.  
GT Microwave Inc.  
Herley Industries Inc.  
Herotek Inc.  
Hesse & Kripps Inc.  
*High Frequency Electronics*  
Hittite Microwave Corp.  
HTMicrowave Co. Ltd.  
*IEEE Communications Magazine*  
*IEEE Microwave Magazine*  
IHP GmbH  
IMST GmbH  
Infineon Technologies  
Inphi Corp.  
Instruments for Industry (IFI)  
Integra Technologies Inc.  
International Manufacturing Svcs.

Ion Beam Milling Inc.  
iTerra Communications  
ITF Co. Ltd.  
ITT Corporation  
IW Inc.  
J MicroTechnology Inc.  
Jacket Micro Devices Inc.  
Jazz Semiconductor  
Jersey Microwave  
JFW Industries Inc.  
Johanson Manufacturing Corp.  
Johanson Technology Inc.  
Johnson Components  
Johnstech International Corp.  
Junper Interconnection Co. Ltd.  
K&L Microwave Inc.  
Keithley Instruments Inc.  
KMIC Technology Inc.  
Krytar Inc.  
Kyocera America Inc.  
L-3 Communications, Narda-East  
LadyBug Technologies LLC  
Landsale Semiconductor Inc.  
Laser Process Mfg. Inc.  
Linear Photonics  
Linearizer Technology  
Litron Inc.  
Lorch Microwave  
LPKF Laser & Electronics  
M/A-COM Inc.  
M2 Global Technology Ltd.  
Marubeni Chemix Corp.  
Mauri Microwave Corp.  
MCV Technologies Inc.  
MECA Electronics Inc.  
Mega Circuit Inc.  
Meggitt Safety Systems Inc.  
Merix Corp.  
Merrimac Industries Inc.  
Metallix Inc.  
MICA Microwave  
Mician GmbH  
Micro Limited  
Micro Lambda Wireless Inc.  
Micro-Chem Inc.  
Microlab/FXR  
Micrometries Inc.  
Microsemi Corp.  
Microtech Inc.  
Microwave Applications Group  
Microwave Communications Labs  
Microwave Development Labs Inc.  
Microwave Device Technology  
Microwave Innovation Group  
*Microwave Journal*  
*Microwave Product Digest*  
Microwave Technology Inc.  
*Microwaves & RF*  
Midwest Microwave  
*MIL/COTS Digest*  
Millitech Inc.  
Mimix Broadband Inc.  
Mini-Systems Inc.  
Mission Telecom Co.  
MITEQ Inc.  
Mitsubishi Electric & Electronics  
Modelithics Inc.  
Modular Components National Inc.

Molex RF/Microwave Div.  
MtronPTI  
Murata Electronics  
NaF Technology Corp.  
Natel Engineering Co. Inc.  
National Instruments  
NDK America Inc.  
Nelco  
Netcom Inc.  
Nitrone Corp.  
NOF Corp.  
Noise Com  
Northrop Grumman/Velocium Prod.  
NTK Technologies Inc.  
Nuhertz Technologies LLC  
NXP Semiconductors  
Octagon Communications  
Orient Microwave Corp.  
Ortel, division of Emcore  
P/M Industries Inc.  
Pascall Electronics Ltd.  
Passive Microwave Technology  
Pendulum Instruments-XL MW  
Penton Media Inc.  
Peregrine Semiconductor Corp.  
Phase Matrix Inc.  
Picosecond Pulse Labs  
Planar Electronics Technology  
Planar Monolithics Industries Inc.  
Plextek Ltd.  
Polyfet RF Devices  
Precision Photo-Fab Inc.  
Presidio Components Inc.  
Prewell Corp.  
Q Microwave Inc.  
QUEST Microwave Inc.  
QuinStar Technology Inc.  
QWED  
R&K Company Ltd.  
R-Theta Thermal Solutions Inc.  
Radant MEMS Inc.  
Reactel Inc.  
Reed Business Information  
Reinhardt Microtech AG  
RelComm Technologies Inc.  
Renaissance Electronics Corp.  
RF Depot.Com Inc.  
*RF Design Magazine*  
RF Globalnet  
RF Morecom  
RFMD  
RFMW Inc.  
Richardson Electronics  
RJR Polymers Inc.  
RLC Electronics Inc.  
Rogers Corp.-Advanced Circuit Mat.  
Rohde & Schwarz Inc.  
Roos Instruments Inc.  
Rosenberger North America LLC  
Roth & Rau AG  
San-tron Inc.  
Schleifring und Apparatebau GmbH  
Schmid & Partner Engineering AG  
Scientific Microwave Corp.  
Shenzhen ATEN Electronics Co.  
Shenzhen Kingsignal Cable Tech  
Sigma Systems Corp.  
Signatone (Lucas/Signatone)

Simulation Technology & Applied  
Sirenza Microdevices Inc.  
Sonnet Software Inc.  
Sources East Inc.  
Southwest Microwave Inc.  
Spectrum Elektrotechnik GmbH  
Spectrum Microwave Inc.  
SSI Cable Corp.  
State of the Art Inc.  
STC Microwave Systems Inc.  
Stellar Industries Corp.  
Storm Products Co.  
StratEdge Corp.  
Summittek Instruments Inc.  
Sunny Electronic Corp. USA  
SUSS MicroTec Inc.  
SV Microwave Inc.  
CW Swift & Associates Inc.  
Synergy Microwave Corp.  
T-Tech Inc.  
Taconic  
Teedica Inc.  
*Tech-On*  
Tegam Inc.  
Tektronix Inc.  
Telcon Co. Ltd.  
Teledyne Microelectronic Tech.  
Temptronic Corp.  
Tensolite  
Terabeam/HXI  
TeraVista Technologies Inc.  
Thales Components Corp.  
Thunderline-Z  
Times Microwave Systems  
Toshiba America Electronic Comp.  
TRAK Microwave Corp.  
Trans-Tech Inc.  
Trilithic Inc.  
TriQuint Semiconductor  
Tronser Inc.  
TRS-RenTelco  
TRU Corporation Inc.  
TTE Inc.  
Tyco Electronics  
UBE Electronics  
UltraSource Inc.  
United Monolithic Semiconductors  
Universal Microwave Corp.  
UTE Microwave Inc.  
Valpey Fisher Corp.  
Vector Fields Inc.  
Vectron International  
VIDA Products Inc.  
Vishay Intertechnology Inc.  
Voltronics Corp.  
Wave-Tech  
Weinschel Associates  
Werlatone Inc.  
West Bond Inc.  
Wiley  
Willtek  
WIN Semiconductor Corp.  
*Wireless Design & Development*  
Wireless Telecom Group  
Yixin Microwave Electronics Co.  
Z-Communications Inc.  
Zeland Software Inc.  
ZIFOR Enterprise Co. Ltd.

[www.ims2007.org](http://www.ims2007.org)

To request exhibiting information, please contact Kristen Dednah at:  
**kdednah@mwjournal.com** or 781-769-9750.

*Microwave Journal*® will provide exhibition management for the 2007 MTT-S IMS Symposium/Exhibition



RS No.	ADVERTISER	PAGE No.	PHONE	FAX	WEB ADDRESS
137	Tampa Microwave	87	813-855-2251		http://mwj.hotims.com/11713-137
138	Teledyne Cougar	125	408-522-3838	408-522-3839	http://mwj.hotims.com/11713-138
139	Teledyne Microwave	77	650-962-6944	650-962-6845	http://mwj.hotims.com/11713-139
140	Teledyne Relays	81	800-351-7368		http://mwj.hotims.com/11713-140
141	Tensolite	13	866-282-4708	562-494-0955	http://mwj.hotims.com/11713-141
142	Thunderline-Z	91	603-329-4050		http://mwj.hotims.com/11713-142
143	Tiger Micro-Electronics Institute	168	+86-28-66070208	+86-28-66070496	http://mwj.hotims.com/11713-143
144,145	Trilithic Inc.	93,95	800-344-2412	317-895-3612	http://mwj.hotims.com/11713-144
146	TriQuint Semiconductor, Inc.	54-55	503-615-9000	503-615-8900	http://mwj.hotims.com/11713-146
147	Tusonix	109	520-744-0400	520-744-6155	http://mwj.hotims.com/11713-147
148,149	Unique Broadband Systems Ltd.	52,183	877-669-8533	905-669-8516	http://mwj.hotims.com/11713-148
150	Universal Microwave Components Corporation	124	703-642-6332	703-642-2568	http://mwj.hotims.com/11713-150
151	UTE Microwave Inc.	37	732-922-1009	732-922-1848	http://mwj.hotims.com/11713-151
152	ValueTronics International, Inc.	187	847-468-8258		http://mwj.hotims.com/11713-152
153	Voltronics Corporation	167	973-586-8585	973-586-3404	http://mwj.hotims.com/11713-153
154	Weinschel Associates	136	877-948-8342	301-963-8640	http://mwj.hotims.com/11713-154
155	Wenzel Associates, Inc.	152	512-835-2038	512-719-4086	http://mwj.hotims.com/11713-155
156	Werlatone, Inc.	COV 4	845-279-6187	845-279-7404	http://mwj.hotims.com/11713-156

Visit Microwave Journal on the Web at [www.mwjjournal.com](http://www.mwjjournal.com)

Visit [mwjjournal.com/info](http://mwjjournal.com/info) and enter RS# to request information from our advertisers



MARCH 2007  
ISSUE

## RF, Analog and Digital Systems for Next Generation Electronics

## Dynamic Range for Today's Digital RF World

## Frequency Synthesis: Current Solutions and New Trends

## SALES REPRESENTATIVES



### CARL SHEFFRES, PUBLISHER

**Eastern and Central Time Zones**  
Chuck Curley  
Northeast Reg. Sales Mgr.  
(New England, Upstate NY, Eastern Canada)  
685 Canton Street  
Norwood, MA 02062  
Tel: (781) 769-9750  
FAX: (781) 769-5037  
ccurley@mwjournal.com

Michael Hallman  
Eastern Reg. Sales Mgr.  
(Mid-Atlantic, Southeast, Midwest)  
4 Valley View Court  
Middletown, MD 21769  
Tel: (301) 371-8830  
FAX: (301) 371-8832  
mhallman@mwjournal.com

Brian Green  
Inside Sales Manager  
685 Canton Street  
Norwood, MA 02062  
Tel: (781) 769-9750  
FAX: (781) 769-5037  
bgreen@mwjournal.com

### Ed JOHNSON, ASSOCIATE PUBLISHER

**Eastern and Central Time Zones**  
Ed Johnson  
Associate Publisher  
PO Box 5962  
Ocala, FL 34478-5962  
Tel: (352) 620-2442  
FAX: (352) 620-2443  
ejohnson@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  
Tel: +44 207 596 8742  
rvaughan@horizonhouse.co.uk

Michel Zoghob  
Deputy Publisher  
Tel: +44 207 596 8741  
mzoghob@horizonhouse.co.uk

46 Gillingham Street  
London SW1V 1HH, England  
Tel: +44 207 596 8740  
FAX: +44 207 596 8749

**Germany, Austria, and Switzerland (German-speaking)**

Juergen Wissling  
Wissling Marketing Services  
Riedstrasse 5  
72813 St. Johann-Wuertingen  
Germany  
Tel: +49 7122 828140  
FAX: +49 7122 828145  
jwissling@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

### KEN HERNANDEZ, TRAFFIC ADMINISTRATOR

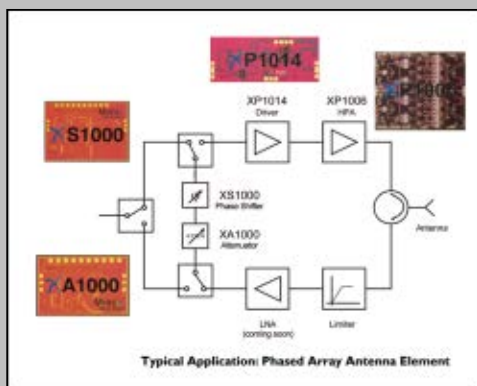
**Japan**  
Katsuhiro Ishii  
Ace Media Service Inc.  
12-6, 4-Chome,  
Nishiiko, Adachi-Ku  
Tokyo 121-0824, Japan  
Tel: +81 3 5691 3335  
FAX: +81 3 5691 3336  
amskatsu@dream.com

**China**  
Alexander Glos  
i2i Media  
16-602 China Central Place  
89# Jian Guo Road  
Chaoyang District, Beijing,  
China - 100025  
Tel: +86-10-65331960/61  
FAX: +86-10-65331959  
aglos@i2i-m.com.cn



## Mimix Defense Products... an Expanding Safety Net!

### Product Highlight: X-Band Radar Chipset



- ✕ Cost Competitive, Superior Performance Chipset
- ✕ Includes Digital Attenuator, Phase Shifter, Driver & Power Amplifier
- ✕ Excellent Linearity Performance
- ✕ Low Phase & Attenuation Errors
- ✕ XP1006: 10W+ Power Amplifier, Driven by XP1014: 1W Buffer Amplifier
- ✕ XA1000: Digital Attenuator & XS1000: Phase Shifter
- ✕ Available as Bare Die or in Packages

Our expanding family of Mimix defense products creates a safety net for design engineers.

We've leveraged our volume commercial products and technologies to offer our customers the best overall value in microwave and millimeter-wave ICs, space qualified and amplifier based modules.

This high performance at a practical cost combined with our superior systems engineering expertise **makes Mimix capable of solving even the toughest microwave integration problems.**

And of course, our defense products offer the same reliability and excellent performance that Mimix customers have come to expect from us.

When you have a tough problem, Mimix is at the ready! Learn more about our **expanding family of defense products** at [www.mimixbroadband.com](http://www.mimixbroadband.com) or by calling 281.988.4600.

Visit <http://mwj.hotims.com/11713-77> or use RS# 77 at [www.mwjjournal.com/info](http://www.mwjjournal.com/info)

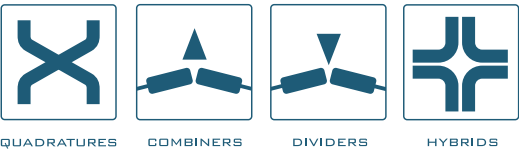
**Mimix**  
BROADBAND™  
*Providing optimal semiconductor solutions worldwide.*

Mimix Broadband, Inc., 10795 Rockley Rd., Houston, TX 77099 U.S. 281.988.4600 [mimixbroadband.com](http://mimixbroadband.com)  
©2006 All rights reserved. Mimix Broadband, Inc. Mimix Broadband is a registered trademark of Mimix Broadband, Inc. Any rights not expressly granted herein are reserved.



Wide bandwidth,  
HIGH POWER DEVICES

Unsurpassed quality + on-time delivery, is the Werlatone promise

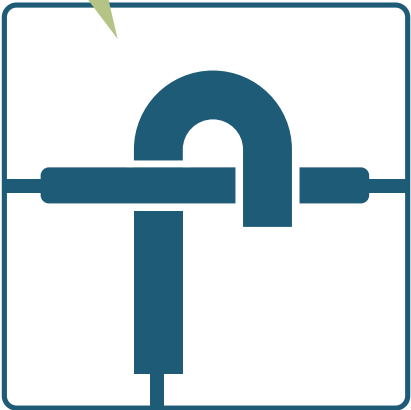


Breaking  
all the  
Rules

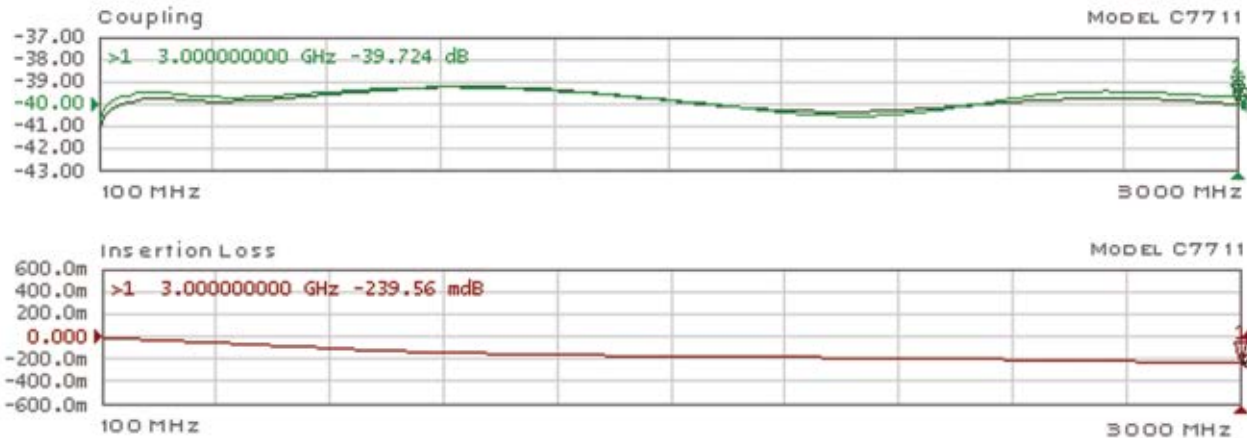


10:1+ Bandwidth  
Lowest Loss  
Directional Couplers

- Superior performance starting at 3:1 bandwidth
  - Newly Patented!
  - No exotic materials needed
- 3X thicker center boards for more power and producibility
- More sections per bandwidth for better coupling flatness
  - Electrically shorter and physically smaller
- Stripline designs invade traditional lumped element territory



COUPLERS



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

Model	Coupler Type	Frequency (MHz)	Power CW (Watts)	Coupling (dB)	Flatness (±dB)	Insertion Loss (dB)	VSWR (Mainline)	Directivity (dB)	Size (Inches)
C7734	Dual Directional	30-2500	100	43	±1.5	0.35	1.25:1	18	3.5 x 2.6 x 0.7
C7148	Bi Directional	60-600	200	10	±1.0	0.35	1.20:1	20	6.0 x 4.0 x 0.75
C7711	Dual Directional	100-3000	100	40	±1.0	0.35	1.25:1	18	3.0 x 2.2 x 0.7
C7783	Bi Directional	200-1000	200	20	±0.75	0.2	1.20:1	20	3.0 x 1.5 x 0.53
C6600	Bi Directional	200-2000	200	20	±1.2	0.25	1.25:1	18	4.0 x 2.0 x 0.72
C7152	Bi Directional	300-3000	100	20	±1.0	0.35	1.20:1	15	3.7 x 2.0 x 0.75
C7811	Dual Directional	500-2500	100	40	±0.5	0.2	1.25:1	20	3.0 x 2.0 x 0.6
C7753	Bi Directional	700-4200	100	20	±1.0	0.35	1.25:1	18	1.8 x 1.0 x 0.6