Vol. 50 • No. 10

October 2007

Microwave Journal

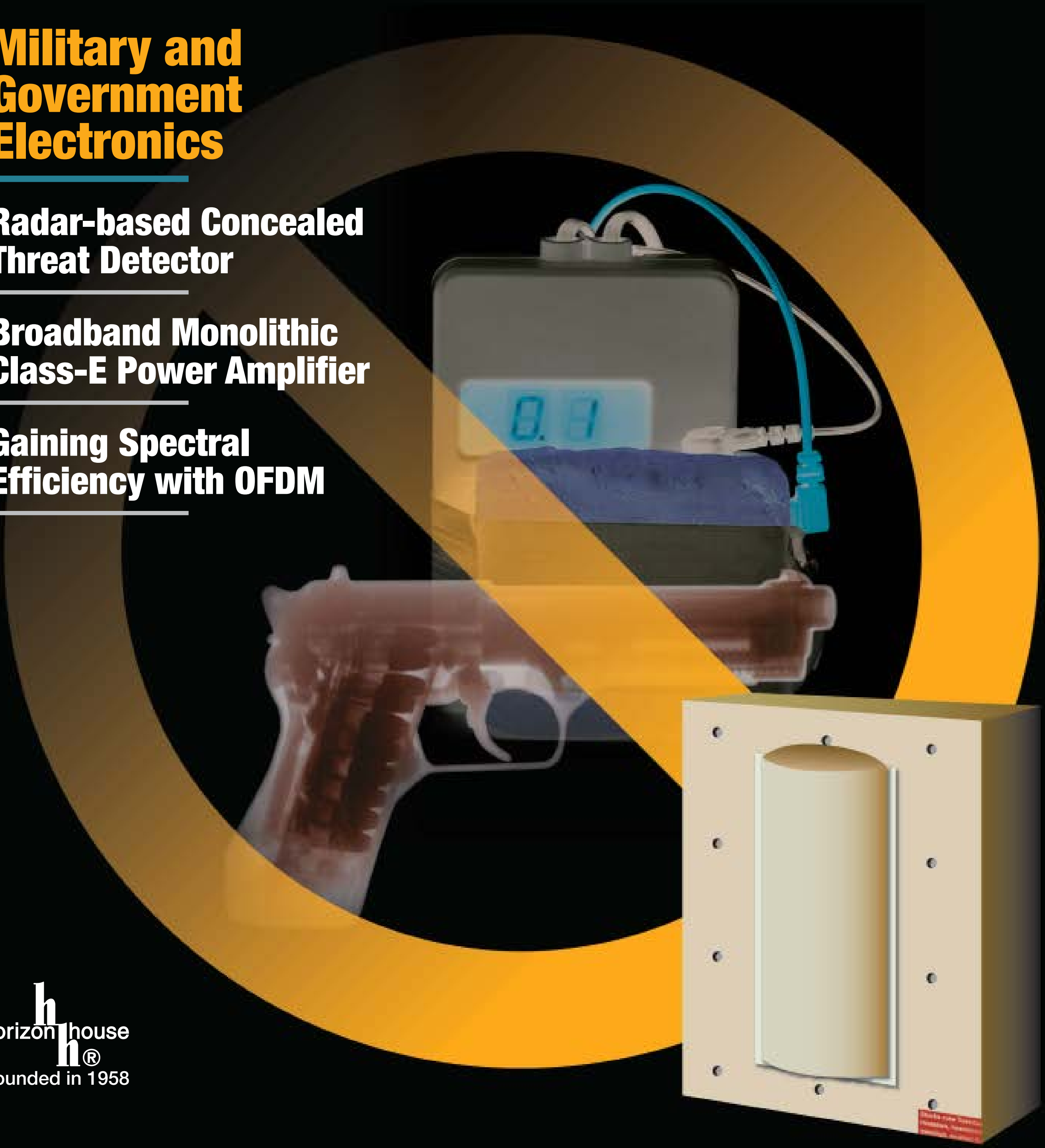
www.mwjournal.com

Military and Government Electronics

Radar-based Concealed Threat Detector

Broadband Monolithic Class-E Power Amplifier

Gaining Spectral Efficiency with OFDM



horizon house®
Founded in 1958

THE WORLD'S LARGEST SELECTION

POWER SPLITTERS/ COMBINERS

IN STOCK

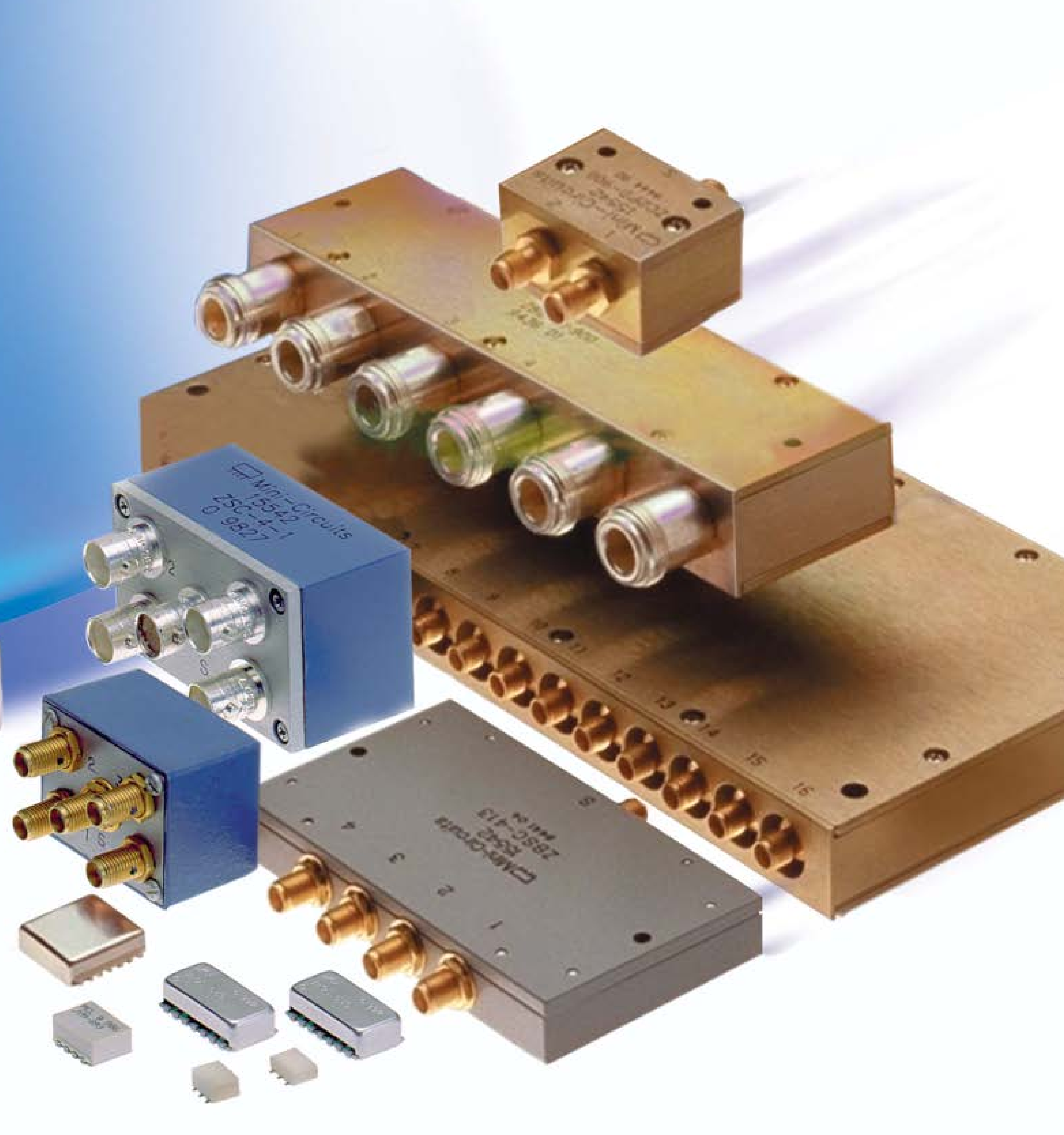
RoHS COMPLIANT

RoHS models available, consult factory.

2 kHz to 12.6 GHz *from* 79¢

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 3 way to 48 way; 0°, 90°, 180°; 50 & 75 ohms covering 2 kHz to 12.6 GHz and beyond, all characterized with detailed data and performance curves available to you in a flash 24/7 on "The YONI2 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 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
15542
ZSC-4-1
O 9827

Kevlin Corporation

MAKING THE CONNECTION

with a full line of RF ROTARY JOINTS and ROTATING SUBSYSTEMS for every need

Standard & Custom Products

Kevlin's product line contains standard rotary joint designs, available in a wide variety of coaxial and waveguide configurations for diverse platform applications. Kevlin is the world's largest developer and manufacturer of custom state-of-the-art rotary joints and rotary joint subsystem technology.

Design Integration & Flexibility

Many of Kevlin's rotary joint designs incorporate ancillary components like encoders, slip rings, Inductosyns®, and fluid joints, to create integrated subassemblies designed to suit unique customer needs.

Engineering, Manufacturing & Test Capabilities

Kevlin operates a custom-built, 80,000 square-foot facility that represents the state of the art in rotary joint engineering. From design through manufacturing and testing, Kevlin provides any service and level of technical support required.

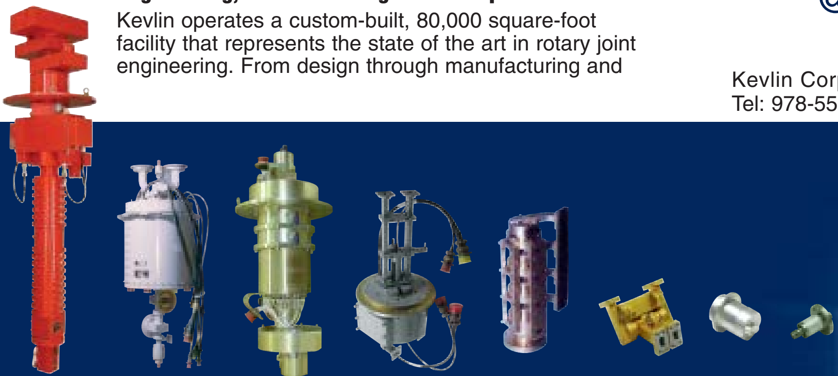
Overhaul & Repair

Kevlin's O&R capabilities cover all known rotary joint brands. Our extensive design database and our industry expertise mean faster O&R turnaround, and ensure robust SLEP* implementation. The result is optimized radar system performance.

* Service Life Enhancement Program

visit us on the Web
@www.kevlin.com
or email us
sales@kevlin.com

Kevlin Corporation 596 Lowell Street, Methuen, MA 01844
Tel: 978-557-2400 Fax: 978-557-2800



For more information contact:

COBHAM
Defense Electronic Systems

Kevlin Corporation

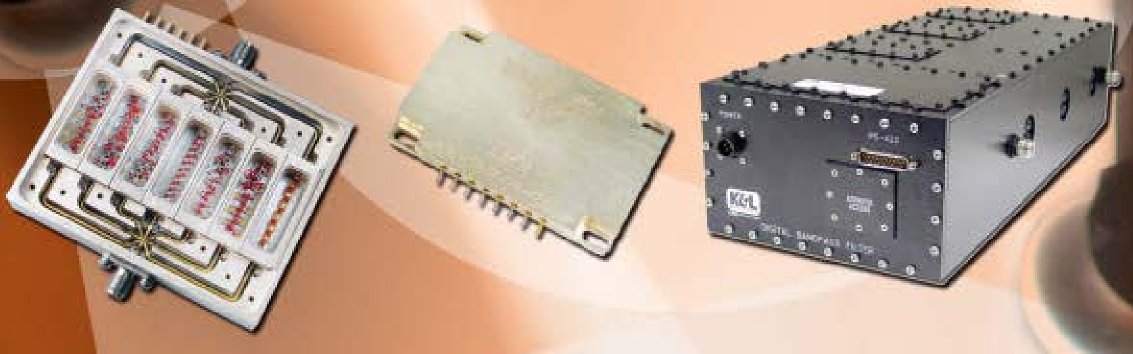
MILITARY | SPACE | COMMERCIAL | AIR TRAFFIC CONTROL | CUSTOM APPLICATIONS

Visit http://mwj.hotims.com/11724-30 or use RS# 30 at www.mwjournal.com/info

K&L MICROWAVE
A DOVER COMPANY

Filter Solutions

Integrated Microwave Assemblies
Frequency Agile Filters
Tunable Assemblies
Extremely Fast Switching
Low Profile Packaging



Product Spotlight

Up-Converter / Down-Converter Assemblies

K&L Microwave's Up-Converter/Down-Converter Assemblies employ state-of-the art RF, analog and digital technologies to maximize performance while minimizing size. These assemblies are configured from proven modular designs consisting of amplifiers, switches, multipliers, couplers and limiters. They also feature:

- Narrowband and Wideband Filtering
- Custom Compact Sizes
- Rugged Design for Military Applications
- Terminated IF Diplexer for Maximum IP3 Performance
- Integrated Low-Noise Amplifiers & Switches
- LO Pre-Amp & Multiplexers
- Available Frequency Ranges: 10.0 MHz to 18.0 GHz
- Operating Temperature Range: -40 to + 85°C

Filter Wizard℠

K&L Microwave's Filter Wizard℠ software simplifies selection of the right filter product for your application from a vast number of designs. Provide desired specifications, and Filter Wizard℠ returns response data and outline drawings for matching products. Visit 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 • www.klfilterwizard.com • sales@klmicrowave.com • sales@kleurope.com

QMI REGISTERED
ISO 9001 Registered
ISO 14001 Registered

Microwave Journal

OCTOBER 2007 VOL. 50 • NO. 10

FEATURES

NOTE FROM THE EDITOR

COVER FEATURE

TECHNICAL FEATURES

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.

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.

Horizon House also publishes *Telecommunications*®

Posted under Canadian international publications mail agreement #0738654

M/A-COM RF and microwave solutions for aerospace and defense

Over 50 years of proven performance in demanding applications

- High power broadband RF and microwave subsystems
- Miniature data links for UAVs and munition applications
- Microwave receivers for SIGINT collection and analysis
- Proven IED defeat and force protection systems
- Reliable, high performance antennas and coaxial cable assemblies
- Large portfolio of RF and microwave components including amplifiers, mixers, attenuators, switches, passive elements, and more

For more details, contact your local M/A-COM sales office or visit www.macom.com/defense

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

Tyco Electronics
Our commitment. Your advantage.

FEATURES

TECHNICAL FEATURES

Microwave Journal CALL FOR PAPERS

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; semiconductors, 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

Microwave Journal

FEATURES

TUTORIAL

DEPARTMENTS

STAFF

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

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

www.mwjournal.com

Printed in the USA

Microwave Journal Online

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

Go to www.mwjournal.com

Webinars

RF Fundamentals – *Passive Component Modeling*

Presented by **Besser Associates** and *Microwave Journal*

Live webcast: 10/18/2007, 11:00 AM (EST)

Executive Interviews

Time-to-market, first-pass success and design for manufacturing are at the forefront of design concerns. Combine these market pressures with geographically separated design teams working in diverse mediums and it's easy to see why workflow is as important as simulation capability. *Microwave Journal* European Editor, Richard Mumford, converses with **CST** Managing Director, Dr. Bernhard Wagner, about the challenges we face due to increasing design complexity and a shortage of skilled high frequency engineers.

Resources

Searching for a Part? *Microwave Journal* teams up with GlobalSpec,® the engineering search engine company, to provide RF/microwave circuit and system designers with the latest in "search by part specification" technology. Visitors to the MWJ web site can now find specific components based on technical specifications such as frequency range, gain, output power or noise figure. Need more information on a particular vendor? MWJ Buyer's Guide currently features over 1000 RF/microwave companies, segmented by category. Each category hosts Vendor Views—our content-rich vendor storefronts containing new product information, press announcements, events, downloads and more.

GLOBALSPEC
The Engineering Search Engine

Online Technical Papers

"Fast Switching Signal Generators"
Ravinder Gill, Gigatronics

"Microstrip Bandpass Filter at S-band Using Capacitive Coupled Resonators"
JS Mandeep, School of Electrical and Electronic Engineering, Universiti Sains Malaysia

"Error Compensation for Digital Predistortion Linearizers"
Jinaing Zhao, Jianyi Zhou, Xiao Liang, Jianfeng Zhai, School of Information Science and Engineering, Southeast University, Nanjing, P.R. China

The **William Bazzy Fellowship Program**, open to graduate students or working engineers, was initiated in 2006 to promote continued study, research and advancement in the field of RF and microwave engineering. The $5000 fellowship program named in honor of William Bazzy, founder of *Microwave Journal*, is awarded each spring. **Apply now online.**

Expert Advice

featuring Ask Harlan

Industry expert Harlan Howe has worked in the global microwave industry for over 50 years. To help build an online community dedicated to peer-to-peer communication and the exchange of technical information, Harlan monitors the responses and chooses the best answer to the online featured microwave-related question of the month. All of the responses to the featured question will be posted on our web site. Now exclusively online.

This Month's Question:

Saadya Mahmood asks–

"What is the formula for calculating the take-over gain of a zero-IF receiver, including a front-end with one low noise amplifier, one LO and one mixer?"

SPEC-BASED PART SEARCH: WAY OF THE FUTURE

DAVID VYE, *Microwave Journal* Editor

Browse through the articles and advertisements in any issue of *Microwave Journal* (MWJ) and you get a pretty good glimpse of the ecosystem that forms our industry. The component manufacturers (active and passive), the integrated circuit developers, the foundries that produce these MMICs and RFICs, the test and measurement equipment providers, the simulation software vendors, engineering services and the commercial and defense system integrators who pull it all together; they are all represented here in print and on our web site. While the editorial (technical and product-related articles, tutorials and special reports) keeps us informed with detailed coverage of recent innovations, the advertisements remind us of who is offering what products and services.

Another reminder of who is doing what is available through *Microwave Journal*'s Online Buyer's Guide. Within each category of this RF/microwave ecosystem is a listing of the companies that are offering products and services. These are the companies fully engaged in advancing the state-of-the-art either by improving the performance or reducing cost, weight and/or size of their products. Included in the Buyer's Guide are the Vendor Views, which together form an online marketplace where all this product information, download material, company events and technical articles of participating companies can be found.

Last month, we mentioned MWJ's focus on expanding the capabilities and offerings of our electronic media, from more web site exclusive features to newsletters and webinars. This month we introduce a new, powerful "product search" engine to our Buyer's Guide that is truly unique for our industry. By partnering with GlobalSpec,® the specialized search and information resource for the engineering, industrial and technical community, visitors to the *Microwave Journal* Buyer's Guide can now search on categories of parts such as voltage-controlled oscillators (VCO), low noise amplifiers (LNA), mixers, antennas, etc. From this top-level search, an engineer could then list and review all products and companies in that category or (and this is the best part) search for a particular component and its manufacturer based on the required specifications.

Here's how it works. Let's say a system integration engineer requires a VCO. From the Buyer's Guide powered by GlobalSpec, the engineer starts the search for this device by typing in "VCO." This request launches the criteria filter that lets him/her specify oscillator type, package style, performance (in this case: oscillation frequency, stability, tolerance, supply voltage, etc.) and other features. The engineer specifies the device's required attributes (or no preference) and continues the search to get an itemized listing of all companies and their products that meet that specification.

Engineers from General Electric developed this search engine technology based on their own (considerable) experience of building systems and maintaining large part catalogs. Having had some time to run searches on various component types, we found the capability easy to use and the results quite impressive. Need to find the right component? This could very well be the way of the future. Give it a try; we think you will also be impressed. ■

FLEX TEST™

CABLES

DC to 18 GHz from $68.95 ea. (qty.1-9) IN STOCK

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-18 GHz 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.

RoHS COMPLIANT

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

Models	Connector Type	Length (Ft.)	Inser. Loss (dB) Midband Typ.	Return Loss (dB) Midband Typ.	Price $ ea. Qty.(1-9)
Male to Male					
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
Female to Male					
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

6 mo. 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

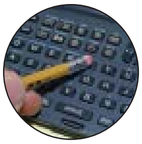
ALL NEW minicircuits.com

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

YONI2™ Patent Pending **The Design Engineers Search Engine** Provides ACTUAL Data Instantly From MINI-CIRCUITS At: **www.minicircuits.com**

RF/IF MICROWAVE COMPONENTS

403 Rev I



CALL FOR PAPERS

IEEE MTT-S International Microwave Symposium 2008
by December 7, 2007

IEEE Radio Frequency Integrated Circuits Symposium
by January 3, 2008

OCTOBER

AOC International Symposium and Convention
October 28–November 1, 2007 • Orlando, FL
www.crows.org

Military Communications Conference (MILCOM 2007)
October 29–31, 2007 • Orlando, FL
www.milcom.org

NOVEMBER

Antenna Measurement Techniques Association (AMTA 2007)
November 4–9, 2007 • St. Louis, MO
www.amta2007.com

IMAPS 40th International Symposium on Microelectronics
November 11–15, 2007 • San Jose, CA
www.imaps40th.org

2nd European Conference on Antennas and Propagation (EuCAP 2007)
November 11–16, 2007 • Edinburgh, UK
www.eucap2007.org

ARFTG 70th Microwave Measurement Symposium
November 27–30, 2007 • Tempe, AZ
www.arftg.org

DECEMBER

International Radar Symposium India (IRSI 2007)
December 10–13, 2007 • Bangalore, India
www.radarindia.com

Asia-Pacific Microwave Conference (APMC 2007)
December 11–14, 2007 • Bangkok, Thailand
www.apmc2007.org

JANUARY

IEEE MEMS 2008 Conference
January 13–17, 2008 • Tucson, AZ
www.mems2008.org

IEEE Topical Symposium on Power Amplifiers for Wireless Communications
January 21–22, 2008 • Orlando, FL
http://pasymposium.ucsd.edu

IEEE Radio and Wireless Symposium (incorporating WAMICON)
January 22–24, 2008 • Orlando, FL
www.radiowireless.org

WCA International Symposium and Business Expo
January 29–February 1, 2008 • San Jose, CA
www.wcai.com

FEBRUARY

International Solid-state Circuits Conference (ISSCC 2008)
February 3–8, 2008 • San Francisco, CA
www.isscc.org

Satellite 2008 Conference and Exhibition
February 25–28, 2008 • Washington, DC
www.satellite2008.com

JUNE

IEEE Radio Frequency Integrated Circuits Symposium (RFIC 2008)
June 15–17, 2008 • Atlanta, GA
www.rfic2008.org

IEEE MTT-S International Microwave Symposium and Exhibition (IMS 2008)
June 15–20, 2008 • Atlanta, GA
www.ims2008.org

Workshops & Courses

'First-pass System Success' Application Workshops

■ **Topics:** Ansoft's 'First-pass System Success' application workshops for high performance design will provide a platform for leading technology companies and Ansoft's technical staff to collaborate and discuss the latest simulation techniques and design methodologies to help engineers achieve first-pass system success when designing high performance electronic systems.
■ **Sites:** Asia, North America and Europe
■ **Dates:** October 16–November 15, 2007
■ **Contact:** For more information, visit www.ansoft.com/firstpass/.

CST EM Studio™ 2006B Training

■ **Topics:** This hands-on training course will show participants how to work efficiently with CST EM STUDIO™ (CST EMS) 2006B. The course will cover set-up of a structure with the modeling interface in CST STUDIO SUITE 2006B; understanding of the various available sources and solvers in CST EMS; ensure efficient workflow; and customize post-processing to specific needs by using power result templates. To register or for additional date and location information, visit www.cst.com.
■ **Site:** Darmstadt, Germany
■ **Date:** November 29, 2007
■ **Contact:** For more information, contact info@cst.com or call +49-6151-7303-0.

Antenna Engineering

■ **Topics:** This course provides an overview of the theory and practice of antenna engineering, including a range of antenna types, applications and electromagnetic properties from basic to state-of-the-art. Explore a wide spectrum of frequency from 550 kHz to 550 GHz, with primary emphasis in the VHF, UHF and microwave regions. Examine communications and radar, commercial and military applications.
■ **Site:** Las Vegas, NV
■ **Dates:** December 3–7, 2007
■ **Contact:** Georgia Institute of Technology, Professional Education, PO Box 93686, Atlanta, GA 30377 (404) 385-3500.

2007 Power Seminars

■ **Topics:** Fairchild is The Power Franchise® and its power experts will provide the latest in design techniques for optimizing system power with analog, discrete and optoelectronic solutions at these one-day events. The 2007 Power Seminar technical sessions include: low cost, isolated current source for LED strings, design considerations of LLC resonant converter and application review and comparative evaluation of low side MOSFET drivers.
■ **Site:** For location information, please visit url.
■ **Dates:** For date information, please visit url.
■ **Contact:** Fairchild Semiconductor Corp., 82 Running Hill Road, South Portland, ME 04106 (207) 775-8100, www.fairchildsemi.com.

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 any-time 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.

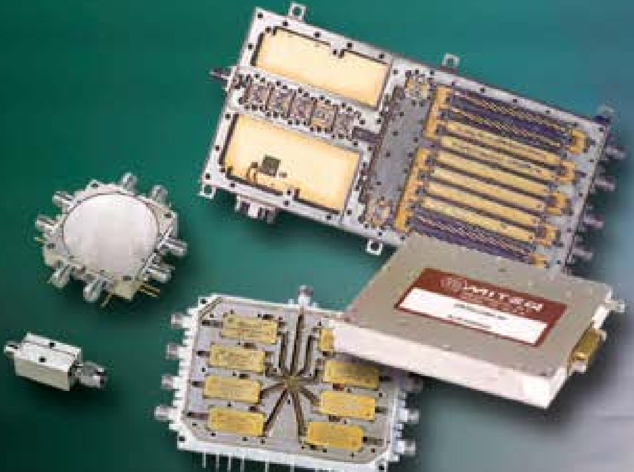
PCB Design Techniques for EMC and Signal Integrity

■ **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, Dept. of Engineering Professional Development, 432 North Lake Street, Madison, WI 53706 (800) 462-0876.

Microwave Components

MIXERS TO 60 GHz

- Single-, double-, and triple-balanced
- Image rejection and I/Q
- Single-sideband, BPSK and QPSK modulators
- High dynamic range
- Active and passive frequency multipliers



CONTROL PRODUCTS

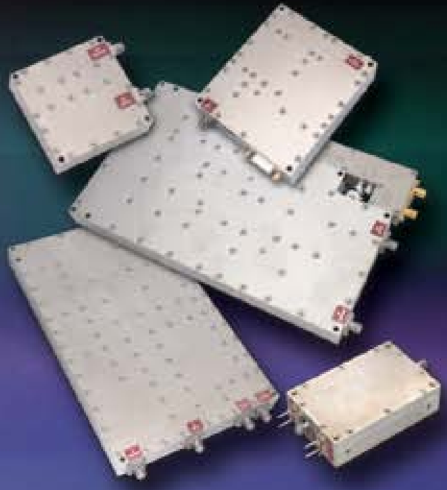
- PIN diode and high power switches
- Switch matrices
- Analog and digital PIN attenuators, phase shifters
- Limiters
- Delay lines

INTEGRATED SUBASSEMBLIES TO 60 GHz

- Integrated up/downconverters
- Monopulse receiver front ends
- Missile receiver front ends
- Switched amplifier/filter assemblies

IF AND VIDEO SIGNAL PROCESSING

- Logarithmic amplifiers
- Constant phase-limiting amplifiers
- AGC/VGC amplifiers
- Digital DLVAs
- Digital logarithmic amplifiers and frequency discriminators



FREQUENCY SOURCES TO 60 GHz

- Synthesizers for radar, instrumentation and broadband communications
- Free-running and phase-locked DROs
- Frequency agile phase-locked sources
- Variable frequency phase-locked sources
- Ovenized crystal oscillators

AMPLIFIERS TO 60 GHz

- Octave to ultra-broadband
- Noise figures from 0.35 dB
- Power to 10 watts
- Temperature/slope compensated
- Cryogenic
- Military screening/space qualified
- Input protected
- Optical modulator drivers, >10 Gb/s

PASSIVE POWER COMPONENTS TO 2.5 KILOWATS

- Power dividers
- Directional couplers
- 90 and 180 degree hybrids
- Coaxial terminations
- Custom passive components

FIBER OPTIC SYSTEM COMPONENTS

- Wideband fiber optic links to 18 GHz
- Fiber optic transmitters and receivers
- RZ and NRZ drivers, low noise and limiting amplifiers
- 10 and 12.5 Gb/s modulator drivers
- 40 Gb/s drivers and linear amplifiers

MITEQ®

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

www.miteq.com

Visit http://mwj.hotims.com/11724-108 or use RS# 108 at www.mwjournal.com/info

COVER FEATURE
INVITED PAPER

A RADAR-BASED CONCEALED THREAT DETECTOR

This article describes a system that is capable of detecting dangerous objects carried under a person's clothing from a standoff position. The system is autonomous and automatically renders a decision regarding the outcome of a test for a particular person's results to an operator. That decision is reached on the basis of processing many parameters extracted from both the frequency and time domain responses of the radar return in an artificial neural net. This system has been extensively tested and been shown to be highly accurate. This work is sponsored by the MacAleese Companies dba Safe Zone Systems.

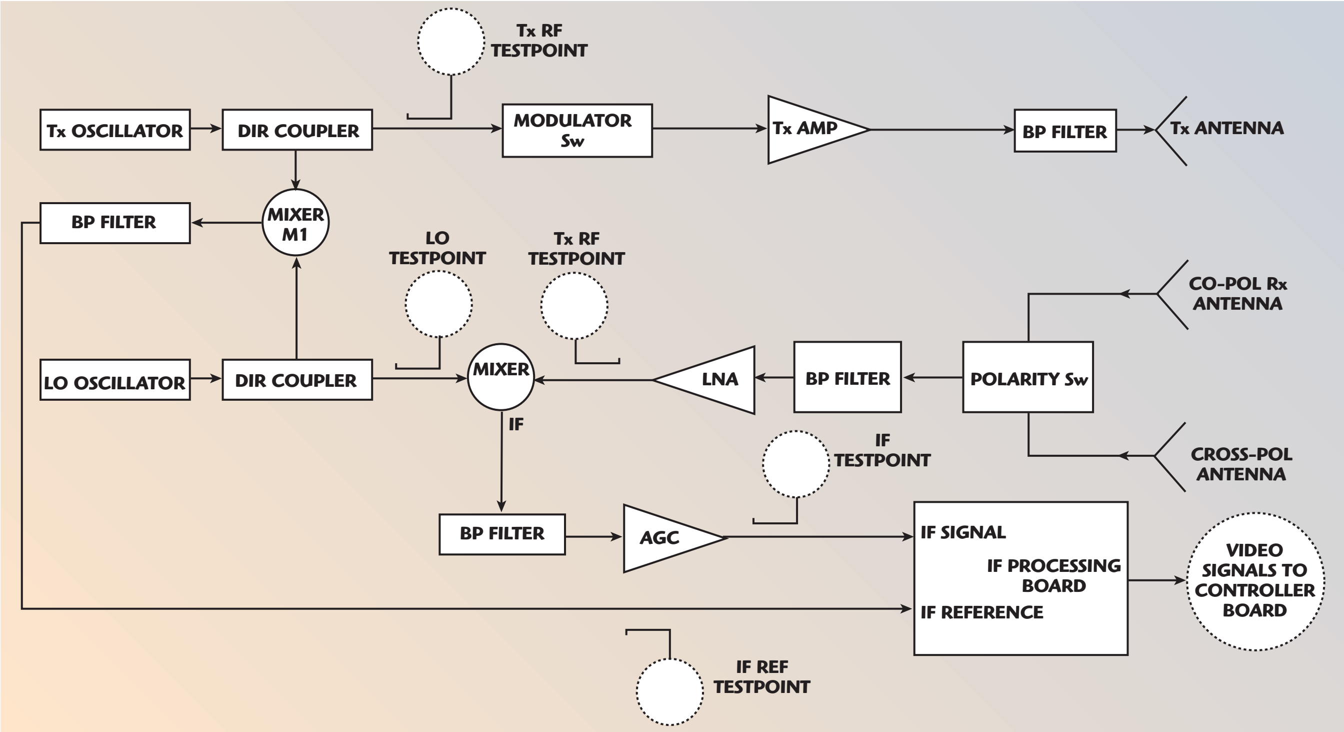
This project was started in order to develop a device that could detect concealed guns on people to protect police officers by allowing them to frisk a suspect at a distance. The original concept was to have the unit in a handheld, battery operated package. Other applications included the protection of people at schools and sporting events by preventing the infiltration of concealed weapons. The applications were expanded with the advent of terrorists to include additional threats, such as suicide bombs. Hence, the resulting product is entitled a concealed threat detector.

BACKGROUND AND INITIATION

The motivation to embark on this project was based on the premise that objects, such as a gun, would have a radar signature that was sufficiently unique that it could be distinguishable from other objects that are normally carried by people. These normal objects are categorized as pocket clutter. To determine whether or not the premise was correct an experiment was devised that used an impulse radar. This was around 1995 when impulse and ultra-wideband radar was an emerging technology.

The initial experiment was conducted in an anechoic chamber. A person with normal pocket clutter was placed in front of an impulse generator terminated in an ultra-wideband antenna, also called an Impulse Radiating Antenna (IRA). Next to the transmitter was a receiver that was shielded from the

JERRY HAUSNER
Electro Science Technologies
Albuquerque, NM



▲ *Fig. 1 Block diagram of the RF section of an interrupted CW radar.*

transmitter by a septum coated with absorptive material. Therefore, the receiver would record the signal being reflected by the person under test. The received signal was recorded by a very wideband oscilloscope. This recorded a time domain waveform of the reflected signal. This test was repeated several times with two or three different people who were either armed with a gun or not.

The result showed a small, but definite increase in the reflected energy in the 1 to 2 GHz band when a gun was present versus the situation when it was not. This test was conducted and plotted several times for an armed and unarmed condition. Based on these results a privately funded venture was launched by The MacAleese Companies to develop such a product. It was quickly realized, however, that an impulse radar is awkward and expensive to produce. The development cost is also very high. Therefore, alternatives to the initial technology were sought. After evaluating various technical approaches, and associated cost to reduce this concept to practice and commercialize such a device, it was decided that the Electro Science Technologies (EST) approach had the best probability of success at the most reasonable cost. That approach was to simulate the operation of an impulse radar by using a wider pulse of many nanoseconds and stepping it across the frequency band of interest thereby creating a frequency domain waveform. That was then converted to the time domain by use of a fast Fourier transform (FFT) and later a Chirp-Z transform. This theoretically provides the same information, but in an easier to obtain form.

As the world situation changed, the emphasis shifted from the detection of concealed handguns to the detection of concealed bombs and assault rifles. This shift has been accommodated with a very high degree of success.

APPROACH

The EST approach was to use a frequency domain approach to collect

▲ *Fig. 2 A Concealed Threat Detector production unit.*

▲ *Fig. 3 Output screen showing the information presented to an operator.*

the data instead of a time domain system. The resulting signal waveform is then converted to time domain using a Chirp-Z transform. The impulse radar transmits a pulse with a duration of several hundred picoseconds and an amplitude of many kilovolts per meter. Such a device is quite expensive, large and heavy, and has many limitations. The EST approach was to transmit a 10 nanosecond pulse at a fixed frequency, read the return in a receiver with a bandwidth of several hundred megahertz, and then take a frequency step and repeat the measurement. This can be done at several hundred frequencies to create a frequency domain response, which can then be transformed into the time domain. The impulse radar collects its data in a matter of picoseconds whereas the frequency-stepped approach requires several milliseconds. Even though this data collection time is many orders of magnitude greater, for all practical purposes it is still real time. The EST approach therefore allows a radar to be built that follows a conventional block diagram with surmountable challenges in the area of narrow pulse widths and the associated bandwidths.

The stepped frequency or spread spectrum approach also offers some additional advantages. The antennas are no longer state-of-the-art specials and the peak power levels are only a fraction of a watt for the short range that needs to be covered. Furthermore, the impulse radar was frequency band limited by the duration of the impulse. That is, the energy in an impulse drops to zero at 1/pulse width. At 80 percent of that frequency the power level is already significantly reduced. Then, to increase the frequency range of the signal, the impulse must be made narrower. The energy in the impulse is the integration of the power as a function of time. Therefore, as the pulse width narrows, the amplitude must proportionately increase in order to maintain a constant energy level.

TABLE I

SYSTEM SPECIFICATIONS

Parameter	Typical Performance
Operating range (f_t)	9 to 15, factory preset
Transmission frequency (GHz)	9.50 to 10.55 in equal increments
Transmit power (W)	0.1, interrupted CW
ERP (W)	3.2
Detection articles	shrapnel and articles with a dielectric constant greater than a human body
Detection rate for partial upper body shrapnel coverage (%)	> 95
False alarm rate (%)	< 10
Power input	12 to 24 V DC, 25 W max.
Size	12" w × 14" h × 4.5" d* (30.5 × 3.5 × 11.5 cm) < 10 lbs (4.55 kg) *includes radome

The frequency-stepped system can scan over a wider frequency range (several gigahertz if desired) and the center frequency can be moved to any desirable band. This is very significant as the desired information may reside better at another part of the spectrum, where the impulse does not have sufficient energy to create a response. Furthermore, most of the energy transmitted by the impulse radar is in the lower frequency portion of the spectrum below 1 GHz. It was experimentally determined that there was no information, useful for the intended detection, in that part of the spectrum. It then becomes very inefficient to use this type of waveform for this application. The EST frequency scan approach corrects this situation.

The approach then was to build a frequency scanning radar. The original experiments, using the impulse radar, produced results that were a representation in the time domain that was then transformed into the frequency domain, while the frequency scanning radar produced a result that was immediately in the frequency domain. Ironically, it turned out that there is only a small amount of the desired information in a frequency domain waveform and most is extracted from the transformed time domain waveform. Thus, the waveform is transformed into a well-behaved time domain response for which accurate readings can be rendered.

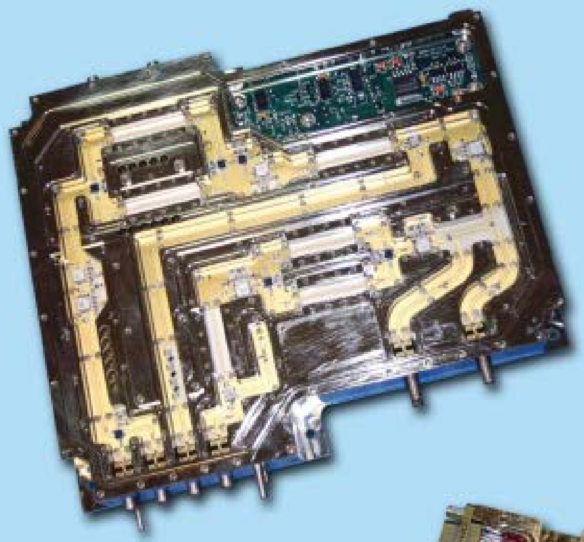
DESIGN AND EVOLUTION

Achieving a well-behaved waveform requires phase coherency of the returned signals. Phase detectors that can respond to pulses on the order of 10 nanoseconds are difficult to realize. Additionally, it became difficult to obtain modulators that could produce a 10 nanosecond pulse with a rise and fall time of less than two nanoseconds at a reasonable price with repeatable performance. As a result, the system was changed to an interrupted CW radar which greatly simplified the phase detectors along with the requirements for the high speed modulator. That also eliminated the T/R and range gate switches. The term interrupted CW is used since the time that the signal is present is long compared to the transit time of the signal to target and back.

The current system transmits an interrupted CW signal with horizontal polarization and simultaneously receives the returns from a test subject in both the vertical and horizontal polarizations. The horizontal return is referred to as the co-pol signal and the vertically polarized return is the cross-pol signal. ***Figure 1*** shows a block diagram of the current system. It was experimentally determined that there is a huge advantage to receiving both polarity returns as many more parameters were available to establish a decision as to whether or not a person is armed. ***Figure 2*** shows a production unit.

Being a CW system, range gating is now done mathematically. A single receiver is used to measure both polarity return signals. The input to the receiver is switched between the co- and cross-pol antennas. The antenna

UPCONVERTERS & DOWNCONVERTERS



UHF to Ka Band

INCORPORATING

- Mixers
- Filters
- Switches
- LNA
- IF Amp
- Limiters
- RF & IF Attenuators
- For Military Environments

Amplifiers

Attenuators/ Modulators

PIN Diode Switches

Synthesizers/ Sources

Converters/ Receivers

Integrated Microwave Assemblies

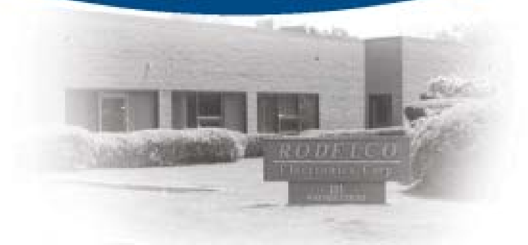
Rodelco
Electronics Corp.

ISO 9001:2000 Certified

FLEXIBLE MICROWAVE SOLUTIONS

WHO ARE WE?

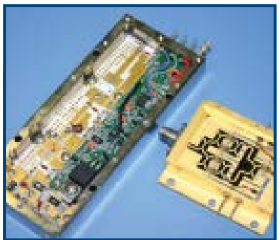
For greater than 38 years Rodelco Electronics has been exceeding our customers expectations for complex custom RF & Microwave Solutions. Using 3D Electromagnetic simulation software and mechanical modeling capability our highly skilled staff utilizes Rodelco Electronics state of the art facility to partner with our customers to solve complex design/integration problems to 50 GHz.



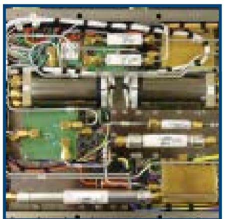
WHAT WE OFFER

"Flexible Solutions" means Rodelco Electronics is your one-stop-shop for design, manufacturing and test of all your RF/Microwave product needs.

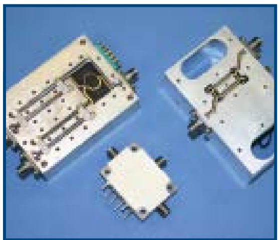
111 Haynes Court • Ronkonkoma, NY 11779
tel 631-981-0900 • *fax* 631-981-1792
www.rodelcocorp.com

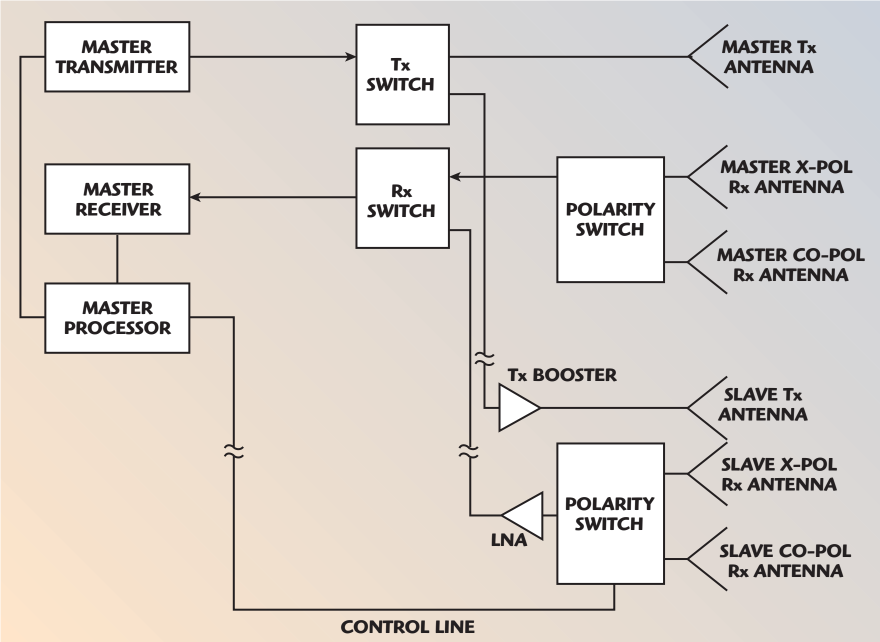

Amplifiers


Converters/Receivers


Integrated Microwave Assemblies


Synthesizers

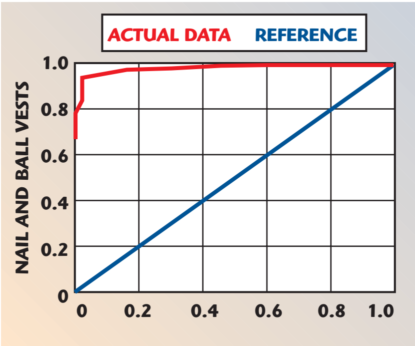

Attenuators/Switches



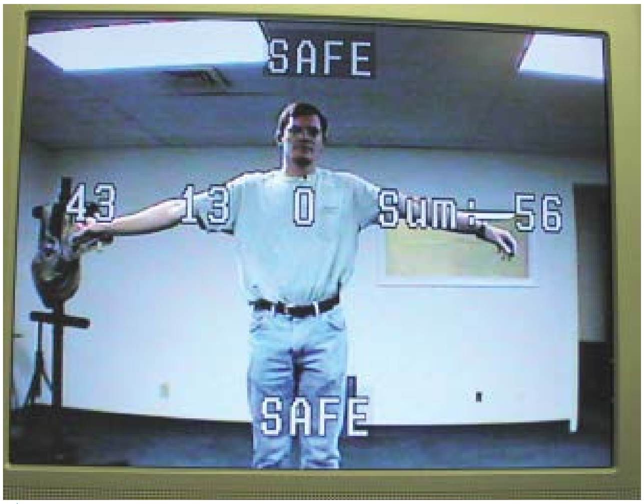
▲ *Fig. 4 Block diagram of the coherent bistatic radar.*

is made in three patch array sections. One is the horizontally polarized transmit antenna. The others are vertically and horizontally polarized receive antennas. The receiver is a conventional superhet erodyne receiver with amplitude and phase detectors. The IF section contains a variable gain feature. This is accomplished by the use of digitally controlled step attenuators. The analog outputs of these detectors are fed to the processor board where they are digitized. The co- and cross-pol values are read and stored at one frequency. The transmit oscillator is then stepped to the next frequency and phase locked. The transmission is then enabled and the readings on the return signals are then measured and stored. This process is repeated 256 times to cover the operating band of 9.50 to 10.55 GHz. At the end of 256 measurements a frequency domain waveform is created. That waveform is then transformed into a time domain waveform from which several pertinent parameters are extracted. Those values are processed in an artificial neural net, which is then able to offer a decision on whether or not the person being examined fits within the trained parameters of being "normal" or "abnormal." If abnormal, a THREAT decision is generated. The output decision, along with a visual image of the test subject, is seen by an operator on a closed

▲ *Fig. 5 A typical setup using two units in a bistatic configuration.*



▲ *Fig. 7 ROC curve showing the actual performance of a CTD system for a particular set of test data.*



▲ *Fig. 6 Output screen showing a SAFE decision along with the person's score superimposed on a visual image of the person being screened.*

▲ *Fig. 8 Various types of suicide bomber vest designs using different types of shrapnel.*

TINY TOUGHEST MIXERS UNDER THE SUN

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

0.2" x 0.18"

Over 21 models are available to operate from an LO level of your choice, +7, +10, +13, and +17dBm. So regardless of the specific frequency band of your applications, narrow or wide band, there is a tiny SIM *RoHS* compliant mixer to select from 100 kHz to 15 GHz. Built to operate in tough environments, including high ESD levels, the SIM mixers are competitively priced for military, industrial, and commercial applications. Visit our website to view comprehensive performance data, performance curves, data sheets, pcb layouts, and environmental specifications. And, you can even order direct from our web store and have it in your hands as early as tomorrow!

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

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

Mini-Circuits®
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

YONI2™ *Patent Pending* ***The Design Engineers Search Engine*** *Provides ACTUAL Data Instantly From MINI-CIRCUITS At:* ***www.minicircuits.com***

IF/RF MICROWAVE COMPONENTS

428 Rev Org

Visit http://mwj.hotims.com/11724-96 or use RS# 96 at www.mwjournal.com/info

circuit TV screen. An example is shown in ***Figure 3***. The general specifications for this system are shown in ***Table 1***.

The usual range of operation, as determined by various users, is in the 9 to 15 foot range. However, significantly longer ranges are possible by the use of a larger patch array antenna. The current antenna produces a pattern that is approximately six feet (1.8 m) high by three feet (0.9 m) wide at a range of 12 feet (3.6 m). This provides full head-to-toe coverage of a subject. Larger people can be fully illuminated by examining them at 15 feet (4.5 m).

It should be mentioned that, except in rare cases, no single parameter provides a conclusive piece of information. Each has a trend, some of which are more definite than others. The combination and weighing of many parameters converges on a reliable decision.

The latest model uses a next level of sophistication by employing both monostatic and bistatic detection. In this configuration, at least two units are used and each makes its own monostatic measurements plus a set of bistatic measurements. The latter is accomplished by transmitting a horizontally polarized signal from the master unit and receiving the horizontal and vertical target scattering at the slave unit. Due to the detection requiring coherency, the received signals are brought from the slave to the master for processing. This system adds many more parameters that can be considered in rendering a decision on a person; hence, another improvement in accuracy. Furthermore, the bistatically received signal is a very significant aid in the detection of all shapes of shrapnel. Being that monostatic detection is used from multiple angles plus bistatic detection, it is virtually impossible to devise a shrapnel form that can avoid detection.

Figure 4 is a block diagram of the bistatic version of the Concealed Threat Detector (CTD). As shown, the signals are all derived at the master unit and brought to the slave via a cable. Then all received signals are cabled back to the master for coherent processing. Therefore, the slave unit in this configuration basically only contains a three-section antenna, some switching circuitry, amplifiers to compensate for the cable losses and a power supply to power the mentioned devices. A laser is also included to assist in the aiming of the device.

Figure 5 shows a typical physical setup using two units. An alternate setup used three units. The third unit is placed behind the subject being tested so that a simultaneous rear view is obtained. This eliminates the need for the subject to turn around. The rear unit operates fairly independently of the two front ones, as its point of view is totally different than the front units. The rear slave unit does send its information to the master so that only one compiled output is presented to the operator. The information from the rear unit is also useful for further verifying some parameters.

APPLICATIONS

While the CTD can process a large amount of people sequentially, it is likely of best value in low volume

situations. Such high value screening points would include:

- Embassies
- Government Buildings—mints, legislative offices, court houses, administrative offices, etc.
- Public buildings—schools, libraries, museums
- Transportation hubs—bus terminals, train stations
- Sporting events
- Border crossing points
- National monuments
- Research facilities and laboratories

The screening process is simply to have a person being checked walk into a marked test box, face the prompter monitor and put their arms out. The reason for arms out is to reveal the area under the armpit, where a weapon like a gun in a shoulder holster could be hidden from the radar by the flesh of the upper arm. The instrument detects the presence of the individual and begins the measurement process. During the process, three sets of readings are taken and the final decision is made by polling the readings and then looking at the total score. In the vast majority of cases, when a weapon or threat is present, the first two readings are conclusive. In those cases, the third reading is not taken and the results are immediately presented. This situation requires only about three seconds to complete the screening process.

The CTD is quite practical as no special portals need be set up and the small units operate well in a simple open space. This allows people to be screened prior to entering a building where generally more damage can be done by a terrorist. The operator can be remotely located since the output is presented as text over video so that the operator has a visual picture of the test subject plus the output information from the system. ***Figure 6*** shows a typical output screen with a SAFE indication along with the individual's score. The operator or system administrator can adjust the threshold at which the decision changes from SAFE to THREAT, and thereby adjust the system sensitivity. As shown, the person's score is also presented so that the operator can apply some human judgment if appropriate. Otherwise the system will provide a definite decision.

PERFORMANCE AND RESULTS

Judging the performance of such a system is not trivial. Even establishing a test plan is quite complex and must contend with many variables. One method that was suggested by the Transportation Security Administration (TSA) is the use of a graphical representation called a Receiver Operational Characteristic or ROC curve. Such a curve is shown in ***Figure 7***. The abscissa is the false positive rate and the ordinate is the true positive (or detection) rate. The reference is a line with a slope of 1. This is equivalent to a coin toss or a 50-50 prediction. An absolutely perfect system would essentially be a point at the upper left hand corner, which represents 100% detection with 0% false alarms. Since no system is so perfect, the actual performance is shown as a curve. This system, like any other, allows for a range of sensitivities. If the

sensitivity is increased, the detection rate is increased along with the false alarm rate. Therefore, there is a tradeoff between the two. Different situations can tolerate different false alarm rates. This curve shows that the Safe Zone System has a detection rate of 98% with a false alarm rate of less than 5%. This is considered to be excellent performance.

Since the operator is presented with a score or certainty factor along with the decision of the artificial intelligence, the accuracy can be further improved by applying some human judgment to the decision. That is, if a person gets a SAFE decision from the processor but their score is very close to triggering a danger level, the operator may want to examine this person again or make some visual judgment or further examination. An example might be that the body and head sizes do not seem to match indicating that there may be more than the person under the clothing. An operator could be assisted with this judgment on future models where a person's radar cross-section is compared to the number of pixels their visual image transcends. There are many such features that can be included in future models to increase the difficulty for a terrorist to pass a screening system of this type.

The current versions of the CTD have been tested with threats that use all shapes of shrapnel and some that use no shrapnel at all. Those contained only packets of C-4 or similar explosive and even a thin layer of sheet explosive. ***Figure 8*** shows a sample of some of the threats that have undergone detection testing with the CTD.

At the time of this writing, the system is in line to be tested and results verified by various government agencies. In anticipation of favorable test results, several hundred units have been produced with excellent repeatability. Additionally, Federal Communications Commission (FCC) approval is expected imminently.

CONCLUSION

A standoff concealed threat detection system has been developed and produced that is capable of detecting objects concealed under a person's clothing that can be considered dangerous. This system operates at a low power level in X-band. The typical range of operation is on the order of 15 feet and can be extended to 100 feet or more by the use of a higher gain antenna. Accuracy and performance depend on many factors, but under normal circumstances the detection rate is in the very high 90s percentile with an associated false alarm rate of only a few percent. ■

ACKNOWLEDGMENTS

Safe Zone Systems, Albuquerque, NM, is the sole sponsor for this program. The microwave assembly is manufactured by Mid Atlantic RF System, Forrest Hill, MD. The patch antenna assembly is manufactured by JEM Engineering, Laurel, MD. The system has been completely designed by and all technical support provided by Electro Science Technologies, Albuquerque, NM.

Northrop Grumman Demonstrates Broad Area Maritime Surveillance

Northrop Grumman Corp. has successfully completed a program of simulations, demonstrations and tests designed to provide the Broad Area Maritime Surveillance (BAMS) program with low programmatic and technical risk. Northrop Grumman's BAMS Head Start Program successfully completed four system-level simulations as hosted on a prototype mission control system and aircraft simulator; airframe modifications and testing; and initiating air vehicle long lead procurements and capital investments. "These pre-contract activities are aligned with our proposed BAMS offer focused on creating the maximum programmatic and technical margins and thereby reducing risk for the US Navy," said Carl Johnson, Northrop Grumman BAMS program vice president. Over the past four months, the mission system was tested on a Northrop Grumman test bed aircraft flying out of California and linked to a Maryland-based prototype ground segment. "We conducted more than 40 hours of flight testing on 19 flights to validate the benefits of our BAMS architecture and to develop our prototyped subsystems," said Bill Beck, Head Start program manager. "We optimized maritime modes on the 360° Active Electrically Scanned Array sensor, which was controlled through the newly developed Advanced Mission Management System. In addition, we were successful in demonstrating our network and bandwidth management system that incorporated L-3's dual communication data link system. Integrating a large quantity of the planned BAMS mission system elements provided key software metrics, which confirm our proposed software development and reuse estimates," continued Beck. "The testing validated the Mission Control System (MCS) architecture—which is an Internet Protocol (IP)-based, service oriented architecture—using real communication and sensor data feeds from our West Coast-based flight tests to the MCS/Tactical Support Center (TSC) prototype in Hollywood, MD." The complete Northrop Grumman BAMS system has also been modeled in a simulation, which, along with the end-to-end mission system testing, is hosted within the MCS prototype. The simulation was built using the proven aircraft models and displays developed to train RQ-4 pilots for the Navy, Air Force and Northrop Grumman. The simulation also included the effects of the IP-based design features for avionics, communication and ground segments. The system model also includes emulated interfaces with the Maritime Patrol and Reconnaissance Forces (MPRF) TSC environment. These interfaces allowed real-time studies of the BAMS system working in an MPRF environment, which refined manning and training predictions for MPRF staffs. The unmanned segment of the Navy BAMS system must operate at all altitudes and environments. Changes to the RQ-4 Global Hawk for the Navy included modifications to a leading-edge section of the wing, which has undergone hail, bird strike and icing/de-icing tests, as well as radome modifications. The baseline BAMS design modifications met all test objectives. "These and other environmental tests are coupled with full scale structural tests for the complete airframe, which have shown that our design modifications are robust enhancements to a great platform," said Beck. "The baseline RQ-4 airframe is largely unchanged in the RQ-4N configuration and by developing a database for new requirements through development and test efforts, we have been able to initiate long lead materials and capital equipment procurement to ensure two air vehicles for the BAMS system design and development phase can be included in the lot 7 RQ-4 production line, reducing the time to first flight."

Harris Corp. Introduces New Border Security System

Harris Corp. unveiled the Harris Border Security Shelter, a system that links information and communications technologies used to detect illegal border crossing or other threats to national security. The shelter's advanced technologies can help increase the flow of information and speed response times to potential threats. The Border Security Shelter is a rugged, self-contained field command center that combines communications, command and control, and sensor systems under a single roof, tied together with either the Harris Falcon® II tactical radio network or existing networking infrastructure. The Border Security Shelter provides an IP-data backbone for receiving, synthesizing and redistributing various forms of secure transmissions. Border Security Shelter can be permanently installed at fixed locations or rapidly deployed to special areas of operation. Multiple shelters can be deployed and linked to form protective networks. The shelter is configurable and scalable to suit customer needs. It is also adaptable to other applications such as protection of ports or other security needs. The shelter was developed through Harris Corp.'s International Government Systems business, which combines the company's expertise in systems integration with its portfolio of world-class radio products. "The Border Security Shelter serves as just one example of what our International Government Systems business will do for customers—creating highly advanced integrated networks that enhance communications and decision-making," said Steve Marschilok, general manager of International Government Systems (IGS) for Harris Corp. "Our customers depend on reliable, robust and secure communications systems. Harris businesses have the integrated capabilities to provide the networked solutions that meet the needs of our customers." The shelter brings together in a single location many of the technologies that border protection forces need to carry out their missions. From these locations, force personnel are able to monitor border areas using ground radar, unattended sensors and SATCOM radio; and send and receive e-mail, images or other forms of media. A version of the shelter being demonstrated at the Defense Systems & Equipment International (DSEi) exhibition combines various tactical radio technologies such as HF, VHF, multiband and microwave radios, as well as unattended ground sensors. The DSEi shelter also features remote networked management and advanced Harris visualization/data fusion software known as Harris Safeguard.

Raytheon to Provide Counter-Narcoterrorism Programs

Raytheon Technical Services Co. (RTSC) LLC, a subsidiary of Raytheon Co., has been awarded a five-year, indefinite delivery, indefinite quantity contract to support the Department of Defense (DoD)'s counter-narcoterrorism activities. This multiple contractor award has an estimated ceiling value of $15 B. The scope of work across all task orders is to provide equipment, material and services to the DoD's Counter-Narcoterrorism Technology Program Office (CNTPO). Work began August 24 and will end August 23, 2012. Under the terms of the contract, RTSC may provide support to CNTPO in three areas: technology development and application; training, operations and logistic support; and professional and executive support. CNTPO is located at the Naval Surface Warfare Center, Dahlgren, VA. RTSC will lead a team that includes EG&G, a division of URS Corp.; Science Applications International Corp., Batelle and others. The team will offer the CNTPO a comprehensive capability to produce innovative solutions, provide responsive support and experienced management committed to the CNTPO mission worldwide. "CNTPO is actively engaged in providing technology and services to meet the immediate and emerging needs of the combatant commanders and others involved in interagency and multinational operations to disrupt, deter and deny narcoterrorist and illegal drug activities," said Tom Arnsmeyer, vice president of the Homeland Security Solution product line of RTSC's Integrated Support Solutions business. "Raytheon is committed to providing the right solution to CNTPO in this critical mission of supporting the DoD, other government agencies and partner nations." RTSC provides technology solutions for defense, federal and commercial customers worldwide. It specializes in Mission Support, counter-proliferation and counter-terrorism, homeland security solutions, base and range operations, and customized engineering and manufacturing. ■

The Lorch trademark—
a promise of quality, value, and service

Lorch Microwave is the leading supplier of RF and Microwave components and systems. For more than four decades, Lorch Microwave has been providing innovative solutions for the most demanding applications to military, industrial, and commercial customers worldwide. We incorporate the latest technology in design and manufacturing to provide the highest quality products quickly and affordably—the Lorch commitment to our clients and to their complete satisfaction.

LORCH MICROWAVE

Salisbury, Maryland 21802
800.780.2169 · 410.860.5100
www.lorch.com

smiths
bringing technology to life

MESL Microwave Acquired From Thales

Thales-MESL Ltd., a manufacturer of microwave components for the communications and defence industries, has been acquired from Thales Holdings UK plc, a subsidiary of Thales SA, by a combination of industrial investors—Lars McBride, Anthony Smith and William Buist-Wells. In the future, the company will be known as MESL Microwave Ltd. and will continue to be run on a day-to-day basis by its current managing director Mike Huggan and his existing management team. Smith has become chairman and McBride and Buist-Wells have joined the board as directors.

MESL Microwave is headquartered near Edinburgh, UK, and is one of Europe's leading designers and manufacturers of microwave components and subsystems, principally supplying customized solutions used in telecommunications base stations, point-to-point radio links and military radar systems. Specific products include high power (waveguide) ferrite components, diplexers, circulators/isolators and SAW pulse compression components.

Commenting on the acquisition Smith said, "MESL has an excellent reputation as a manufacturer of custom microwave components and can count many of the world's leading telecoms and defence companies among its customers. With Mike Huggan and his team we have widely experienced management, keen to grow the business both in developed markets and in China where we already manufacture. We are looking forward to supporting the company with substantially increased levels of capital investment."

Microwave Network Deal for Ericsson and Deutsche Telekom

Ericsson and Deutsche Telekom have entered a strategically important six-year managed services partnership, which covers the operation and maintenance of Deutsche Telekom's microwave network in Germany. Through the transaction, around 200 employees will be transferred from T-Com, along with its microwave assets and related operation activities.

The partnership is a logical one as the majority of the current data traffic in the microwave network is already transmitted over systems delivered by Ericsson. Under the agreement Ericsson will take over full responsibility for the realization and operation of the telecom vendor's microwave-based links in Germany, including planning, deployment, operation and field services, and T-Com will buy capacity from the company as part of the ongoing managed services contract.

Hans Vestberg, executive vice president and head of Business Unit Global Services at Ericsson, said, "We are confident that we not only can maintain the high quality of the network while helping reduce costs for our customer, but that we can also improve profitability in the operation of microwave networks over the coming years by adding new customers. This agreement will also lay the foundation for our strategy to make managed services a growth area and success story in Germany. We welcome the highly qualified new employees from T-Com, whom we will offer attractive career paths in an international environment of a true global player."

QinetiQ to Lead UK Energetics Consortium

The UK MoD Research Acquisition Organisation (RAO) has awarded QinetiQ an initial three-year enabling contract, which could be worth over £10 M, to lead the UK Energetics (UK-E) consortium. The consortium's remit is to maintain and refresh UK expertise, facilities and technologies in energetic materials, thereby providing a cornerstone in the implementation of the Defence Technology Strategy (DTS) and the Defence Industrial Strategy (DIS) for general munitions and complex weapons.

The capacity of the UK's Armed Forces in delivering decisive military effects is dependent upon the capability of its complex weapons and general munitions, for which energetic materials are a crucial component. In addition to their vital role in the delivery of conventional military capability, energetics technologies are also essential to counter terrorism and the strategic deterrent.

Bringing together the capabilities of the founder consortium members within a single enabling contract framework will provide the RAO with a focus for all of its energetics related research. This framework will also compliment the energetics expertise of the new Defence Equipment & Support (DE&S) organisation, Defence Science and Technology Laboratory (Dstl), the Counter Terrorism Centre, AWE, and other UK government departments, providing them with an onshore readily accessible centre for energetics expertise.

India Now Second Largest Market for Nokia

Growth in sales is establishing India as a major growth market for Nokia and a target for continued inward investment. The company announced that in the quarter ended June 2007 India became the second largest market for the company in terms of sales, overtaking the United States. Over the last three years, the country has been gaining significant ground year on year, moving from fourth position in 2005 to third position in 2006 and is today poised right behind China.

In another milestone, the company announced that it has started exporting to 58 countries from its Sriperumbudur, Chennai manufacturing plant in India, which demonstrates the operational efficiencies of the factory and conducive business environment provided by the state and central government. Today, the factory has reached production volumes of 60 million handsets (August 2007) and is exporting half of its production to 58 countries across the Middle East, Africa, Asia, Australia and New Zealand.

The factory currently employs 4700 people and the Nokia Telecom Park has received an investment of $500 M with seven global component manufacturers likely to generate in excess of 30,000 jobs when fully functional. Nokia Siemens Networks has also announced plans to invest $100 M in India over the next three years as part of its commitment to develop a strong telecommunications environment in the country. The aim is to better address and drive the growth of the Indian mobile industry and to better serve its customers.

This investment will include setting up a proposed telecommunication equipment manufacturing facility in Tamil Nadu for wireless network equipment, new offices across various cities, additional development of an existing R&D centre, and expanding the Global Networks Solution Centre.

IET Certifies Link's RF Safety Training

Link Microtek, the UK's leading supplier of non-ionising RF safety instrumentation products and services, has been certified by the Institution of Engineering & Technology (IET) as a provider of RF safety training. The company's training courses are already recognised by UK telecoms operators and broadcasters, and the IET endorsement means that other potential customers can be confident that they will be receiving professional training from a competent organisation.

To achieve IET certification, the company's personnel and procedures had to undergo rigorous vetting to demonstrate issues such as the competence of its trainers, how the trainers are trained, how the company keeps up to date with new issues, how it obtains and assesses customer feedback, and how training material is documented.

The IET endorsement covers Link's training courses on RF radiation awareness, basic measurements and survey techniques. The certification is timely as the company is anticipating increased demand for its training courses in the next few years. ■

Demand for RF and Microwave Discrete Semiconductors is Alive and Growing

Many end-users, ranging from cellular infrastructure OEMs to the military, will continue to purchase various types of discrete RF/microwave diodes and transistors. For several applications, hybrid circuits implementing discrete RF devices, as opposed to MMICs or RFICs, offer economically and technically attractive tailored solutions—occasionally even for modules destined for volume shipments. A new industry and merchant markets report from Engalco indicates that global markets for these classes of semiconductors will increase from $2.05 B in 2006 to reach $4.41 B by 2014. Silicon power transistors (LDMOS, VDMOS, etc.) will continue to be required in base station final RF power amplifiers and this report identifies the continuing clear market leadership held by such products. There will be strong growth in markets for GaN FETs and GaN HEMTs, but a near-future market decline for small-signal GaAs FETs. Until 2013, GaAs FETs will occupy the third largest market, but power GaAs FETs, in particular, are facing increasing competition from GaN FETs and GaN HEMTs. Markets for the group of transistor devices including PHEMTs and GaN HEMTs just nudge ahead of those for GaAs FETs by the end of 2013 and advance further to exceed GaAs FET market levels by 2014.

In general markets for small-signal RF/microwave transistors of all types are continually being eroded by MMICs and RFICs. Led by Schottky detectors (but including other devices) the overall classes of passive diodes collectively occupy the second largest overall market position, rising steadily to $788 M by 2014. This is a result of consistently large volume sales. By 2014, cellular infrastructure and defense form the major end-user segments, but the former has increased somewhat—mainly at the expense of the defense market, which shrinks relatively by three percent in under eight years. Globally, but mainly influenced by North America, there is an on-going resurgence in satellite systems while sophisticated defense applications are slowing down somewhat. The major overall markets are always in North America, but this share is slowly declining in relative terms in favor of strongly increasing Asia/Pacific Rim application opportunities. In this report, average selling prices (ASP) and shipments are also provided in several instances—again with forecasts to 2014. A total of 52 manufacturing supply companies are profiled in depth and the industry structure is covered in detail including worldwide sales operations. 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. For further information, contact Engalco at +44 (0) 1262 424 249 (GMT) or by e-mail: enquiries@engalco-research.com.

Wireless 4G Technology Beginning to Shape Up

Although an official definition of wireless 4G technology will not be released until the 2008/2009 timeframe in the form of the ITU's IMT-Advanced requirements, there are already clear contenders for the designation, reports In-Stat. The primary 4G technologies of the future are expected to be Long Term Evolution (LTE), Ultra Mobile Broadband (UMB) and IEEE 802.16m WiMAX, the high tech market research firm says.

"Companies are extremely uncomfortable talking about '4G' technologies, since the ITU has not defined 4G yet," says Gemma Tedesco, In-Stat analyst. "However, each of the contending 4G technologies has a cheerleader, with Ericsson touting LTE, Qualcomm preferring UMB and Intel touting 802.16m WiMAX."

Recent research by In-Stat found the following:

- Two widely expected requirements for 4G technologies are that they be OFDMA-based, and that they support 100 Mbps for wide area mobile applications.
- With the dominant worldwide technology currently being GSM/EDGE, and HSPA and EV-DO handsets not expected to be dominant until 2012, 4G technology roll-outs will most likely start in the 2010-2012 timeframe.
- It is widely believed that mobile operators will initially deploy 4G very slowly, relying on their EV-DO or HSPA networks to provide for more ubiquitous coverage.
- Drivers of LTE, UMB and 802.16m WiMAX adoption will include the following: the re-allocation of older spectrum for 4G technologies; the resolution of any WiMAX IPR issues; the creation of FDD profiles for 802.16e WiMAX; the uptake rate of 802.16e in Mobile PCs; the uptake rate of 3G cellular in Mobile PCs; the continued evolution of the mobile handset; and an increase in the uptake rate of wireless broadband technologies into portable CE devices.
- Realistically, initial implementations of LTE, UMB and 802.16m WiMAX may fall short of throughput and other expectations, with later enhancements, or even some type of technology combination, actually bringing real 4G to the table.

The research, "The Road to 4G: Will LTE, UMB and WiMAX Just be Stops Along the Way?," examines possible 4G technologies and the drivers that will influence the uptake of each of these technologies. It provides forecasts of cellular handset chipsets per technology, 3G cellular modems in mobile PCs and 802.16e mobile WiMAX chipsets through 2011. It also contains background information about contending 4G technologies and analysis of the current cellular and WiMAX markets. Profiles of vendors driving contending 4G technologies are included. In addition to the report, Gemma and other In-Stat analysts provide consulting services on a variety of technical and market topics regarding the semiconductor and electronics industries.

Increased Interest in WiMAX Will Impact The Cellular M2M Market

The cellular M2M market will be impacted by the growing momentum behind the deployment of WiMAX as a next-generation WWAN communications technology. WiMAX is even more spectrally efficient and cost-effective to operate in carrier networks when compared with W-CDMA and CDMA EV-DO, making WiMAX very suitable for low data rate, low ARPU M2M applications—when and where WiMAX connectivity is available.

Sam Lucero, ABI research senior analyst, states, "Sprint and Clearwire are the two most significant service providers deploying WiMAX in the United States. Sprint, a CDMA-based operator, has selected WiMAX as its path to 4G service offerings. Sprint will work with Clearwire—a Craig McCaw startup that has received $600 M in venture backing from Intel and $300 M from Motorola—to provide joint coverage to each other's respective customers on the national WiMAX networks deployed by the two companies. Sprint is rapidly deploying WiMAX infrastructure in North America and believes WiMAX is well-suited to deliver cost-effective, wide area M2M services: a view point borne out by ABI Research analysis." There is also growing interest in Europe in the development of WiMAX. Furthermore, there are indications suggesting an interest in employing WiMAX for M2M applications such as Advanced Metering Infrastructure (AMI). ABI Research continuously monitors and evaluates these trends. Sprint and Clearwire are only two among a number of interested parties. Lucero adds, "Intel is a key member of a developing WiMAX ecosystem that includes network infrastructure equipment vendors, Motorola and Samsung as well as CPE vendors such as ZyXEL and Accton. Intel expects nearly a few dozen operators to have deployed WiMAX by 2012." Additionally, municipal Wi-Fi can be deployed at very low cost and is well suited for select M2M applications, such as AMI, public safety telematics and video surveillance. The recent ABI Research study, "3G Machine-to-Machine (M2M) Communications," examines the market for cellular 3G M2M from the perspective of cellular embedded module vendors and analyzes the impact that WiMAX and municipal Wi-Fi will have on market development. It forms part of three annual ABI Research services: M2M, Mobile Operators and Mobile Devices. ■

INDUSTRY NEWS

■ **RF Micro Devices Inc.** (RFMD), a leader in the design and manufacture of high performance radio systems and solutions for applications that drive mobile communications, and **Sirenza Microdevices**, a supplier of radio frequency (RF) components, announced they have signed a definitive merger agreement. Under the terms of the merger agreement unanimously approved by the respective boards of directors of the two companies, each outstanding share of Sirenza's common stock will be exchanged for a combination of 1.7848 shares of RFMD common stock and $5.56 in cash. Outstanding options to purchase Sirenza stock will be assumed by RFMD and converted into options to purchase RFMD stock.

■ **DC Capital Partners LLC**, a private equity firm headquartered in Washington, DC, focused primarily in the defense and government services sector, announced that it has signed a definitive agreement to acquire a controlling interest in **ClearComm Technologies LLC** and **RelComm Technologies Inc.** The transaction is expected to close in the fourth quarter of 2007.

■ **Agilent Technologies Inc.** and **NetworkFab Corp.** announced that they have signed a definitive agreement for NetworkFab to join Agilent. Privately held NetworkFab designs and builds advanced signal intelligence, communications and jammer systems for the US military, intelligence agencies and law enforcement groups. The transaction is subject to various standard closing conditions and is expected to close in 30 to 60 days. Financial details were not disclosed.

■ **TriQuint Semiconductor**, a manufacturer of wireless products, announced that it has entered into a definitive agreement to acquire **Peak Devices Inc.**, Boulder, CO, in a cash transaction. Peak Devices is a privately held, fabless semiconductor company with a highly experienced RF team that focuses on RF discrete transistor technology. Its market segments include two-way communications, FM and television broadcast, telecommunications, avionics, radar and military.

■ **Texas Instruments Inc.** (TI) announced that it has acquired **Integrated Circuit Designs Inc.** (ICD), a privately held company that specializes in the design of RF integrated circuits (IC). Combining ICD's design expertise with TI's extensive high performance analog and low power microcontroller product portfolio will enhance TI's ability to provide low power RF solutions for industrial, commercial and consumer applications.

■ **Microsemi Corp.**, a manufacturer of high performance analog mixed signal integrated circuits and high reliability semiconductors, and **SemiSouth Laboratories Inc.**, Starkville, MS, announced that they have entered into an agreement that provides for cooperation between the two companies in the area of silicon carbide (SiC) epitaxy wafer supply as well as certain technical exchanges. SemiSouth is a privately held company specializing in SiC material and device fabrication (www.semisouth.com).

■ **California Eastern Laboratories** and **LS Research** have signed an exclusive global agreement to design, manufacture and market miniature transceiver modules for ZigBee and other low cost, low power IEEE 802.15.4 data transmission applications. Based on Freescale's™ MC13192 transceiver IC and MC9S08GT60 microprocessor, the CEL/LSR Freestar module is a fully-integrated, drop-in RF transceiver solution that is ideal for office and building automation, applications including HVAC and lighting control, and security systems.

■ **Aeroflex** has opened a new regional service center in Singapore that enables the Aeroflex Test Solutions (ATS) division to provide instrument service support to its customers within the major growth markets in Asia. Located next to Singapore Science and Technology Park in the Technopreneur Centre in Ayer Rajah, the new service center will be the operational hub for ATS products in the Asia-Pacific region. The center will provide regional support to customers, sales teams, direct service operations and third-party service channels.

■ **Cascade Microtech** announced that it has opened a wholly owned subsidiary in Munich, Germany, to support its rapidly growing European business. Cascade Microtech GmbH will provide sales, applications and service support to European customers for both the Engineering Products Division (EPD) and the Production Products Division (PPD). Both divisions have numerous strategic customers in Germany and throughout Europe, and the new subsidiary will help ensure the highest level of support for these customers. The company continues to operate an office in the UK and works with distribution partners throughout Europe for sales and applications support.

■ **Park Electrochemical Corp.** announced that it has selected the Newton City-County Airport in Newton, KS as the site for its new Advanced Composite Materials development and manufacturing facility for aircraft structures. The facility, which Park plans to complete by the end of the company's next fiscal year, will be approximately 50,000 square feet, and will contain manufacturing, laboratory and office space. The company plans to spend approximately $15 M on the facility and equipment.

■ **Inphi® Corp.** established the first of its Global Centers for Design Innovation in the heart of the Silicon Valley. The Silicon Valley Design Center, which will be managed by Ali Wehbi, expands the depth of technical resources Inphi applies in designing integrated circuits that deliver the world's best performance and highest signal integrity for processing data in the most demanding communication and computing systems.

■ **Fairchild Semiconductor** (FCS) has expanded its Global Power Resource℠ Center with the addition of a facility in Ann Arbor, MI. This new center—near the heart of the

Ultra WIDE BANDWIDTH VCOs

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

RoHS COMPLIANT

DCMO & DCFOSeries

Model	Frequency (MHz)	Tuning Voltage * (VDC)	DC Bias VDC @ I (Max)	Minimum Output Power (dBm)	Typical Phase Noise @ 10 kHz (dBc/Hz)
DCMO514-5	50 - 140	0.5 - 24	+5 @ 30 mA	+3.5	-110
DCMO616-5	65 - 160	0.5 - 24	+5 @ 35 mA	+3	-108
DCMO1027	100 - 270	0 - 24	+5 to 12 @ 35 mA	+2.5	-112
DCMO1129	110 - 290	0.5 - 24	+5 to +12 @ 35 mA	+2.5	-105
DCMO1545	150 - 450	0.5 - 24	+5 to 12 @ 35 mA	+4	-108
DCMO1857	180 - 570	0.5 - 24	+5 to 12 @ 30 mA	+3	-108
DCMO2260-5	220 - 600	0.5 - 24	+5 @ 35 mA	+2	-108
DCMO2476	240 - 760	0.5 - 24	+5 to 12 @ 35 mA	+4	-108
DCMO3288-5	320 - 880	0.5 - 24	+5 @ 35 mA	+3	-109
DCFO35105-5	350 - 1050	0 - 25	+5 @ 40 mA	+7	-112
DCMO40110-5	400 - 1100	0.5 - 24	+5 @ 42 mA	+5	-103
DCMO40110-8	400 - 1100	0.5 - 24	+8 @ 45 mA	+5	-104
DCMO50120-5	500 - 1200	0.5 - 24	+5 @ 40 mA	+6	-118
DCMO50120-12	500 - 1200	0.5 - 24	+12 @ 35 mA	+6	-103
DCMO60170-5	600 - 1700	0 - 25	+5 @ 35 mA	+3	-99
DCMO80210-5	800 - 2100	0.5 - 24	+5 @ 35 mA	+5	-96
DCMO80210-10	800 - 2100	0.5 - 24	+10 @ 35 mA	+6	-100
DCMO90220-5	900 - 2200	0.5 - 24	+5 @ 35 mA	+4	-98
DCMO90220-12	900 - 2200	0.5 - 25	+12 @ 35 mA	+6	-99
DCMO100230-12	1000 - 2300	0.5 - 24	+12 @ 35 mA	+3	-101
DCMO100230-5	1000 - 2300	0.5 - 24	+5 @ 35 mA	+3	-98
DCMO110250-5	1100 - 2500	0.5 - 28	+5 @ 35 mA	+6	-100
DCMO135270-8	1350 - 2700	0.5 - 20	+8 @ 35 mA	+4	-93
DCMO150318-5	1500 - 3200	0.5 - 20	+5 @ 30 mA	+7	-93
DCMO150320-5	1500 - 3200	0.5 - 18	+5 @ 60 mA	0	-92
DCMO172332-5	1720 - 3320	0.5 - 24	+5 @ 30 mA	+4	-94
DCMO190410-5	1900 - 4100	0.5 - 16	+5 @ 50 mA	+2	-90
DCMO250512-5	2500 - 5125	0.5 - 24	+5 @ 50 mA	-2	-78

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

Visit http://mwj.hotims.com/11724-153 or use RS# 153 at www.mwjournal.com/info

SYNERGY® MICROWAVE CORPORATION

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

Visit Our Website At WWW.SYNERGYMWAVE.COM

North American automotive market—responds to the burgeoning need for functional power solutions, including multi-die modules, for automotive power applications.

■ **Shimadzu Scientific Instruments** (SSI) announced the opening of a new regional office in Carlsbad, CA. This office allows Shimadzu to provide more direct sales, technical and service support for southern California, southern Nevada and Hawaii, and will be fully supported through the corporate office in Columbia, MD.

■ **Quantum Leap Packaging Inc.** (QLP), a provider of high performance air cavity packages for semiconductor assembly, announced that it has added a second manufacturing site in Poway, CA. QLP plans to manufacture in its new Poway site by early 2008. The new 18,000 square foot facility will provide QLP with much needed capacity to support growing demand and provide product service and support to its Wilmington, MA facility.

■ **Anritsu Co.** announced that its ME7873F W-CDMA TRX/Performance Test System, which supports 3G mobile terminal conformance test, has earned the world's first HSUPA RF/RRM test case approvals from the Global Certification Forum (GCF). The approvals provide HSUPA RF/RRM device and system manufacturers with an authorized set of verification tests to ensure global inter-compatibility between HSUPA mobile terminals. It also confirms Anritsu's commitment to provide test solutions for next-generation technologies.

■ The **Evans Capacitor Co.** announced that it has earned Silver Level Preferred Supplier certification from the Missiles and Fire Control business unit of Lockheed Martin. Evans Capacitor joins just 35 other companies that achieved this status out of thousands of Lockheed Martin suppliers. The Silver Level designation reflects excellence in quality, consistent and on-time delivery, responsiveness and process control. Evans Capacitor Co. provides Lockheed Martin Missiles and Fire Control with energy-dense tantalum capacitors and capacitor banks that are smaller, lighter and more powerful than traditional capacitors.

■ **Richardson Electronics Ltd.** announced it recently received its highest ranking ever in a reader's survey of preferred distributors conducted by Electronics Supply and Manufacturing–China. Richardson Electronics was ranked second overall among International Distributors in the annual survey of purchasing professionals. Richardson also placed in the Top 10 in all four Franchised Distributor categories: Best Supply Capacity, Best Technical Support, Best Logistics Service and Best e-Commerce.

CONTRACTS

■ **TRAK Microwave Corp.** announced that it has been selected by **L-3 Communications Narda-East** to supply 9100AN-44 time and frequency processors for the GMT program. The transportable quadband SATCOM terminals developed for the GMT program by L-3 will utilize TRAK's time code processors enabling communication nodes to be synchronized over the entire network. TRAK will deliver several hundred units over a period of performance of five years.

■ **Andrew Corp.**, a leader in communications systems and products, has won a major upgrade contract for the Mass Transit Railway Corp.'s (MTRC) territory-wide radio network in Hong Kong. As part of this project, Andrew will modify MTRC's communications infrastructure in stations, tunnels and other buildings to enable migration of the railway's radio system from a conventional 80 MHz trunk radio system to an 800 MHz TETRA system.

■ **Astron Wireless Technologies** was awarded a Small Business Innovation Research (SBIR) Phase II award from the Department of Defense (DoD) for development of an 'Adaptive Bandwidth High Power RF Antenna.' The objective is to develop a universal approach to the design of high power broadband antennas for the non-lethal utilization of RF energy. This development and production of a prototype system is based on the Phase I development of a 10:1 bandwidth basic Log-conical antenna. Astron had previously developed a similar antenna operating above 1 GHz. During Phase II, the program will focus on creating a truly miniature high gain, high power antenna operating within the general operating band of up to 1000 MHz.

FINANCIAL NEWS

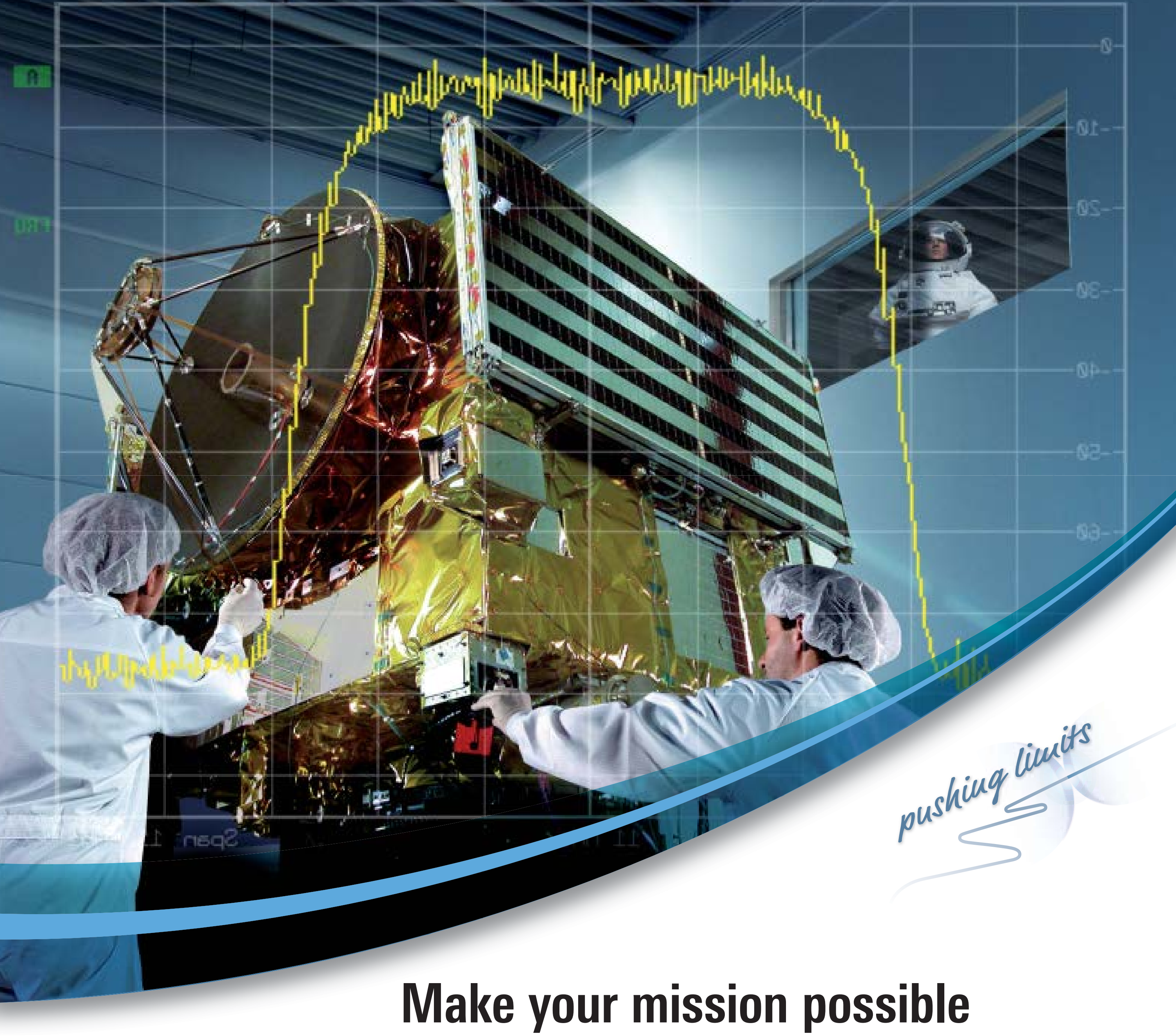
■ **Ansoft Corp.** reports sales of $19.9 M for the first quarter of fiscal 2008 ended July 31, 2007, compared to $17.3 M for the same period in 2007. Net income for the quarter was $3.9 M ($0.15/per diluted share), compared to $2.3 M ($0.09/per diluted share) for the first quarter of last year.

■ **Superconductor Technologies Inc.** (STI), a provider of high performance infrastructure products for wireless voice and data applications, has entered into an agreement with **Hunchun BaoLi Communication Co. Ltd.** (BAOLI) under which BAOLI has agreed to invest $15 M in exchange for 9,216,590 shares of STI's common stock. The purchase price is $1.6275 per share, based on a five percent premium over the average closing price of STI's common stock on the NASDAQ stock exchange for the 30 days ended August 17, 2007.

NEW MARKET ENTRIES

■ Following the sale of **ITT**'s switch division, the company announced the creation of **C&K Components**. The new privately held C&K Components is leading the switch industry with innovative products delivered with the legendary service that made C&K the world's preferred supplier. The new C&K combines the history and experience of three of the industries leading suppliers: C&K Components, Newton MA, US; the Rudolf Schadow Co., Berlin, Germany; and the Jeanrenaud Switch Co., Dole, France.

■ A new start-up company, **GraSen Technology LLC**, has been established to provide technology solutions in the growing requirements for Heterojunction Bipolar Transistor (HBT) and Heterostructure Field-Effect Transistor (HFET) devices in the US and international commercial communications and defense electronics markets. GraSen Technology's HBT and HFET products are de-



Make your mission possible

The R&S®FSU – now up to 67 GHz

Some missions simply must not fail. That's when you need extreme precision and a wealth of capabilities – just what you get from our flagship spectrum analyzer, the R&S®FSU. It offers the utmost of what state-of-the-art spectrum analysis can achieve in every regard: an extremely wide dynamic range and low noise up to 67 GHz, a truly all-in-one solution with everything that makes work more efficient, plus realtime performance that speeds up every step of your task. You will rarely exhaust this analyzer's potential. Rather, you can rest assured that you will be equipped for every challenge. With the R&S®FSU at your side, your work can have only one result: mission accomplished.

ROHDE&SCHWARZ

www.rohde-schwarz.com/ad/fsu

Visit http://mwj.hotims.com/11724-138 or use RS# 138 at www.mwjournal.com/info

signed in the company's San Jose, CA engineering offices and are manufactured, tested and packaged in three qualified semiconductor foundries in order to meet any small-to-large volume production requirements.

PERSONNEL

▲ Fred Shlapak

■ SiGe Semiconductor, a global supplier of RF front-end solutions for wireless systems, announced the appointment of **Fred Shlapak** as chairman of the Board of Directors. Shlapak's addition expands the Board to seven members. Shlapak was president and chief executive officer of the Semiconductor Products Sector at Motorola Corp. when he retired in February 2004. Shlapak's 33-year career at Motorola included leading the company's Canadian semiconductor operations.

■ Skyworks Solutions Inc. announced that **Donald W. Palette** has joined Skyworks as vice president and chief financial officer. Palette, 50, most recently served as senior vice president of finance and controller of Axcelis Technologies Inc., a publicly-traded company that supplies capital equipment to global semiconductor manufacturers. Prior to joining Axcelis, Palette held various financial executive management positions throughout his career at Simplex Corp., Bell and Howell, and Publication Systems Co.

▲ Nic du Toit

■ AR RF/Microwave Instrumentation has announced the appointment of **Nic du Toit** to the post of engineering manager. du Toit will assume responsibility for all aspects of product development, configuration management and technical support. A cum laude graduate of South Africa's University of Stellenbosch, with a master's of science degree in engineering, du Toit has lectured in RF and microwave engineering at the university; he also worked in South Africa's defense industry, creating EW receivers; and managed sales and technical support for a South African company before coming to the US.

■ **David Distler** has recently joined Coaxial Dynamics near Cleveland, OH as the company's new sales and marketing manager. Over the past 30 years, Distler has held senior sales, marketing and product management positions at Bird Technologies Group in Cleveland, Trilithic and Wavetek in Indianapolis, IN. His duties will include managing worldwide sales and promotional efforts for CDI's extensive line of RF test equipment and passive components. Contact information: David Distler, Coaxial Dynamics, 6800 Lake Abrams Drive, Middleburg Hts., OH 44130 (440) 243-1100, e-mail: ddistler@coaxial.com.

■ **OML Inc.**, a manufacturer of vector network analyzer frequency extension modules for waveguide bands from 50 to 500 GHz, has received a "Certificate of Recognition" honor-

ing **Chuck Oleson**, the company president, "for the creative development of a technical innovation which has been approved for publication as a NASA Tech Brief entitled *On-Wafer Vector Network Analyzer Measurements for 220 to 325 GHz*. This recognition included a cash award and was shared with two other NASA and industry individuals.

REP APPOINTMENTS

■ **Microphase Corp.**, a manufacturer of microwave and RF components, announced the appointment of **RUPPtronik** as the company's exclusive manufacturer representative serving Austria, Germany and Switzerland. Contact information for RUPPtronik is Bernd Rupp, +49 80 62 – 80 00 99 or e-mail: Brupp@RUPPtronik.de.

■ **MU-DEL Electronics Inc.**, Manassas, VA, has just signed on two new representatives to market its products. MU-DEL manufactures high technology RF equipment that includes: RF multicouplers from 1 kHz to 40 GHz; RF frequency converters (up and down converters) that work from baseband to 26.5 GHz; RF switching distribution systems that work from DC to 26.5 GHz and specialized RF products. **Integral Marketing** will be covering the mid-atlantic states that include VA, MD, NJ and PA. Integral's contact number is (301) 731-4370. **Don DuPont Sales** will be covering FL and can be reached at (321) 432-0516.

■ **Coaxial Dynamics** has appointed **Evergo Instruments Inc.** as its representative in Taiwan. The offices are strategically located in Taipei and Taichung. Contact information: Evergo Instruments Inc., 5 Fl. No. 495, Chung-Cheng Road, Hsin-Tien, Taipei, Taiwan, ROC 231, ph: 886-2-2752-0767, fax: 886-2-8773-0678 or e-mail: sales@evergo.com.tw.

■ **Auriga Measurement Systems LLC** announced the addition of two new sales organizations to its sales channel. **Compomill Nordic Components AB** will exclusively represent Auriga in the Nordic region while **Base Eight Inc.** will cover the Midwest United States.

■ **RLC Electronics**, an RF and microwave component manufacturer, announced the appointment of **Omecon Electronic GmbH** as a new representative in Germany, Austria and Switzerland. Omecon delivers products from manufacturers for wireless communication and microwave applications.

■ **International Manufacturing Services Inc.** (IMS), a manufacturer and supplier of high quality thick film resistors, terminations, attenuators, planar dividers and planar filters to the electronics industry, announced the appointment of **Votron Electronics** as its representative for the territory of Canada. Votron is headquartered in Concord, Ontario (outside Toronto) and has regional offices in Montreal and Vancouver. For more information, visit www.votronelectronics.com.

■ Electronic components distributor **Digi-Key Corp.** and **Advanced Thermal Solutions Inc.** (ATS) announced the signing of a global distribution agreement. The terms of this agreement will enable Digi-Key to fulfill both the design and production quantity thermal management needs of its diverse customer base.

NOVEL DESIGN OF A PRINTED MONOPOLE ANTENNA FOR WLAN/ WiMAX APPLICATIONS

In this article, a novel design of a printed coplanar waveguide (CPW)-fed monopole antenna is implemented to simultaneously satisfy wireless local area network (WLAN) and worldwide interoperability for microwave access (WiMAX) applications. First, a printed half-elliptic monopole antenna was constructed for broadband operation. A printed half-elliptic monopole antenna, with two sections of the metal surface etched, was then investigated to obtain a dual-band operation with two bands: 2.30 to 4.15 GHz and 4.93 to 5.83 GHz. The low band (2.5 to 2.7 GHz) is quite near the middle band (3.3 to 3.8 GHz) of WiMAX, resulting in a large coupling effect or interference between these two bands; a band-reject function is needed to suppress the undesired frequency band between the low band and the middle band of WiMAX. Therefore, by etching two narrow slits on the dual-band printed monopole antenna, a triple-band antenna design for WLAN/WiMAX applications can be obtained. The low cost, ease of manufacture, good impedance match and good radiation pattern properties of the proposed antenna are also investigated.

In recent years, wireless communications have progressed very rapidly and wideband and multi-band antenna designs have become very important for wireless applications. Several promising wideband antennas are suitable for applications in wireless local area network (WLAN) systems and worldwide interoperability for microwave access (WiMAX). Some monopole antennas for WLAN[1,2] and WiMAX[3,4] applications have recently been reported. ***Figure 1*** shows the frequency allocations for WLAN and WiMAX. There are many popular products for WLAN applications in the 2.4 and 5 GHz bands. The operating frequency bands of WiMAX are the 2.4, 3.5 and 5.2/5.8 GHz bands. For brevity, the low band denotes the band of 2.4 GHz (2.4 to 2.7 GHz); the middle band denotes the band of 3.5 GHz (3.3 to 3.8 GHz); and the high band denotes the band of 5.2/5.8 GHz (5.15 to 5.35 GHz/5.725 to 5.825 GHz). It is a standard for broadband wireless access at high speed, low cost and easy to deploy. A theoretical 30-mile coverage radius and data rates up to 75 Mbps can be achieved with WiMAX technology. Throughput close to 1.5 Mbps,

WEN-SHAN CHEN AND
YU-CHEN CHANG
Southern Taiwan University of Technology
Tainan, Taiwan, ROC

Integrated Microwave Assemblies

Advanced Technology - Extensive Experience - Superior Performance

CPI
Communications & Power Industries

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

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

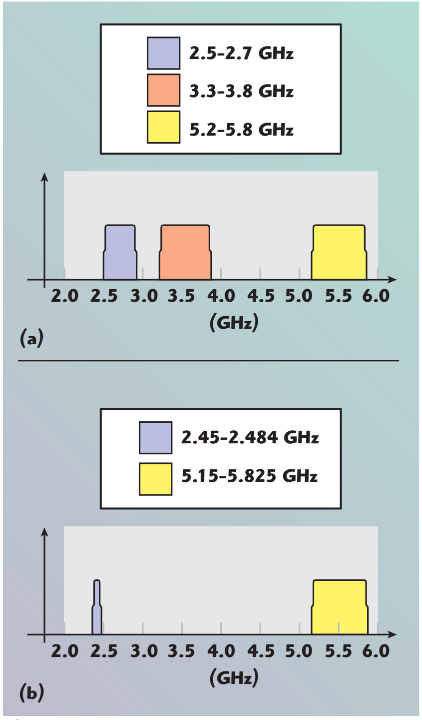
Communications & Power Industries
Beverly Microwave Division

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

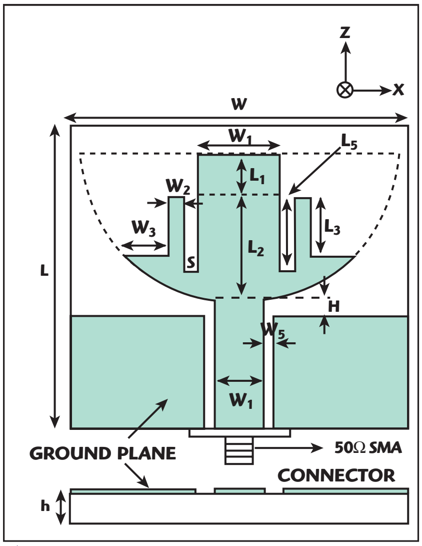
marketing@bmd.cpii.com
www.cpii.com/bmd

typical of broadband services,[5–8] can also be obtained. The development of WiMAX technology is the immediate focus of the receiving industry. Presently, the design of antennas for WLAN/WiMAX applications is an important issue. Because CPW-fed antennas have the advantages of wide bandwidth, simple structure, single metallic layer and easy integration with active devices or MMICs,[9] they are good candidates for wireless communications antennas.

Some methods for WiMAX antenna design can be suggested. The design of a triple-band antenna with three resonant modes fitting the three bands of WLAN/WiMAX is not an easy task. A triple-band antenna has been reported,[9] but is not suitable for WiMAX applications. Furthermore, the antenna design with three modes suffers from interference between the three resonant modes.[10,11] Using a wideband/broadband antenna[3,4] fits the requirements of WLAN/WiMAX antennas. In addition, some dual-band antennas covering the bands of WiMAX have been published.[12] However, the low band is very near the middle band, which causes interference and coupling between the two bands of WiMAX. A triple-band polygonal slot antenna, using a dual-band rejection technique,[13] has been constructed and investigated. In this article, a novel design of a triple-band antenna is proposed, which evolved from a dual-band WiMAX antenna. For WLAN/WiMAX applications, the antenna bandwidth of the low band and high band should be enhanced. Bands I, II and III are defined as the band of 2.4 to 2.7 GHz, the band of 3.3 to 3.8 GHz and the band of 5.15 to 5.825 GHz, respectively. The design of the antenna for WLAN/WiMAX follows the methods used in designing WiMAX antennas. First, a CPW-fed printed half-elliptic monopole antenna for broadband operation is constructed and investigated. Some specified parts of the half-elliptic monopole are then etched to obtain dual-band operation at 2.30 to 4.15 GHz and 4.93 to 5.83 GHz, and a novel design, for a CPW-fed antenna with dual-band operation for WLAN/WiMAX applications, is achieved. In practical applications of WiMAX, the low band is close to the middle band, which leads to large coupling and interference effects. The wideband and dual-band antennas must use a filter to suppress this coupling, leading to increased cost. By etching a pair of slits in the proposed dual-band antenna, a rejected frequency band from 3 to 3.2 GHz is obtained and a novel design of a CPW-fed monopole antenna with three bands for WLAN/WiMAX applications is achieved. Good impedance matching and radiation characteristics of the constructed prototype are also shown.



▲ *Fig. 1 The frequency locations of (a) WLAN and (b) WiMAX applications.*

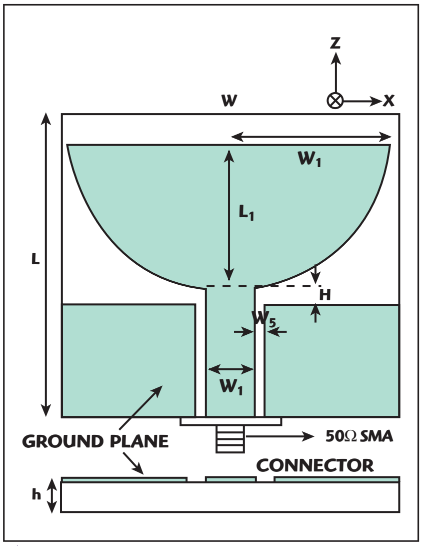


▲ *Fig. 2 The structure of the triple-frequency monopole antenna.*

ANTENNA DESIGN

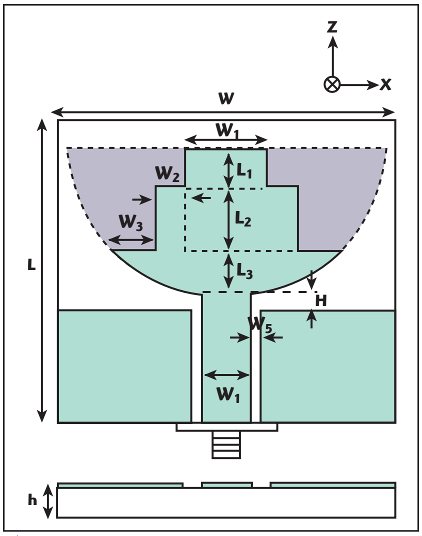
The geometry of the simple triple-frequency monopole antenna is shown in ***Figure 2***, where the conductor is printed on a FR4 substrate of thickness h = 0.4 mm and dielectric constant ε_r = 4.4. A CPW transmission line, with a fixed signal-strip width W_f = 6 mm and a gap distance W_s = 0.5 mm between the strip and ground, is used to feed the antenna. Two finite ground patches of the same size (21 × 16.5 mm) are situated symmetrically on each side of the CPW line. The other antenna dimensions are: H = 2.8 mm, L = 53 mm, L1 = 6 mm, L_2 = 19.7 mm, L_3 = 12 mm, W = 33 mm, W1 = 11 mm, W_2 = 2.5 mm, W_3 = 4.5 mm, S = 1 mm and L_s = 15.5 mm.

Figure 3 illustrates the geometry of the proposed CPW-fed printed half-elliptic monopole antenna for WLAN/WiMAX operation in the 2 to 5.8 GHz bands. By properly tuning the dimensions L_1 and W_1, the CPW-fed printed wideband monopole, connected to the end of the CPW transmission line with a spacing H = 2.8 mm from the ground plane, a wideband antenna can successfully be created. The antenna dimensions are: h = 0.4 mm, L = 53 mm, W = 33 mm, L_1 = 25.7 mm, W_1 = 16 mm, W_s = 0.5 mm, W_f = 6 mm and S = 1 mm. By etching some parts of the half-elliptic monopole antenna, as shown in ***Figure 4***, a dual-band monopole antenna for WLAN/WiMAX can be achieved. Its dimensions are: h = 0.4 mm, H = 2.8 mm, L = 53 mm, L_1 = 6 mm, L_2 =



▲ *Fig. 3 The structure of the half-elliptic monopole antenna.*

15.5 mm, L_3 = 4.2 mm, W = 33 mm, W_1 = 11 mm, W_2 = 3.5 mm, W_3 = 4.5 mm, W_s = 0.5 mm and W_f = 6 mm.

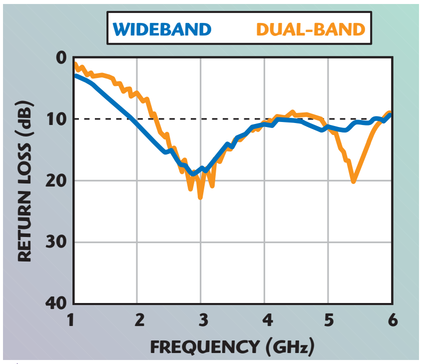


▲ *Fig. 4 The structure of the dual-band monopole antenna.*

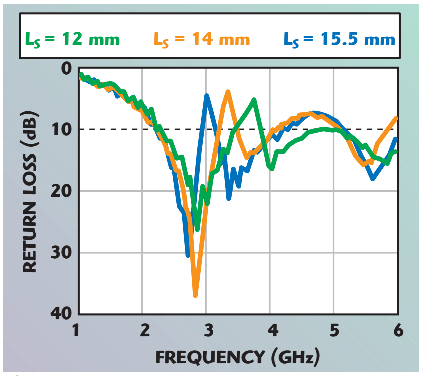
The dual bands cover the 2.30 to 4.15 GHz and 4.93 to 5.83 GHz bands. It is observed that the dual-band operation of the printed CPW-fed dual-band monopole antenna satisfies the requirements of WLAN/WiMAX operations. In practical applications of WiMAX, because the low band is close to the middle band, leading to large coupling effects and interference, a band-reject technique must be used to suppress these undesired effects. In order to reduce the interference, a band-reject function of the proposed antenna must be added to the dual-band monopole antenna. By etching one pair of slits (S × L_s mm) on the dual-band monopole antenna, a triple-band antenna for WLAN/WiMAX can be obtained. The slits determine the center frequency and bandwidth of the rejected-band. The suppressed mode at 3 GHz is achieved by using a pair of slits whose length is approximately 15.5 mm (L_s = $\lambda_g/4$ = 15.25 mm at 3 GHz). For WiMAX applications, the optimal parameters of the proposed antenna were numerically obtained.

EXPERIMENTAL RESULTS AND DISCUSSION

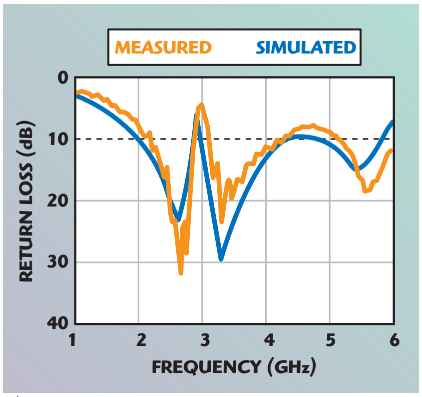
In this study, experimental results of impedance, radiation and gain characteristics of the proposed antenna are measured and presented. An HP 8753ES vector network analyzer was used for measurements of impedance characteristics. The NSI model FFC-600 far-field antenna measurement system permitted the measurements of radiation and gain characteristics of proposed antennas. The surface current distribution was analyzed using the commercial software tool HFSS. ***Figure 5*** shows the



▲ *Fig. 5 Measured return loss of the wideband and dual-band antennas.*



▲ *Fig. 6 Simulated return loss of the triple-band monopole antenna as a function of the slit length (L_S).*



▲ *Fig. 7 Measured and simulated return loss of the triple-band antenna.*

Power measurements have never been so mobile

This power sensor goes where you go. Whenever and wherever you need to make power measurements—whether for manufacturing, antenna or base station testing—the Agilent U2000 Series of USB power sensors is always up to the task.

With the U2000 Series, you can make measurements without a power meter. And you won't need power adapters and triggering modules so often necessary with other USB-based solutions. Now, even multiple-channel power measurements are easier and more affordable.

Simply plug the U2000's cable into your PC, or selected Agilent instruments, and start monitoring and analyzing with the N1918A Power Analysis Manager software. When you need high performance power measurements in a portable and convenient package... you'll want to use the Agilent U2000 Series power sensors. Go to www.agilent.com/find/usbsensor1 for more information.

Agilent U2000 Series USB Power Sensors

- *Frequency range from 9 kHz to 24 GHz*
- *Wide dynamic range from -60 dBm to +20 dBm*
- *Built-in triggering for synchronization with external instrument*
- *Internal zeroing capability*
- *Feature-packed Power Analysis Manager software*

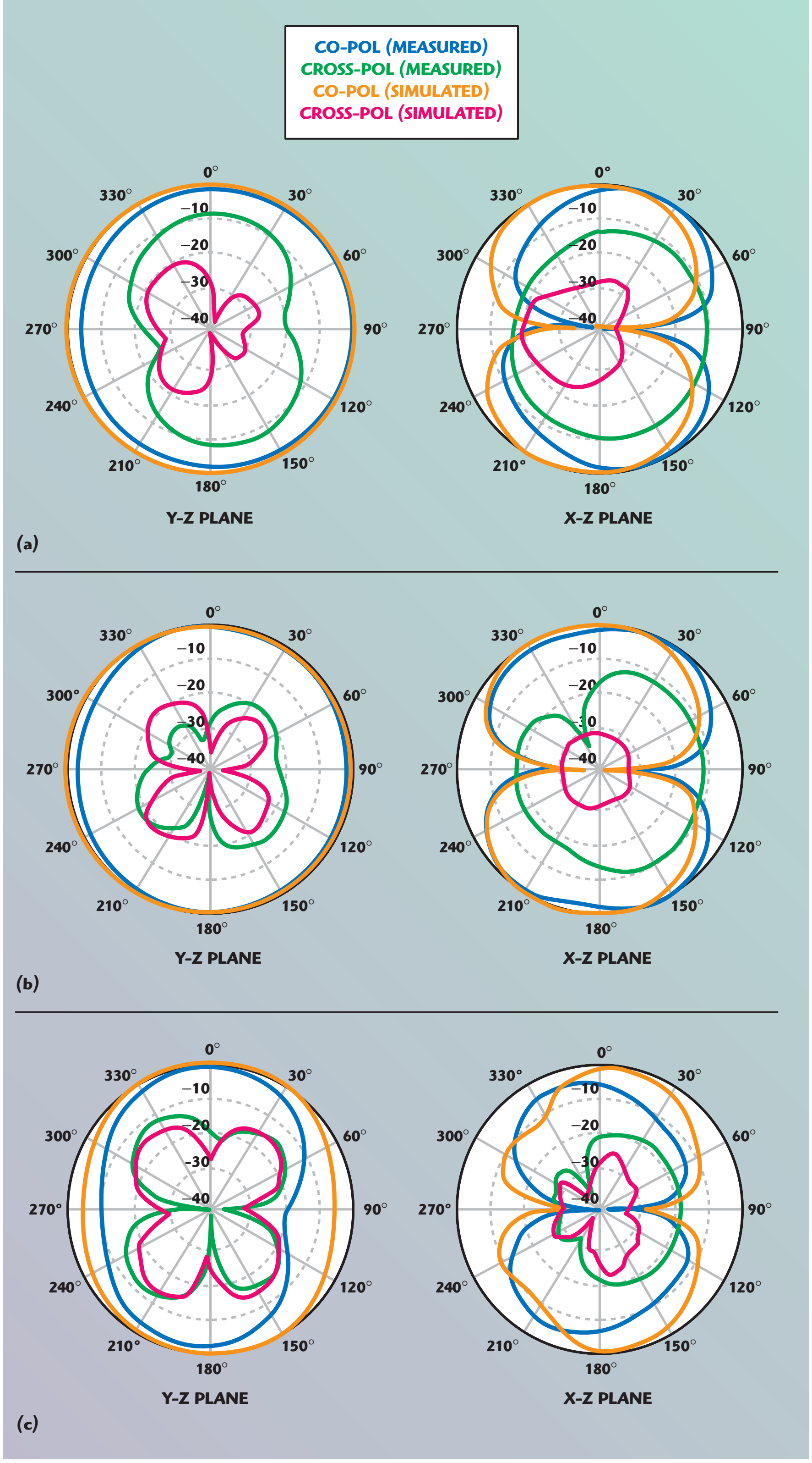
u.s. 1-800-829-4444
canada 1-877-894-4414

www.agilent.com/find/usbsensor1

Agilent Technologies

Visit http://mwj.hotims.com/11724-9 or use RS# 9 at www.mwjournal.com/info

measured return loss of the wideband printed half-elliptic monopole antenna. Its bandwidth (1.93 to 5.8 GHz) is approximately 100 percent. By etching two sections (yellow area) from the printed CPW-fed wideband antenna, the printed CPW-fed dual-band monopole antenna has been obtained and its return loss is also shown. The impedance matching ob-



▲ *Fig. 8 Measured and simulated far-field radiation patterns of the dual-band antenna at 2.45 (a), 3.5 (b) and 5.5 GHz (c).*

tained (determined from a 10 dB return loss) of the proposed antenna can reach 2.30 to 4.15 GHz and 4.93 to 5.83 GHz. By choosing the proper dimensions of the slits etched on the dual-band monopole antenna, a tri-band for a WLAN/WiMAX antenna can be obtained (see ***Figure 6***). The antenna parameters have been given previously. A comparison of the simu-

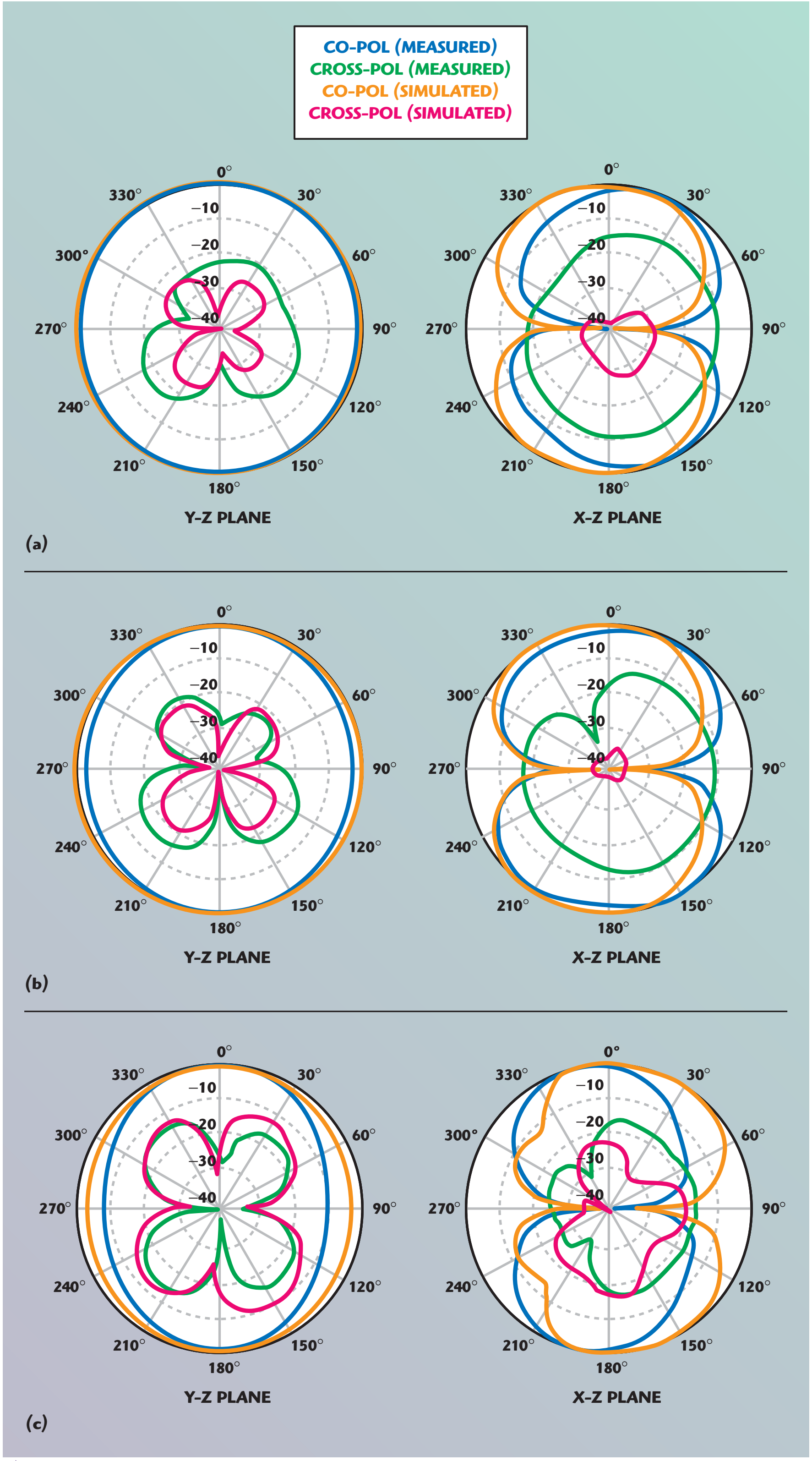
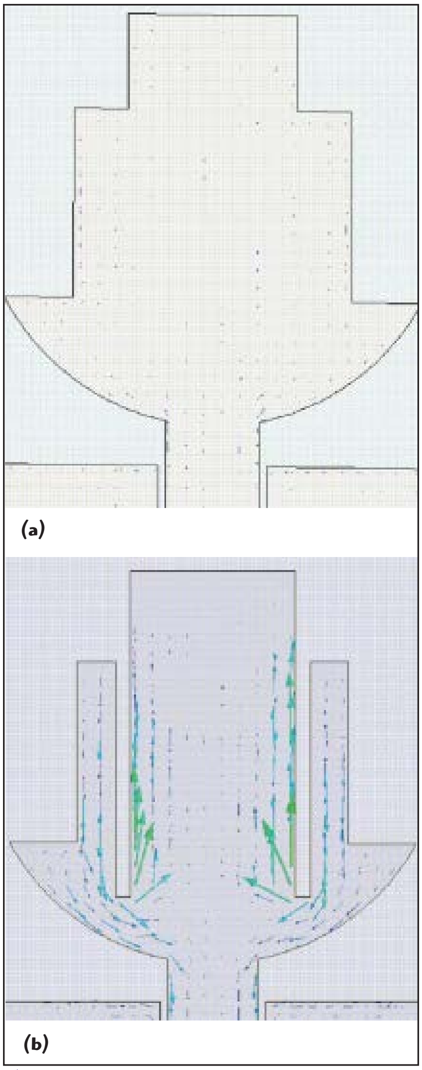


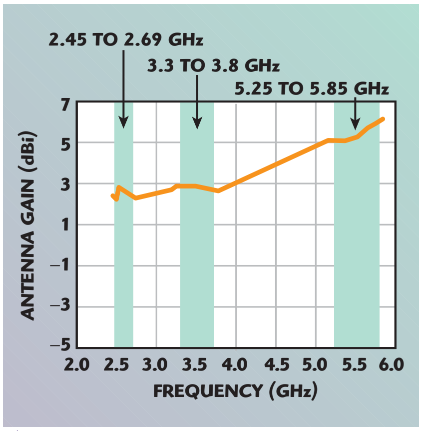
Fig. 9 Measured and simulated far-field radiation patterns of the triple-band antenna at 2.45 (a), 3.5 (b) and 5.5 GHz (c).

lated and measured return loss for the triple-band antenna is shown in ***Figure 7***. The measured and simulated radiation patterns of the proposed printed CPW-fed dual-band antenna at 2.45, 3.5 and 5.5 GHz are shown in ***Figure 8***. The measured and simulated radiation patterns of the proposed triple-band antenna at 2.5, 3.5 and 5.5 GHz are shown in ***Figure 9***. The radiation patterns of the proposed antenna are well behaved. For comparison, the simulated surface current distribution at 3 GHz of the dual-band and the triple-band antennas are shown in ***Figure 10***. It can be clearly seen that the current is concentrated at the edge of the two slits at 3 GHz. Therefore, the impedance mismatching and the gain drop at the rejected band is present in this design.

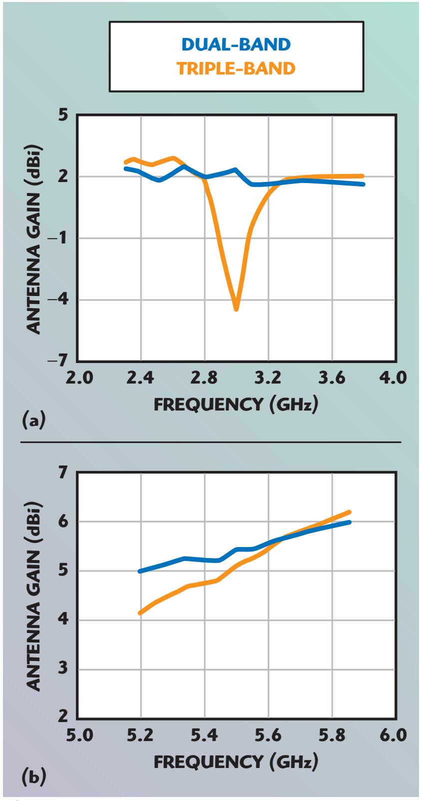


▲ *Fig. 10 Simulated surface current distribution for the dual-band (a) and triple-band (b) antennas at 3 GHz.*

Figure 11 shows the measured antenna gain for the wideband operation of the half-elliptic monopole antenna. The gain of the half-elliptic antenna varies from 2.25 to 6 dBi within the 2.25 to 5.85 GHz band. ***Figure 12*** compares the measured gains of the dual- and triple-band antenna. A strong gain reduction in the rejected band near 3.2 GHz is shown for the WiMAX antenna. The antenna gain is between 1.68 and 2.39 dBi for the 2.5 to 2.7 GHz band of the WiMAX antenna; the antenna gain goes from 1.9



▲ *Fig. 11 Measured antenna gain of the wideband half-elliptic monopole antenna.*



▲ *Fig. 12 Measured peak gains of the dual- and triple-band antennas at 2.3 to 3.8 GHz (a) and 5.2 to 5.8 GHz (b).*

to 2.24 dBi for the 3.3 to 3.7 GHz band of the WiMAX antenna; and the antenna gain varies from 4.85 to 5.9 dBi for the 5.2 to 5.825 GHz band of the WiMAX antenna. The 2.5 to 2.7 GHz band of the WLAN/WiMAX antenna gain varies from 1.93 to 2.55 dBi; the 3.3 to 3.7 GHz band of the WLAN antenna is between 1.88 and 2.7 dBi; and the 5.2 to 5.8 GHz band of the WLAN antenna shows a gain from 5.1 to 5.61 dBi. Consequently, this antenna design is suitable for WLAN or WiMAX applications.

CONCLUSION

A novel printed CPW-fed monopole antenna, usable in WLAN and WiMAX applications, has been discussed and fabricated. This article focuses on a band-rejected design to fit WLAN/WiMAX operations. The band-rejected function is obtained by etching a pair of slits in the printed CPW-fed dual-band monopole antenna to reject frequencies from 3 to 3.22 GHz. This is needed to eliminate coupling, which occurs between the low and middle frequency bands and creates interference. The WLAN/WiMAX antenna shown in this article eliminates the use of a filter and thus reduces the cost. ■

References

1. T.H. Kim and D.C. Park, "CPW-fed Compact Monopole Antenna for Dual-band WLAN Applications," *Electronic Letters*, Vol. 41, 2005, pp. 291–293.
2. J.W. Wu. Y.D. Wang, H.M. Hsiao and J.H. Lu, "T-shaped Monopole Antenna with Shorted L-shaped Strip-sleeves for WLAN 2.4/5.8-GHz Operation," *Microwave and Optical Technology Letters*, Vol. 46, 2005, pp. 65–69.
3. Y.T. Liu and K.L. Wong, "A Wideband Stubby Monopole Antenna and a GPS for WiMAX Mobile Phones with E911 Function," *Microwave and Optical Technology Letters*, Vol. 46, 2005, pp. 485–487.
4. K.L. Wong, W.C. Su and F.S. Chang, "Wideband Internal Folded Planar Monopole Antenna for UMTS/WiMAX Folded-type Mobile Phone," *Microwave and Optical Technology Letters*, Vol. 48, 2006, pp. 324–327.
5. "Deploying License-exempt WiMAX Solutions," *WiMAX White Papers*, Intel Corp., 2005, http://www.intel.com/netcomms/technologies/wimax/306013.pdf.
6. "Understanding Wi-Fi and WiMAX as Metro Access Solutions," http://www.intel.com/netcomms/technologies/wimax/304471.pdf.
7. IEEE802.16 Working Group on Broadband Wireless Access Standards, http://grouper.ieee.org/groups/802/16/index.html.
8. Worldwide Interoperability for Microwave Access Forum or WiMAX Forum, http://www.wimaxforum.org.
9. W.C. Liu and C.C. Huang, "A CPW-fed L-shaped Slot Planar Monopole Antenna for Triple-band Operations," *Microwave and Optical Technology Letters*, Vol. 44, 2005, pp. 510–512.
10. W.S. Lee, W.G. Lim and J.W. Yu, "Multiple Band-notched Planar Monopole Antenna for Multiband Wireless Systems," *IEEE Microwave and Wireless Component Letters*, Vol. 15, 2005, pp. 576–578.
11. W.S. Lee, D.Z. Kim, K.J. Kim and J.W. Yu, "Wideband Planar Monopole Antenna With Dual Band-notched Characteristics," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 54, 2006, pp. 2800–2806.
12. C.Y. Pan, T.S. Horng, W.S. Chen and C.H. Huang, "Dual Wideband Printed Monopole Antenna for WLAN/WiMAX Applications," *IEEE Antennas and Wireless Propagation Letters*, accepted for publication.
13. W.S. Chen and B.H. Kuo, "A Triple-band Polygonal Slot Antenna for WiMAX Applications," *Microwave Journal*, Vol. 50, No. 1, January 2007, pp. 134–143.

Wen-Shan Chen *received his BS degree in electronic engineering technology from the National Taiwan Institute of Technology (now known as the National Taiwan University of Technology) and his PhD degree from National Sun Yat-Sen University, Kaohsiung, Taiwan, ROC, in 2001. From 2001 to 2002, he was an assistant professor at the Chien-Kuo Institute of Technology, Changhua, Taiwan, ROC. He is currently an assistant professor in the department of electronic engineering at the Southern Taiwan University of Technology, Tainan, Taiwan, ROC. His research interests include antenna design, RF and microwave circuits.*

Yu-Chen Chang *received his BS degree from the Southern Taiwan University of Technology, Taiwan, ROC, in 2004, where he is currently pursuing his master's degree. His main research interests include printed antenna for wireless communications, especially printed antennas for WiMAX applications.*

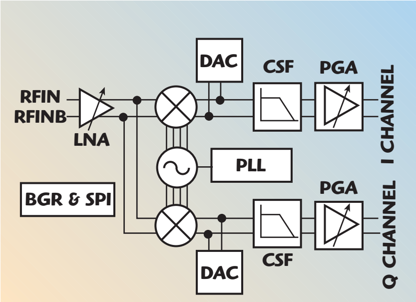
A Direct-conversion Receiver for 5 GHz Wireless LAN with Sub-harmonic Down-conversion

This article describes a CMOS direct-conversion receiver for 5 GHz wireless LAN. Sub-harmonic mixing is used for down-conversion to minimize the DC-offset due to LO-leakage. The residual DC-offset is cancelled by a digital-to-analog converter at the output of the mixer. For quadrature down-conversion with sub-harmonic mixing, octa-phase LO signals are generated by an integer-N type frequency synthesizer. Implemented in a 0.18 μm CMOS technology, the receiver dissipates 97 mA from a 1.8 V supply, has a 6.5 dB noise figure (NF) and a –4 dBm input third-order intercept point (IIP3). The phase noise of the closed-loop voltage-controlled oscillator (VCO) is –108 dBc/Hz at 1 MHz offset.

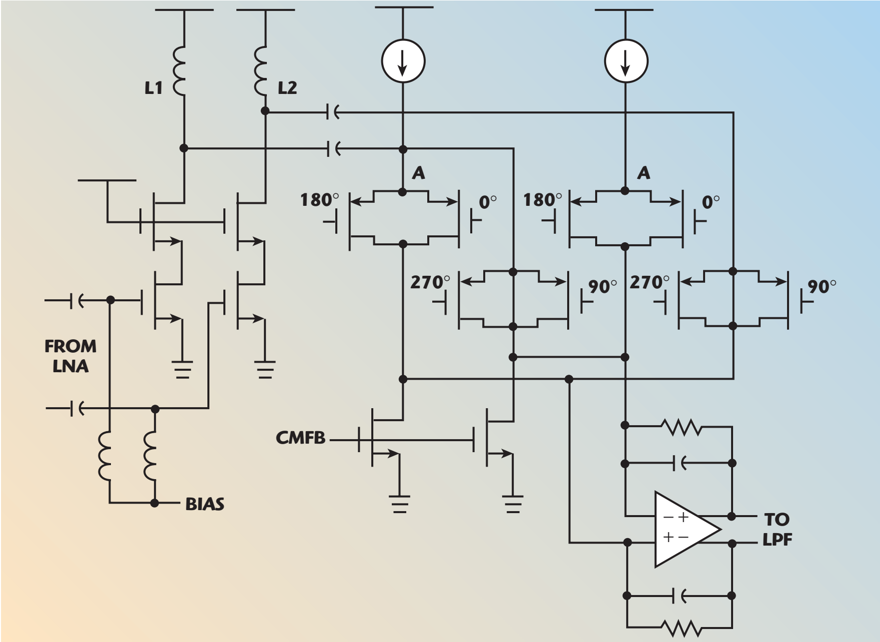
Among the various kinds of wireless communication systems, wireless LAN (WLAN) is the most popular for short-range communications, due to its high data rate. For low cost and low power implementation of a WLAN terminal, a fully integrated CMOS RF transceiver is required for which a low or zero-IF (direct-conversion) architecture is best suited because the number of external components is minimized.[1,2] A low IF architecture provides a much higher immunity for DC-offset and flicker noise than a direct-conversion architecture, but a high level of matching between signal paths is required for sufficient image rejection.[3] The 5 GHz WLAN standard, IEEE 802.11a, uses OFDM, where the first sub-carrier is not used and the channel bandwidth is wide.[4] Therefore, it is relatively immune to DC-offset and flicker noise and a direct-conversion receiver architecture has been a popular choice.[1,2]

In this article, a fully integrated CMOS direct-conversion receiver, including a frequency synthesizer, is described for 5 GHz WLAN applications. Sub-harmonic mixing minimizes the DC-offset and the residual DC-offset of the baseband circuits is compensated by a digital-to-analog converter (DAC). The octa-phase local oscillator (LO) signals, required for quadrature sub-harmonic mixing, are generated by an integer-N type frequency synthesizer. The architecture and circuit implementation of the receiver is described and the detailed experimental results are given.

Mi-Young Lee, Chan-Young Jeong, Jae-Woo Park and Changsik Yoo
Hanyang University
Seoul, Korea
Jin-Soo Park
Samsung Advanced Institute of Technology
Kiheung, Korea



▲ *Fig. 1 Direct-conversion receiver for WLAN.*



▲ *Fig. 2 Sub-harmonic mixer for I-channel.*

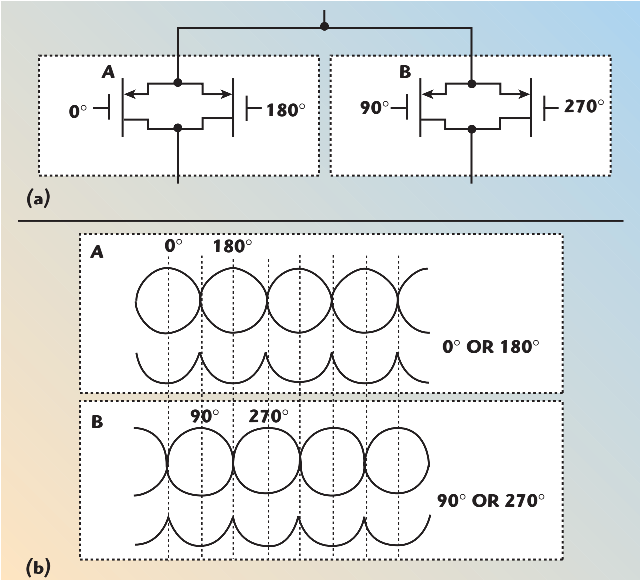
DIRECT-CONVERSION RECEIVER WITH SUB-HARMONIC MIXING

The overall block diagram of the 5 GHz direct-conversion receiver is shown in ***Figure 1***. The bandgap reference (BGR) generates the required bias voltages and currents for each block. The serial port interface (SPI) is used to provide the various control signals such as gain-control of the low noise amplifier (LNA) and programmable gain amplifier (PGA).

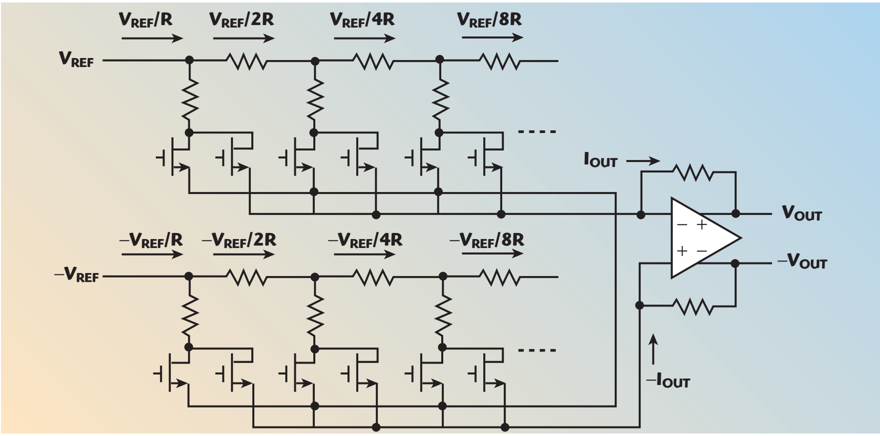
To minimize the DC-offset due to LO self-mixing, sub-harmonic mixing is used for down-conversion. The residual DC-offset of the baseband circuits is cancelled by a DAC at the output of the down-conversion mixer. All the signal paths are fully differential to minimize noise coupling and even-order harmonic distortion. For quadrature down-conversion with sub-harmonic mixing, octa-phase LO signals are generated by an integer-N type frequency synthesizer. The channel selection filtering is performed by a fifth-order Chebyshev active-RC filter, which is followed by a programmable gain amplifier (PGA).

RF Front-end

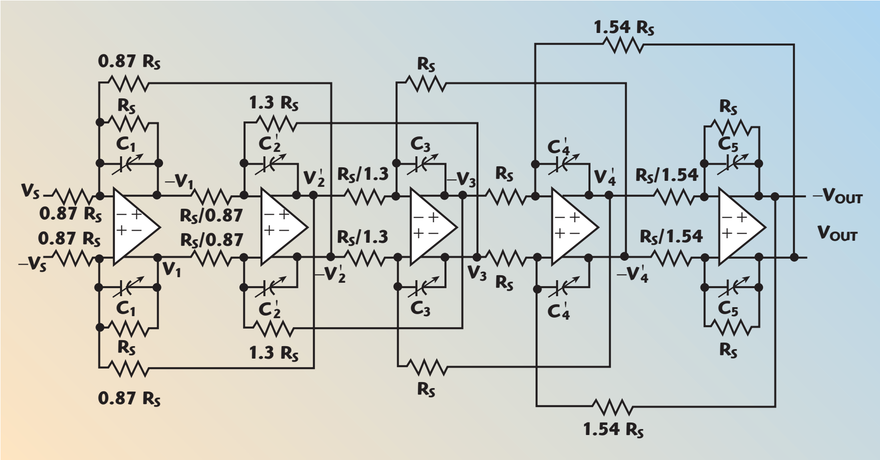
The pseudo differential low noise amplifier (LNA) uses the nMOS common-source cascode topology with inductive source degeneration provided by the bonding wire to minimize the chip size. The LNA is switched to low gain mode to alleviate the linearity requirement on the following stages when a large RF input signal is present. To remove the DC-offset due to the LO self-mixing, the double-balanced sub-harmonic mixer shown in ***Figure 2*** is used for quadrature down-conversion. The LO frequency is half that of the RF input frequency. Therefore, octa-phase LO signals, spaced by 45°, are required for quadrature down-conversion. As shown, the I-mixer uses 0°, 90°, 180° and 270° LO signals, while for Q-channel, 45°, 135°, 225° and 315° LO signals are used. For sub-harmonic mixing, conventionally two stacked LO switching stages are used, which requires large voltage headroom.[5,6] In this work, only one stack of switching stage is used to allow the low voltage operation and the principle of harmonic mixing is illustrated in ***Figure 3***. The



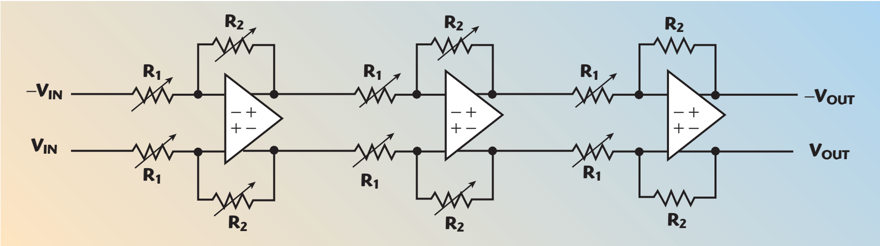
▲ *Fig. 3 Sub-harmonic switching stage (a) and its operation principle (b).*



▲ *Fig. 4 R-2R ladder type DAC for DC-offset cancellation.*



▲ *Fig. 5 Fifth-order Chebyshev active-RC filter.*



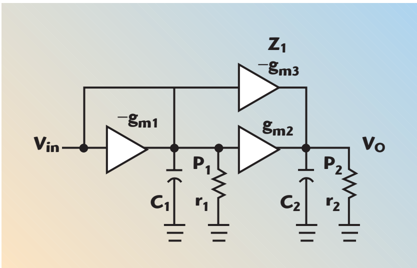
▲ *Fig. 6 Programmable gain amplifier.*

switching stage is composed of pMOS transistors to minimize the flicker noise.[7,8] The output of the transconductance stage is AC-coupled to the switching stage to prevent the low frequency even-order harmonics and DC-offset of the transconductance stage from being leaked to the mixer output. An additional advantage of the AC-coupling is the independent biasing of the transconductance and switching stages, facilitating the design optimization such as conversion gain, noise figure and linearity. The output current of the mixer is converted to voltage by an active-RC first-order filter whose cut-off frequency is tuned by the same code as the channel selection filter (CSF) following the mixer.

Analog Baseband

The analog baseband consists of I/Q signal paths, which include CSF, programmable gain amplifier (PGA) and DAC for DC-offset cancellation. At the input of the CSF, I- and Q-paths have separate DC-offset canceling R-2R ladder type DAC with 7-bit resolution, as shown in ***Figure 4***. The DC-offset canceling code is generated by a separate digital baseband modem. For channel selection filtering, a fifth-order Chebyshev filter shown in ***Figure 5*** is used because it provides a relatively large stop-band attenuation with moderate group delay variation within the passband. Between Gm-C and active-RC type implementation options, the active-RC type is adopted for its better linearity. The dynamic range of the filter is maximized by scaling the resistor's values to have the same maximum signal swing for all internal nodes. The gain of the PGA (see ***Figure 6***) can be controlled from 2.5 to 52.5 dB in 0.5 dB steps.

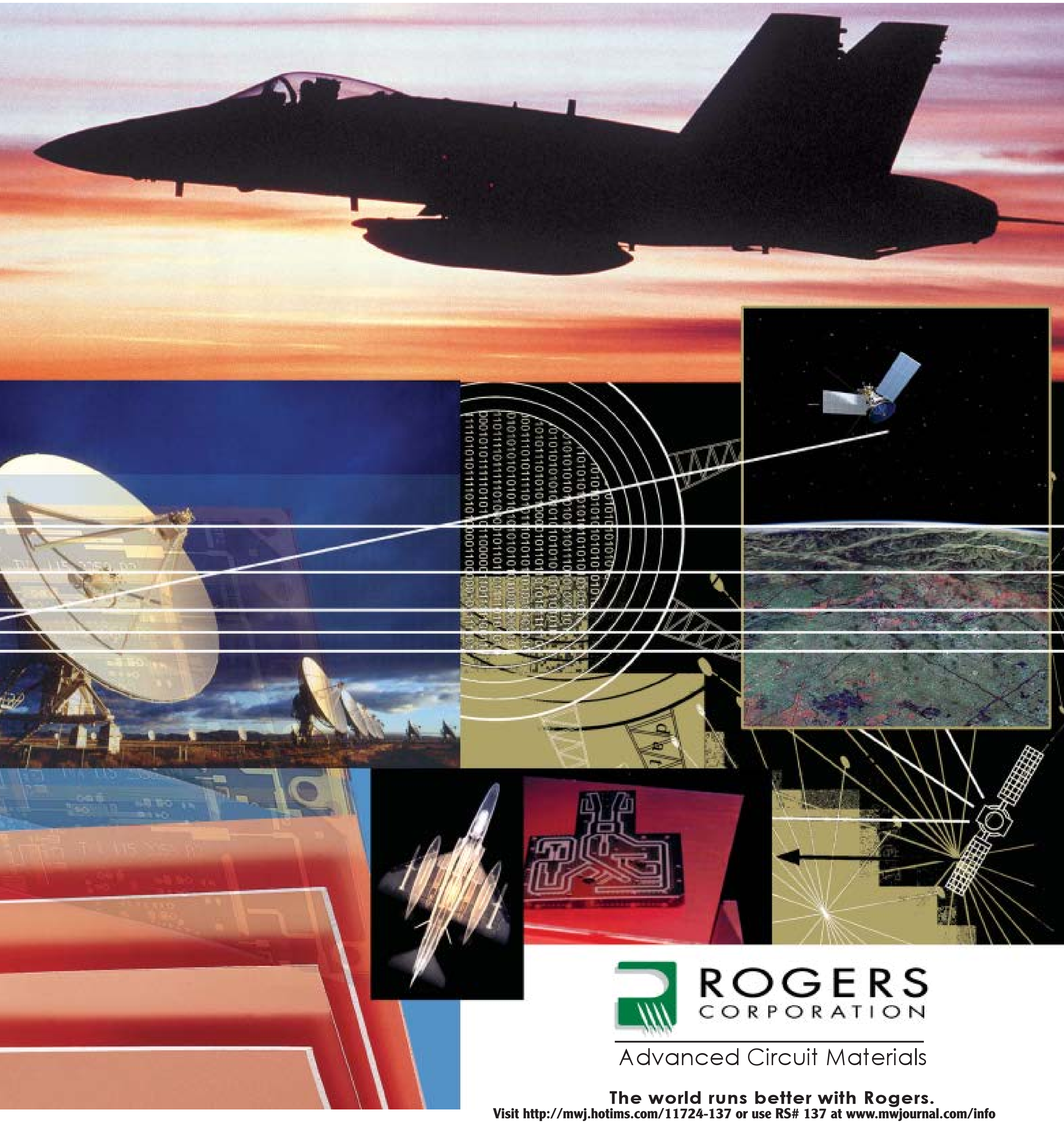
Because the operational amplifier (op-amp) for CSF and PGA should



▲ *Fig. 7 Frequency compensation with feedforward zero.*

There's a reason why we call them "advanced" circuit materials.

We build on years of experience to create custom materials that provide optimum solutions for your designs; materials that are highly efficient and extremely reliable. Some more advancements? Tightly controlled DK for panel to panel uniformity; low loss for excellent performance in high frequency applications; superior flexibility in claddings, thicknesses, designs, and applications. For more information, visit **www.rogerscorporation.com/acm/info9**.



Visit http://mwj.hotims.com/11724-137 or use RS# 137 at www.mwjournal.com/info

USA - AZ, tel. +1 480-961-1382 • EUROPE - Belgium, tel. +32 9 235 3611 • ASIA - Taiwan, tel. +886 2 8660 8056

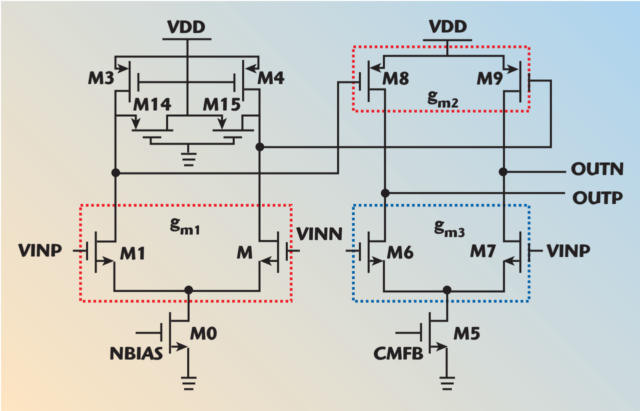


Fig. 8 Operational amplifier for CSF and PGA.

be able to provide virtual ground for out-of-band signals, the required bandwidth of the op-amp is much larger than the channel bandwidth. However, with a conventional frequency compensation method using a Miller capacitor, a large bandwidth can be obtained only with large power consumption. The op-amp used here employs a feedforward frequency compensation method shown in ***Figure 7***, whose transfer function is given as

$$H(s) = -\frac{g_{m1}r_1g_{m2}r_2 + g_{m3}r_2 + sC_1r_1g_{m3}r_2}{(1+sC_1r_1)(1+sC_2r_2)} = -(A_1A_2+A_3)\times\frac{1+s/z_1}{(1+s/p_1)(1+s/p_2)} \quad (1)$$

where

$A_1 = g_{m1}r_1$
$A_2 = g_{m2}r_2$
$A_3 = g_{m3}r_2$
$p_1 = 1/C_1r_1$
$p_2 = 1/C_2r_2$

z_1 is given as

$$z_1 = p_1\left(1+\frac{A_1A_2}{A_3}\right) \quad (2)$$

From Equations 1 and 2, the phase shift of the poles can be compensated with a left-half plane zero whose position can be varied by controlling A_3. The op-amp, employing the feedforward frequency compensation scheme, is shown in ***Figure 8***. In order to reduce the current consumption, the differential pair (M6 and M7) generating g_{m3} is re-using the bias current of g_{m2}.[11] The simulation results, including all the parasitic capacitance, indicate 57.4 dB DC gain and 332 MHz unity gain frequency with 6 pF load capacitance, as shown in ***Figure 9***.

Octa-phase LO Generation

For quadrature down-conversion with sub-harmonic mixing, octa-phase local oscillator (LO) signals are required at half of the RF input frequency. A ring-type four-stage LC voltage-controlled oscillator (VCO), shown in ***Figure 10***, is used for low phase noise. The switched tail current biasing scheme is applied, which is known to reduce the flicker noise of the biasing transistor by periodically releasing the trapped electrons.[12–14] Two-bit digital inputs,

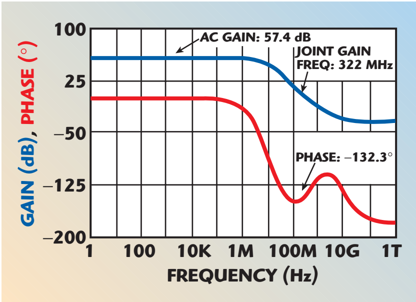


Fig. 9 Simulated frequency response of the operational amplifier.

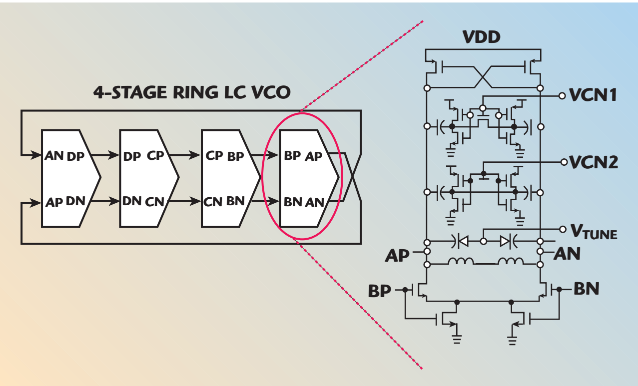


Fig. 10 Octa-phase ring-type LC VCO.

"LEADERSHIP"

in HIGH POWER *Design!!*

OUR 35th YEAR

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:

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.

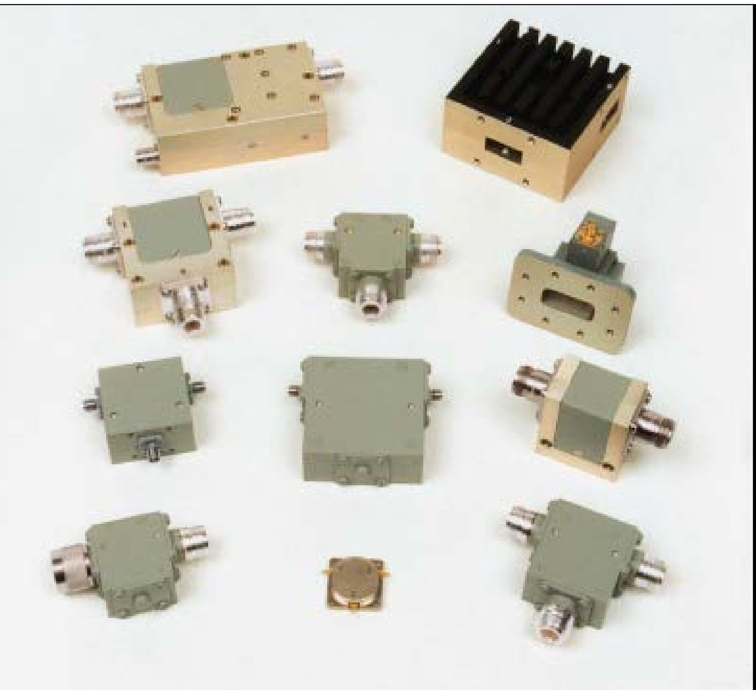
UTE MICROWAVE INC.

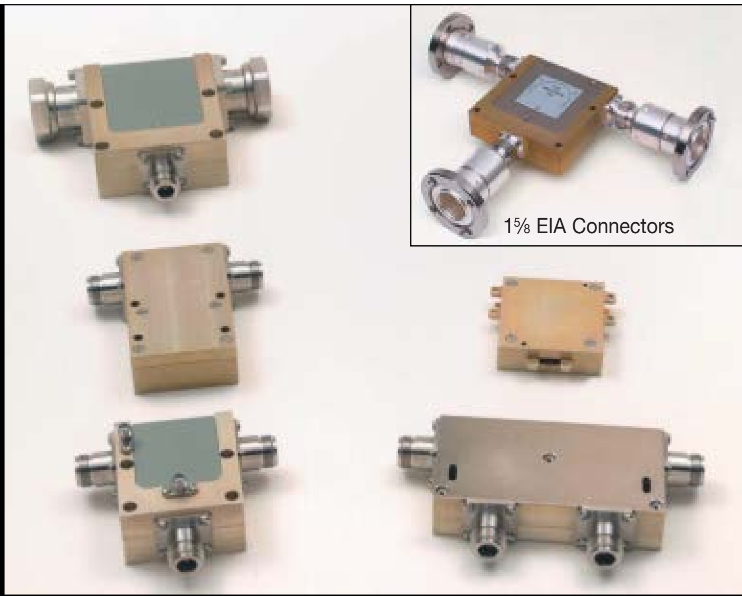
"The Ferrite Solutions Company"

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

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

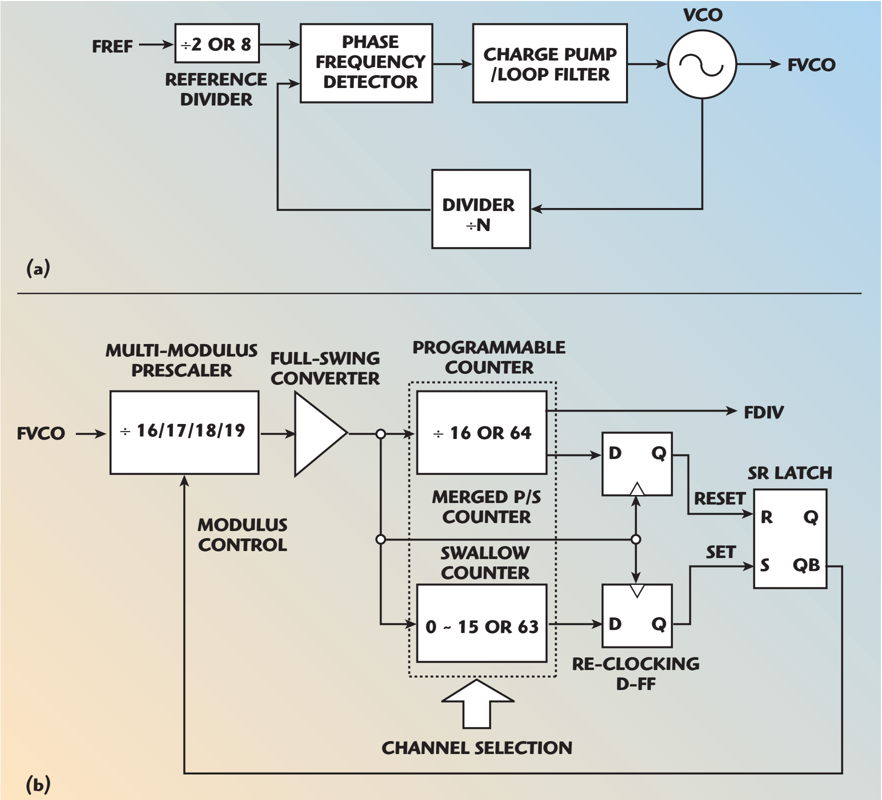
Visit http://mwj.hotims.com/11724-168 or use RS# 168 at www.mwjournal.com/info





1⅝ EIA Connectors

WWW.UTEMICROWAVE.COM



▲ *Fig. 11 Frequency synthesizer (a) and divider-by-N (b).*

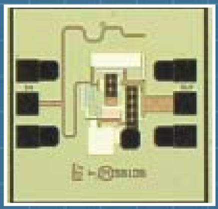
VCN1 and VCN2, coarsely control the oscillation frequency with a capacitor bank.

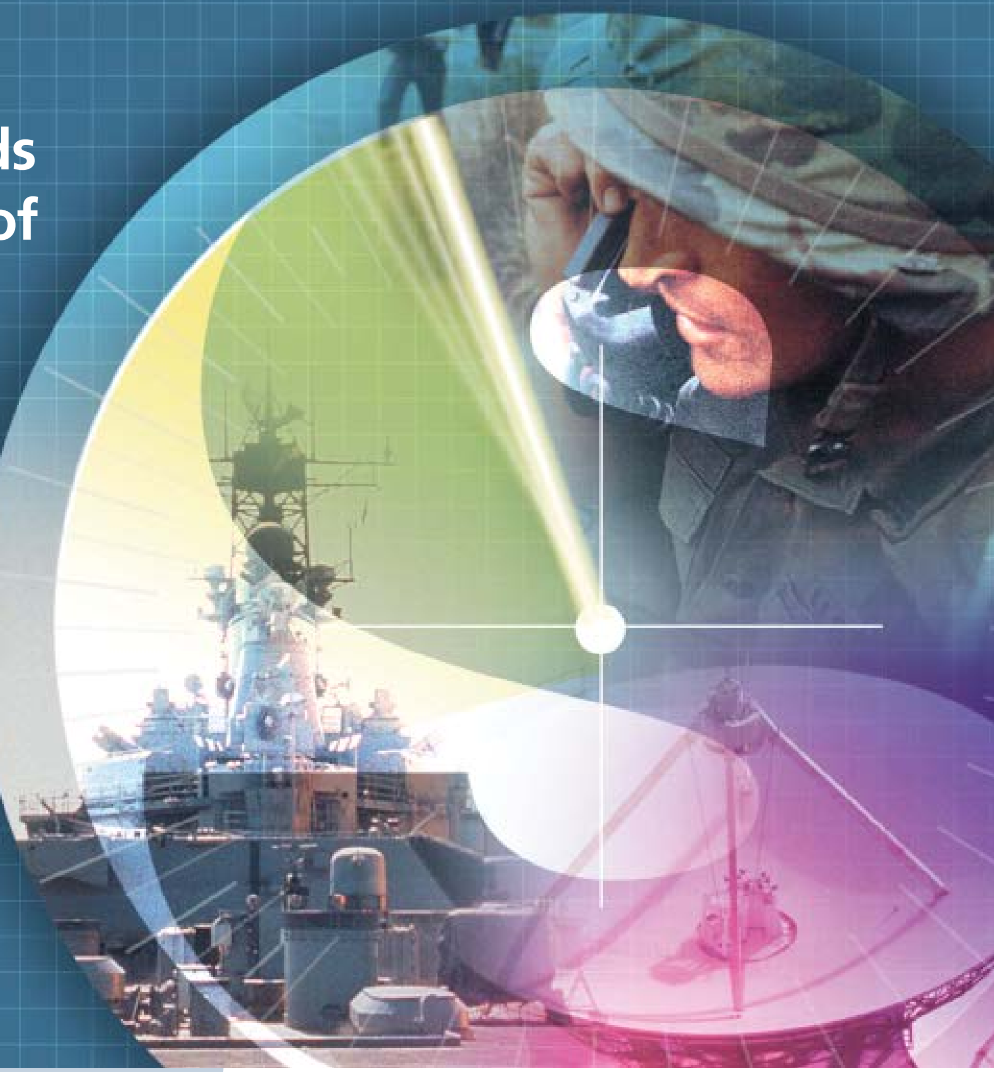
The LC VCO is embedded in an integer-N type phase-locked loop (PLL), as shown in ***Figure 11***. The divide-by-N block of the PLL shown has a multi-modulus (16/17/18/19) prescaler, instead of the normally used dual-modulus one. With a conventional dual-modulus prescaler, the counting ratio of an asynchronous programmable counter can be as large as 256, resulting in a large delay and the re-timing with the prescaler output becomes very difficult. The programmable and swallow (P/S) counters are merged together to reduce the silicon area. The output of the merged P/S counter is re-timed by the output clock of the multi-modulus prescaler to reduce the jitter of the divided-by-N clock. The loop filter of the PLL is implemented off-chip. The octa-phase outputs of the VCO are buffered by Cherry-Hooper type amplifiers to have sufficient voltage swing. The phase noise of the open- and closed-loop octa-phase VCO is –120 dBc/Hz and –108 dBc/Hz, respectively, at 1 MHz offset, as shown in ***Figure 12***. The phase error between the octa-phase LO signals is less than 1° over the whole frequency range.

EXPERIMENTAL RESULTS

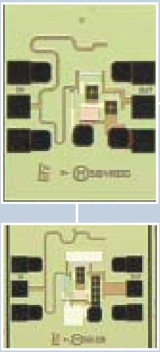
The 5 GHz direct-conversion receiver has been implemented in a 0.18 μm CMOS technology, whose microphotograph is shown in ***Figure 13***. The chip occupies a core area of 5.76 mm^2 and is packaged in a 48-pin MLF package with exposed die. The measured voltage gain and noise figure of the overall receiver are 71.0 to 73.5 dB and 6.0 to 6.5 dB, as shown in ***Figures 14*** and ***15***, respectively. The third-order input intercept point (IIP3) is measured to be –4 and –16 dBm, respectively, at the low and high gain modes of the LNA, as shown in ***Figure 16***. The cut-off frequency of the CSF can be controlled from 5 to 12.7 MHz, as shown in ***Figure 17***, and the stop-band rejection is greater than 40 dB. The gain error of PGA is less than 0.25 dB over the whole gain control range. The measured performance of the receiver is summarized in ***Table 1***.

Sirenza extends its SUF Series of pHEMT MMIC Amplifier Solutions...





...to give you more RF/Microwave options.



SUF Series

- DC-20GHz frequency range
- Broadband 50-ohm match; no external matching required
- Single-biased 3.3 or 5.0V operation
- On-chip temperature compensated gain

Flexible Product Platforms

- Bare Die 100% RF/DC probed
- Hermetic: surface mount or connectorized
- Plastic packaged (COTS) SUFs

SIRENZA MICRODEVICES

Sirenza Microdevices' SUF series of pHEMT Microwave MMIC Amplifiers extends Sirenza's patented Darlington MMIC technology through the microwave frequency band. These wide-band cascadable amplifiers provide outstanding electrical performance due to patented self-bias circuitry, on-chip temperature compensation, and internal 50-ohm matching circuitry. The SUF-1000 through SUF-9000 pHEMT amplifiers provide solutions for various microwave driver-stage applications including homeland security communications, military and space applications.

Visit us at www.sirenza.com for more information about our Aerospace, Defense & Homeland Security RF Solutions.

QMI REGISTERED

ISO 9001:2000
ISO 14001:2004

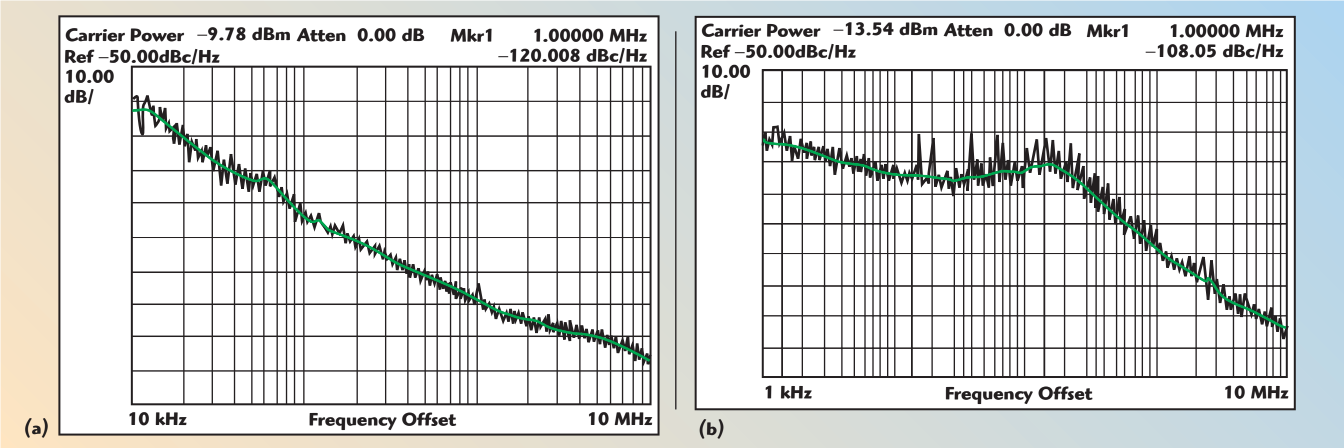


Fig. 12 Phase noise of the open-loop (a) and closed-loop (b) VCO.

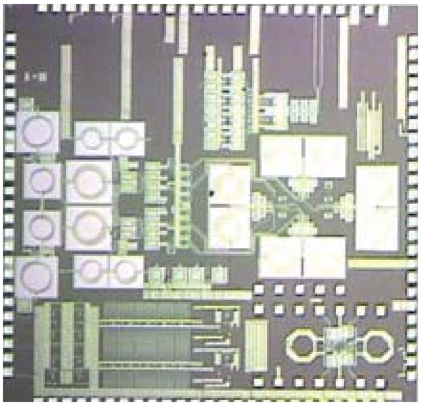


Fig. 13 Die microphotograph of the direct conversion receiver.

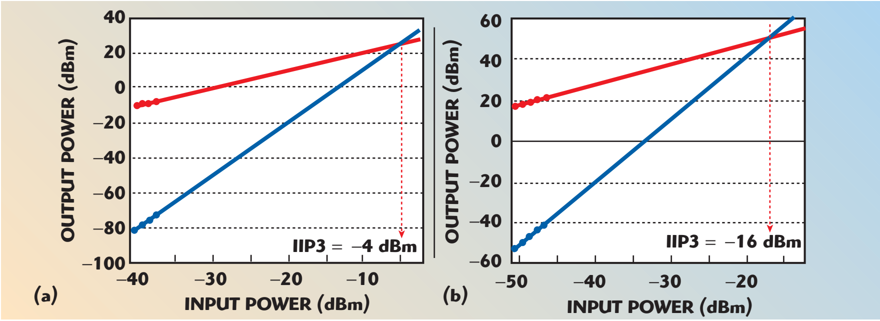


Fig. 16 Measured IIP3 of receiver in (a) low gain and (b) high gain mode.

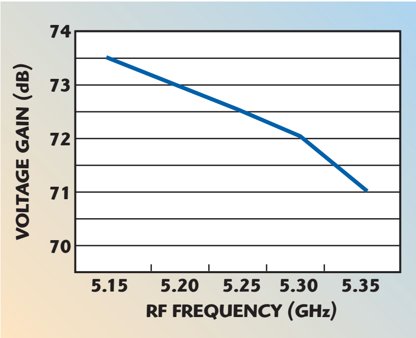


Fig. 14 Measured voltage gain of the overall receiver.

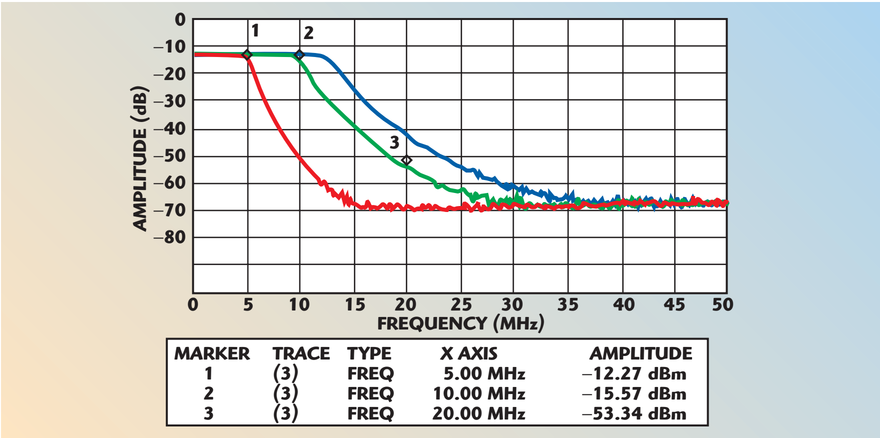


Fig. 17 Measured frequency response of the channel selection filter.

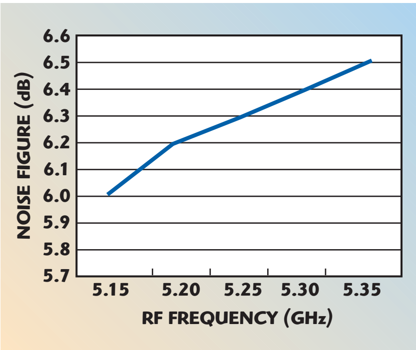


Fig. 15 Measured noise figure of the overall receiver.

TABLE I

SUMMARY OF THE RECEIVER PERFORMANCE

Specification	Measured Value
Frequency band (GHz)	5.15 to 5.35
Voltage gain (dB)	71 to 73.5
Noise figure (dB)	6 to 6.5
IIP3 (dBm): low gain mode high gain mode	–4 –16
S_{11} (dB)	< –10
DC offset (mV)	< 1 after calibration
Power (mA/V)	97/1.8

CONCLUSION

A direct-conversion receiver for 5 GHz wireless LAN has been developed. To minimize the DC-offset due to LO self-mixing, sub-harmonic mixing is used for the down-conversion. For quadrature sub-harmonic mixing, octa-phase LO signals are generated by an integer-N type frequency synthesizer. Implemented in a 0.18 μm CMOS technology, the receiver dissipates 97 mA from a 1.8 V supply and has 6.5 dB NF and –4 dBm IIP3. ■

ACKNOWLEDGMENT

Part of this work was supported by the Center for Advanced Transceiver Systems (CATS), Seoul National University, and the HY-SDR Research Center, Hanyang University, Seoul, Korea, under the ITRC Program of MIC, Korea. The CAD tools were supported by IDEC.

References

1. J. 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 5.12–5.825 GHz, 0.18 µm CMOS Transceiver for 802.11a Wireless LAN," *IEEE Journal of Solid-State Circuits*, Vol. 38, No. 12, December 2003, pp. 2221–2231.
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. 2232–2238.
3. B. Razavi, *RF Microelectronics*, Prentice-Hall, Upper Saddle River, NJ, 1998.
4. *IEEE Standard 802.11a-1999, Part 11*: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications.
5. L.E. Larson, "A Wide-bandwidth SiGe HBT Direct-conversion Sub-harmonic Mixer/Down-converter," *IEEE Journal of Solid-State Circuits*, Vol. 35, No. 9, September 2000.
6. S.J. Fang, S.T. Lee and D.J. Allstot, "A 2 GHz CMOS Even Harmonic Mixer for Direct-conversion Receivers," *2002 IEEE International Symposium on Circuits and Systems*, Vol. 4, pp. 807–810.
7. J. Chang, A.A. Abidi and C.R. Viswanathan, "Flicker Noise in CMOS Transistors from Subthreshold to Strong Inversion at Various Temperatures," *IEEE Transactions on Electron Devices*, Vol. 41, No. 11, November 1994, pp. 1965–1971.
8. D.M. Binkley, J.M. Rochelle, B.K. Swanna, L.G. Clonts and R.N. Goble, "A Micropower CMOS Direct-conversion, VLF Receiver Chip for Magnetic-field Wireless Applications," *IEEE Journal of Solid-State Circuits*, Vol. 33, No. 3, March 1998, pp. 344–358.
9. M.T. Terrovitis and R.G. Meyer, "Intermodulation Distortion in Current-commutating CMOS Mixers," *IEEE Journal of Solid-State Circuits*, Vol. 35, October 2000, pp. 1461–1473.
10. H. Darabi and A.A. Abidi, "Noise in RF-CMOS Mixers: A Simple Physical Model," *IEEE Journal of Solid-State Circuits*, Vol. 35, No. 1, January 2000, pp. 15–25.
11. J.H. Hwang and C. Yoo, "A Low Power Wide-bandwidth Fully Differential Operational Amplifier with Current Re-using Feedforward Frequency Compensation," *2004 IEEE Asia-Pacific Conference on Advanced System Integrated Circuits Proceedings*, pp. 32–35.
12. C.Y. Jeong and C. Yoo, "5 GHz Low Phase Noise CMOS Quadrature VCO," *IEEE Microwave and Wireless Component Letters*, Vol. 16, No. 11, November 2006, pp. 609–611.
13. C.C. Boon, M.A. Do, K.S. Yeo, J.G. Ma and X.L. Zhang, "RF CMOS Low Phase Noise LC Oscillator Through Memory Reduction Tail Transistor," *IEEE Transactions on Circuits and Systems*, Part II, Vol. 51, No. 2, February 2004, pp. 85–90.
14. E.A.M. Klumperink, S.L.J. Gierkink, A.P. van der Wel and B. Nauta, "Reducing MOSEF 1/f Noise and Power Consumption by Switched Biasing," *IEEE Journal of Solid-State Circuits*, Vol. 35, No. 7, July 2000, pp. 994–1001.

ANALYSIS OF ULTRA-WIDEBAND RIDGED-HORN ANTENNAS FOR GROUND PENETRATING RADAR SYSTEMS

In this article, the characterization by numerical analysis and the experimental results for two real ultra-wideband (UWB) ridged-horn antennas, used in the reflection configuration that is usually exploited in ground penetrating radar (GPR) prospecting applications, are presented. The numerical analysis is fully three-dimensional and is performed by the finite element method (FEM). In order to assess the validity of the results of the numerical analysis, they have been compared to measurements collected in the laboratory. The comparison confirms that the FEM simulation tool can provide accurate results, provided that all the details of the antennas are carefully taken into account and that the embedding environment is sufficiently characterised with regard to its electromagnetic properties.

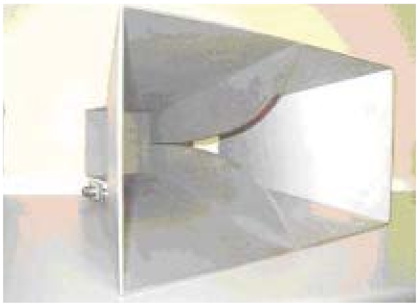
Ultra-wideband (UWB) antennas are used in several applications, ranging from GPR prospecting, wireless communications, to detection for safety and non-destructive diagnostic sensing.[1,2] In particular, with regard to the specific issue of non-destructive microwave sensing, the availability of a larger band implies that it is possible to obtain images with a finer resolution.[3]

Furthermore, a reliable simulation of the behaviour of the antennas is relevant for antenna designers,[4] especially when complicated antennas (as UWB antennas usually are) must be dealt with. In this framework, because of the complexity of the geometrical parameters and the variety of the materials involved, as well as the constructive modalities of the feeding, the analysis of the final performances of the antenna is possible only with a full-wave numerical code.[5] In particular, in the case of GPR systems, the analysis of the antennas is made more difficult by the fact that they have to work close to or in contact with an air-soil interface or, in general, within an inhomogeneous medium. This affects both their impedance parameters and their radiation pattern, that can be quite different from the homologous quantities in free space.[6] Actually, in order to achieve an accurate characterization of the antennas in these

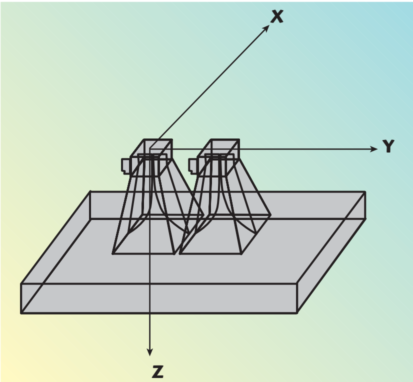
FRANCESCO SOLDOVIERI
IREA-CNR
Naples, Italy
GIANCARLO PRISCO
Second University of Naples, Italy
RAFFAELE PERSICO
IBAM-CNR
Lecce, Italy
HARALD LENTZ
Raumfahrt Systemtechnik GmbH
Salem, Germany

situations, not only do all the details of the antennas have to be accounted for, but also some accurate information about the geometric and electromagnetic characteristics of the embedding environment is needed. Even though this knowledge is available, it is not precise enough for this purpose. However, in practical cases, even an approximate estimation of the characteristics of the inhomogeneous environment is sufficient to determine important antenna features. In addition, when an inhomogeneous scenario is considered, while the measure of the scattering parameters of two antennas is easily carried out, any direct measurement of the radiation pattern is much more difficult.[7] This increases the relevance of achieving reliable simulations of the antennas. In the field of GPR prospecting, one may test the accuracy of the simulation by comparing the numerically computed scattering parameters with the experimentally measured ones and, if a good agreement is achieved, one can retrieve reasonably valuable information about the antenna pattern numerically. In particular, one can approximately guess the width of the main lobe, or can check the undesired occurrence of a multi-lobe pattern.

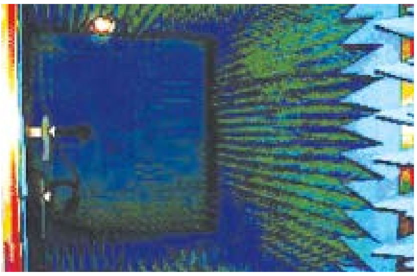
In this article, the modeling and characterization of two ridged-horn antennas designed for GPR prospecting or in general for non-destructive testing is addressed. The antennas are simulated in free space and in contact with a tuff masonry, by means of an FEM[8]-based commercial code HFSS/Ansoft.[9] Such a code allows getting a full-wave



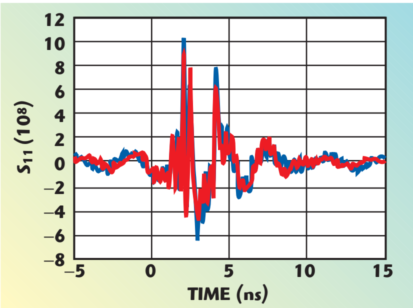
▲ *Fig. 1 The ridged-horn antenna.*



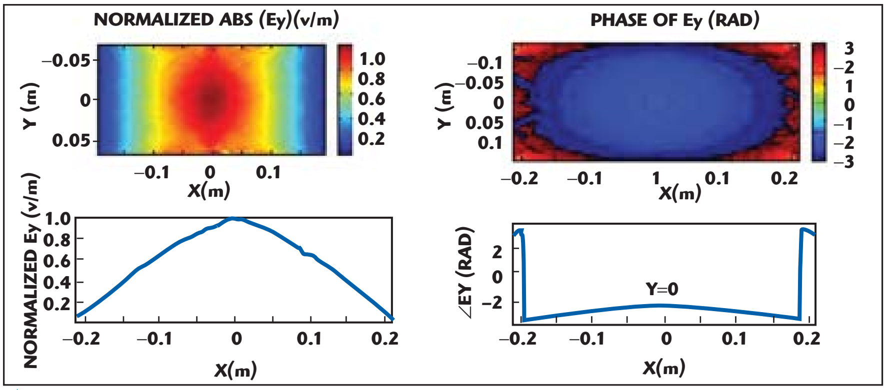
▲ *Fig. 2 Reflection configuration for the antennas.*



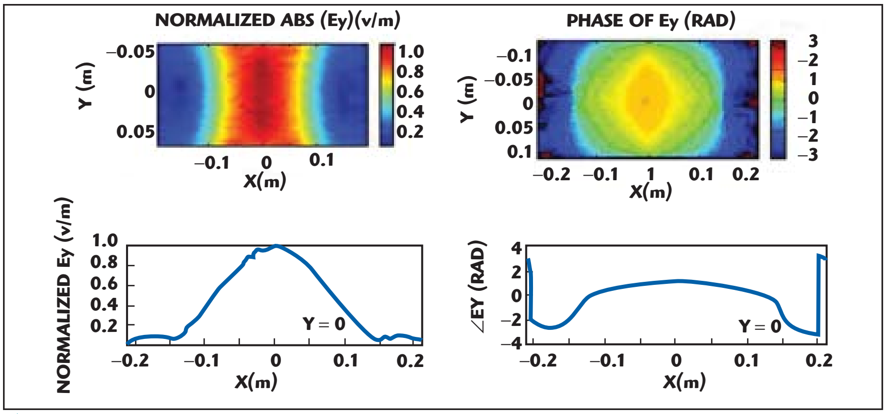
▲ *Fig. 3 The anechoic chamber.*



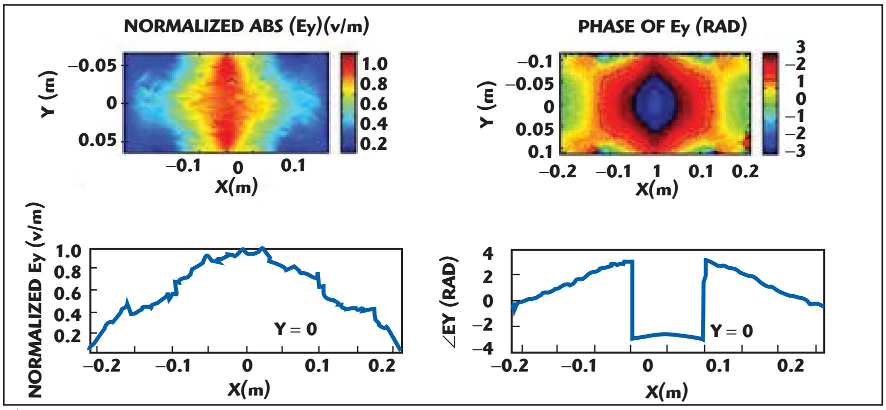
▲ *Fig. 4 Simulated and measured free-space S_{11} of a single antenna in time-domain.*



▲ *Fig. 5 y-component of the aperture electric field at F= 0.5 GHz.*



▲ *Fig. 6 y-component of the aperture electric field at F=1.6 GHz.*



▲ *Fig. 7 y-component of the aperture electric field at F=2.5 GHz.*

three-dimensional model of the feeding and the radiating parts of the antennas. This article follows a previous one devoted to the characterization of two bow-tie antennas.[10] Compared to the bow-tie antennas, the ridged-horn antennas are less complicated with regard to the materials. However, they are larger and many of their geometrical details were not reported in their data sheet, so that they had to be measured accurately in order to perform the numerical simulations. The simulated scattering parameters are compared with the measurements collected in the laboratory of electromagnetic diagnostics of the Dipartimento di Ingegneria dell'Informazione at the Second University of Naples (Italy).

THE ANTENNAS AND THEIR MODELING

The ridged-horn antennas under test have been designed by RST Raumfahrt Systemtechnik GmbH, Salem, Germany. Each of the two antennas consists of a pyramidal horn radiation cavity and two metallic ridges with exponential taper, as shown in ***Figure 1***. The dimensions of the main and smaller face of the pyramidal horn are 43 × 23 cm and 20.5 × 10.8 cm, respectively. The length is 32 cm. The pyramidal horn is connected to the outer conductor of the coaxial feed and serves as a ground plane, providing a current return path. The combined use of the inner and outer conductors of the feed creates a balun transformer for the ridges. The ground plane also helps to confine the main beam of the radiation pattern at the aperture of the horn, so as to ensure a compact radiation pattern.

The numerical analysis of the antenna has been performed for the full three-dimensional model by HFSS. The geometric model is divided into a large number of tetrahedra, where each single tetrahedron is a four-sided pyramid. This collection of tetrahedra is referred to as the finite element mesh. The curved metal surfaces of the antenna are modeled through a triangular mesh, constituted by the tetrahedra faces. The code uses an iterative process, called adaptive analysis, where the mesh is automatically refined in critical regions. First, a solution based on a coarse initial mesh is generated, then the mesh is refined in areas of high error density and a new solution is generated. When some selected parameters converge to some limit value, the code breaks out of the loop, when a Cauchy criterion[11] is exploited. As for most commercial codes, this involves the problem of simulating the infinity of the external medium, both in the case that this is made up of free space and when it is an inhomogeneous medium. The problem is addressed by making use of the boundary conditions provided by the code itself and, in particular, the standard radiation conditions have been used.

NUMERICAL AND EXPERIMENTAL RESULTS

In this section, the results of the FEM-based analysis are compared with experimental data. A reflection configuration is considered, where the two antennas (transmitting and receiving) are close to each other and are placed on the same side of the


From Cell Site to Satellite...
...CMT has the filter for
your application.
look to CMT, for microwave filters with
quality and performance designed in!
Microwave Filters and Multiplexers up to 40GHz
CMT INC.
www.cmtfilters.com
For The Best In Product, Price, Service And Delivery Call CMT!
ISO 9001: 2000
BSI
FM512714
Visit http://mwj.hotims.com/11724-32 or use RS# 32 at www.mwjournal.com/info

object under test. This reflection configuration is the one customarily exploited in GPR prospecting. An example of the geometry is shown in ***Figure 2***, where the horns' apertures lay in the x, y plane and are aligned along the y-axis. The UWB performances of the antennas are evaluated in terms of the scattering matrix between the input port of the transmitting antenna and the output port of the receiving antenna. The reference ports are located at the connectors on the back of the two antennas. The chosen convergence criterion for the FEM code is based on the change of the four elements S_{ij} (i,j = 1,2) of the scattering matrix between two consecutive iterations at finer meshes. In particular, when at the N-th iteration,

$$\Delta S = \mathrm{Max}_{ij}\left|S_{ij}^{N} - S_{ij}^{N-1}\right| \tag{1}$$

where i and j cover all matrix entries.

When $\Delta S \leq 0.01$, the iterations analysis stop; otherwise, they continue with a finer mesh, up to a prefixed maximum number of iterations. In the case at hand, the scattering parameters have been calculated assuming a 50 Ω characteristic impedance of the feed-line. The results of the numerical analysis have been compared with measurements collected at the electromagnetic diagnostics laboratory of Second University of Naples. The antennas are fed by an Anritsu 37225B network analyzer (VNA), covering a band of 40 MHz to 13.5 GHz, connected to the antennas by means of two coaxial cables. The network analyzer port impedance and the intrinsic impedance of the coaxial cables are equal to 50 Ω, and are consistent with the choice of the characteristic impedance of the feed lines used in the simulations. The near field scattering parameters have been measured in free space, using an automatic 2D positioning system, located in an anechoic chamber (see ***Figure 3***). However, the measurements for the antennas in contact with the tuff masonry have been collected by a different system in a semi-anechoic environment.

As an index of the agreement between simulated and measured scattering parameters, the following correlation coefficient was adopted:

$$r = \frac{\left|\int_{f_{min}}^{f_{max}} S_M(f)\,S_T^{*}(f)\,df\right|}{\sqrt{\int_{f_{min}}^{f_{max}} \left|S_M(f)\right|^2 df}\,\sqrt{\int_{f_{min}}^{f_{max}} \left|S_T(f)\right|^2 df}} \tag{2}$$

where $S_M(f)$ and $S_T(f)$ denote the measured and the numerically calculated scattering matrix element, respectively, and * stands for the complex conjugate. The integrals in Equation 2 are calculated within the working frequency band of the antennas, which is 0.5 to 3 GHz.

THE FREE-SPACE CASE

The first analysis is performed for a single antenna in free space and, in this case, the only scattering parameter to be considered is S_{11}. The analysis dealt with here is useful, since the accurate numerical determination of this scattering parameter, when com-

High Power Amplifiers

Ultra Broadband ▸ Wireless Communications ▸ Broadcasting ▸ Counter Communication ▸ Special Applications ▸

We Empower the RF Industry

Broadband P.A. Modules

Featured Product: BBM3K5KEL (SKU 1117)
500 - 2500 MHz, 25 Watts, 44 dB

Compact, scalable amplifier module that can be utilized in base stations, test equipment, P, L & S-band mobile radar and man-portable communications and counter-communications systems.

- Ideal for battery-powered field equipment
- Withstands extreme environmental conditions
- Suitable for new designs or retrofits

High Power T/R Switches

Featured Product: TRS02 - 1000 - 1000
1.5 MHz - 1 GHz, 1000 Watts power handling

High-power wideband transmit/receive switch offers a reliable, low-cost solution for modern radio communications and electronic warfare systems.

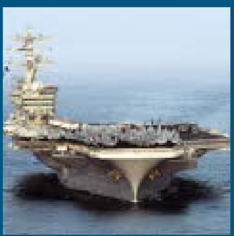
- Fast switching is ideal for active jamming
- Long service life ensures reliable performance
- More cost effective than PIN diode switches
- Excellent isolation with minimal insertion loss

Jamming Amplifier

Featured Product: GCS2E3KKO (SKU 4049)
20 - 520 MHz, 100 Watts, 50 dB

With the ability to transmit in VHF and UHF simultaneously, the 4049 system offers unparalleled power and flexibility for communications, electronic warfare and command and control applications.

- Optional LCD interface and ANSI/EIA-422 port
- Fast blanking is ideal for active jamming
- Suitable for sea, land and airborne applications



Broadband Systems

Featured Product: BBS3Q7EKO (SKU 2030)
800 - 4200 MHz, 100 Watts, 50 dB

This ultra broadband amplifier system allows the designer to reduce cost, weight and complexity of communications systems. Suitable for all operating modes including spread-spectrum, wireless radiotelephone and high-speed data.

- Customizable for specialized applications
- Optional LCD interface and ANSI/EIA-422 port
- Integrated cooling and electrical fault protection

Hundreds of standard products are available on our Web site at: www.EmpowerRF.com or contact us for custom and special solutions.

Visit http://mwj.hotims.com/11724-53 or use RS# 53 at www.mwjournal.com/info

EMPOWER
RF SYSTEMS, INC.

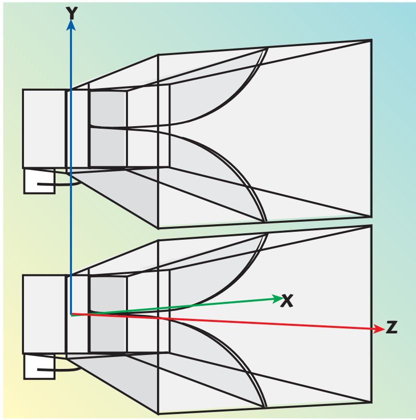
ISO 9001 : 2000 ANAB ACCREDITED Registered Company

Inc. 500

316 W. Florence Avenue, Inglewood, CA 90301 U.S.A.
Phone: +1(310) 412-8100, Fax: +1(310) 412-9232
sales@empowerrf.com

pared to the measured one, leads one to consider the simulation of the constructive features of the antenna to be reliable. ***Figure 4*** shows the agreement between the numerically evaluated and the measured scattering parameter S_{11} in the time domain. The time domain quantities are obtained by a Fourier transform of the scattering parameters in the frequency domain. The good agreement between measurements and computation is also confirmed by the correlation factor r = 0.94, evaluated for the scattering parameter S_{11} in the frequency domain. To increase the confidence in the accuracy of the antenna simulation, a numerically evaluated significant component of the aperture field (more precisely the y-component) in modulus and phase is shown in ***Figures 5, 6*** and ***7*** for three different frequencies within the operating band. In particular, the frequencies 0.5, 1.6 and 2.5 GHz have been considered. It can be seen that as the frequency increases the field is more and more confined between the two ridges of the antennas; it is known that this is the usual behavior for this kind of antenna.[12]

For the analysis of the single antenna, the discretization of the box (whose dimension is $\lambda_{max} \times \lambda_{max} \times \lambda_{max}$) involves about 150,000 tetrahedra and the computation time for the entire frequency band is approximately four hours using the dual processor AMD Opteron 64 bit, 6 GB DDR SDRAM. After the case of the single antenna, the case of two antennas in free space was considered. The two aperture antennas are aligned along the y-axis and quasi in contact at the aperture edges (see ***Figure 8***). First, the scattering parameter S_{11} is considered, which accounts for the influence of the receiving antenna on the mismatching of the transmitting one. The measured data and computation are consistent and the correlation coefficient is r = 0.9. The parameters of the impedance matrix are linked in a well-known way to the parameters of the scattering matrix.[13] ***Figure 9*** shows the comparison between the measured (red line) and the computed (blue line) real and imaginary parts of the self-impedance parameter Z_{11}. The same analysis has also provided the impedance parameter Z_{21}, which accounts for the mutual coupling between the transmitting and receiving antenna. ***Figure 10*** shows the good agreement between the real and imaginary parts of the measured and computed values. The consistency between the measurements and the



▲ *Fig. 8 HFSS model of the two ridged-horn antennas in free space.*

Telogy's Got It.

Get The Test Equipment You Need Now.
At the Price You Want to Pay.

RENT IT **LEASE IT** **BUY IT**

Telogy is your number one source for renting test equipment. Every month we invest millions of dollars in the latest equipment from leading manufacturers and in a wide range of product categories. You can count on Telogy to have the test equipment you need, when you need it.

Telogy makes it easy. Whether you're looking to rent, lease or buy, our superior customer support and service will deliver the highest quality test equipment in the time you need, at the price you want to pay. Whatever your test equipment needs, Telogy's got it.

TELOGY™

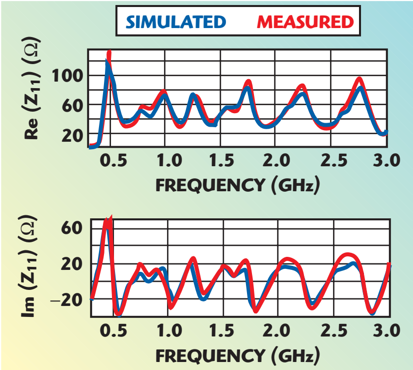
WWW.TELOGYLLC.COM
1.800.835.6494

Visit http://mwj.hotims.com/11724-161 or use RS# 161 at www.mwjournal.com/info

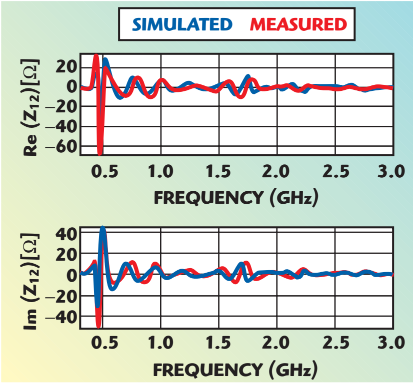
computation results are confirmed also by the correlation coefficient, which for the scattering parameter S_{21}, is equal to r = 0.87.

THE CASE OF ANTENNAS ON TUFF MASONRY

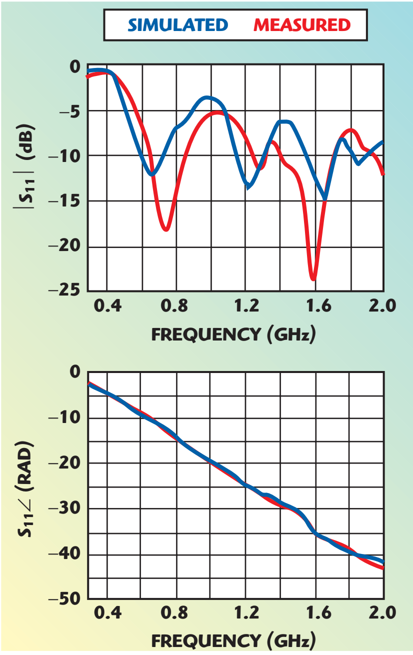
Consider the case of the two antennas placed in front of a tuff masonry. Tuff is a porous material largely present in South Italy and used in the construction of historical buildings. The configuration is the same as the free-space case and the antennas are directly in contact with the masonry. The thickness of the masonry is 11 cm. The electromagnetic behaviour of tuff has been characterized independently, and the analysis assumes a relative dielectric permittivity equal to 5 and a conductivity equal to 0.01 S/m. ***Figure 11*** shows the comparison between the numerically evaluated and the measured magnitude and phase of the scattering parameter S_{11}. The correlation index is r = 0.81. Again, the scattering parameter S_{21} is considered. In this case also, a



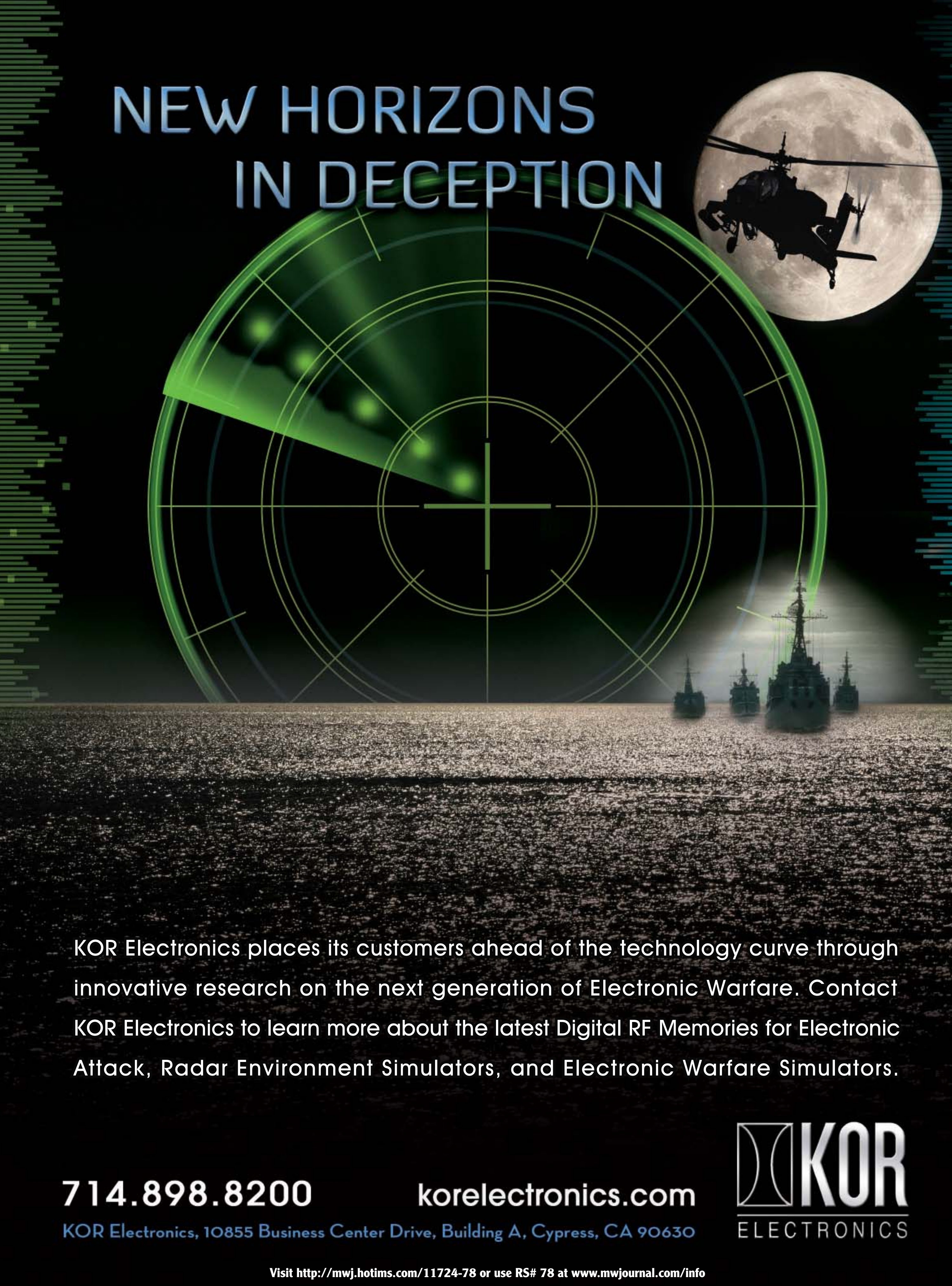
▲ *Fig. 9 Comparison between the simulated and measured self-impedance of two antennas in free space.*



▲ *Fig. 10 Comparison between the simulated and measured mutual impedances for two antennas in free space.*



▲ *Fig. 11 Comparison between the simulated and measured magnitude and phase of S_{11} for two antennas in contact with masonry.*


NEW HORIZONS
IN DECEPTION
KOR Electronics places its customers ahead of the technology curve through innovative research on the next generation of Electronic Warfare. Contact KOR Electronics to learn more about the latest Digital RF Memories for Electronic Attack, Radar Environment Simulators, and Electronic Warfare Simulators.
714.898.8200
korelectronics.com
KOR Electronics, 10855 Business Center Drive, Building A, Cypress, CA 90630
KOR
ELECTRONICS

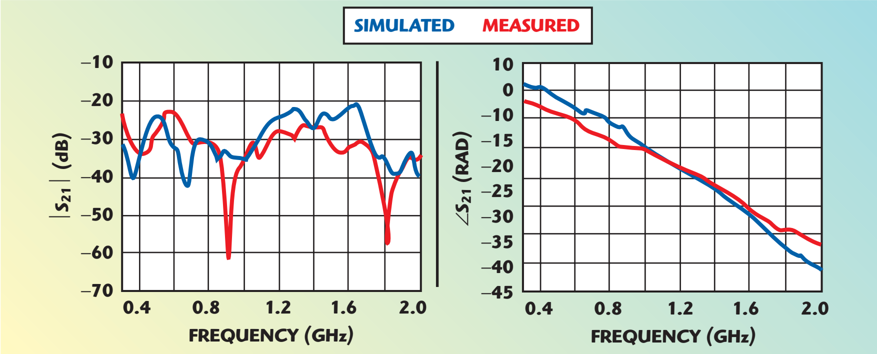


Fig. 12 Comparison between the simulated and measured magnitude and phase of S_{21} for two antennas in contact with masonry.

good agreement is observed between the numerically evaluated and the measured scattering parameters (see ***Figure 12***). The correlation index is r = 0.67. As a comment, for the case of tuff masonry, the agreement between the measured and computed quantities is less consistent; this is due to the fact that the frequency behaviour of the permittivity and conductivity of the tuff is not accounted for.

For the analysis of the two antennas, the discretization of the box (whose dimension is $\lambda_{max} \times \lambda_{max} \times \lambda_{max}$) involves about 200,000 tetrahedra and the computation time for the entire frequency band is approximately six hours on an AMD Opteron 64 bit, 6 GB DDR SDRAM dual processor.

CONCLUSION

In this article, the reliability and accuracy of a FEM-based numerical analysis, accounting for the full complexity of ridged-horn antennas in free space and close to a tuff masonry, has been shown. The results of the numerical analysis are consistent with the experimental measurements both in the free space and in the more challenging case of a non-homogeneous scenario. This activity is of interest in GPR prospecting, where the choice of the antennas to be used depends also on the electromagnetic features of the investigated structure. ■

References

1. D.J. Daniels, *Ground Penetrating Radar*, Second Edition, The Institution of Electrical Engineers, Stevenage, UK, 2004.
2. T.P. Montoya and G.S. Smith, "Land Mine Detection Using a Ground Penetrating Radar Based on Resistively Loaded Vee Dipoles," *IEEE Transactions on Antennas and Propagation*, Vol. 47, No. 12, 1999, pp. 1795–1806.
3. D.A. Noon, "Stepped-frequency Radar Design and Signal Processing Enhances Ground Penetrating Radar Performance," PhD Thesis, Department of Electrical & Computer Engineering, University of Queensland, Australia, 1996.
4. F. Soldovieri, R. Persico and G. Leone, "Effect of Source and Receiver Radiation Characteristics in Subsurface Prospecting Within the DBA," *Radio Science*, Vol. 40, RS3006, May 2005.
5. H. Nakano, Y. Okabe, H. Mimaki, and J. Yamauchi, "A Monofilar Spiral Antenna Excited Through a Helical Wire," *IEEE Transactions on Antennas and Propagation*, Vol. 51, No. 3, 2003, pp. 661–664.

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).

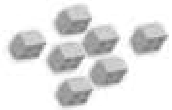
Xinger® 0805, ultra-low profile hybrid couplers

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).

800-411-6596 > www.anaren.com

Visit http://mwj.hotims.com/11724-15 or use RS# 15 at www.mwjournal.com/info

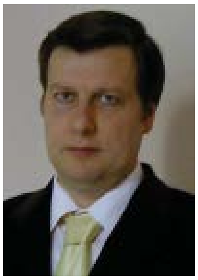
Anaren®
What'll we think of next?™

In Europe, call 44-2392-232392 > ISO 9001 certified
Visa/MasterCard accepted (except in Europe)

6. G. Prisco and R. Persico, "Antenna Characterization in Near Field and in Inhomogeneous Media: Their Use in Microwave Imaging," *Proceedings of the Leading Inside Workshop*, Rome, 15 November 2006.
7. P. Meincke and T.B. Hansen, "Plane-wave Characterization of Antennas Close to a Planar Interface," *IEEE Transactions on Geoscience and Remote Sensing*, Vol. 42, No. 6, 2004, pp. 1222–1232.
8. J.L. Volakis, L.C. Kempel and A. Chatterjee, *Finite Element Method for Electromagnetics*, IEEE Press, Piscataway, NJ, 1998.
9. http://www.ansoft.com/products/hf/hfss/.
10. F. Soldovieri, G. Prisco, A. Brancaccio and G. Leone, "Characterization of Ultra-wideband Bow-tie Antennas for Ground Penetrating Radar Systems," *Microwave Journal*, Vol. 49, No. 8, August 2006, pp. 186–194.
11. R. Beals, *Analysis: An Introduction*, Cambridge University Press, Cambridge, UK, 2004.
12. www.ifh.ee.ethz.ch/~fvtd/fvtd_horn.html.
13. R. Collin, *Foundation for Microwave Engineering*, Second Edition, Institute of Electrical and Electronics Engineers, Piscataway, NJ, 2001.

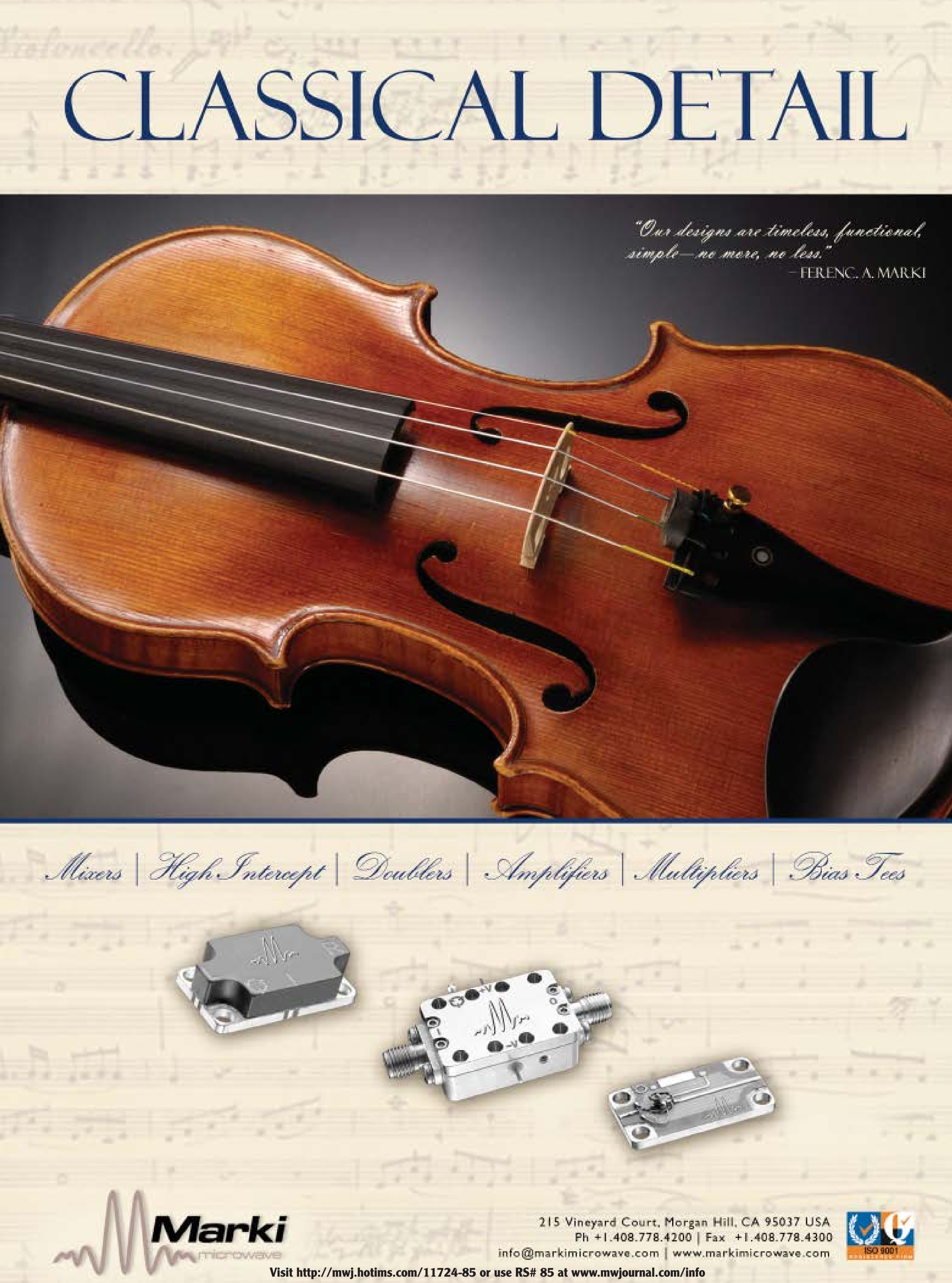
Francesco Soldovieri *received his Laurea degree in electronic engineering from the University of Salerno in 1992 and his PhD degree in electronic engineering from the University of Naples "Federico II" in 1996. In 1993, he joined the electromagnetic research group of the University of Naples and in 1998-1999 he held a postdoctoral fellowship at the same university. In 1999-2000, he collaborated with the research group on applied electromagnetism at the Second University of Naples. Since 2001, he has been a researcher at the Institute for Electromagnetic Sensing of the Environment of the Italian National Research Council (IREA-CNR). His main scientific interests include electromagnetic diagnosis, inverse scattering and GPR applications.*

Giancarlo Prisco *received his Laurea and PhD degrees in electronic engineering from the Second University of Naples, Aversa, Italy, in 2002 and 2005, respectively. Since 2003, he has collaborated with the research group on applied electromagnetism at the Second University of Naples. His scientific interests include UWB antennas, inverse scattering and GPR applications.*



Raffaele Persico *received his electronic engineering degree from the University of Naples Federico II in 1996 and his PhD degree from the second University of Naples in 1999. He has been a research scientist at the Consortium for Advanced Research in Remote Sensing Systems (CORISTA) and at the Institute for the Electromagnetic Sensing of the Environment (IREA). Since January 2007, he has been a research scientist at the Institute for Archaeological and Cultural Heritage (IBAM, Lecce, Italy). His main research interests include linear and nonlinear inverse scattering problems and related topics, especially in relationship with GPR data processing.*

Harald Lentz *received his degree in electrical engineering from the Technical University, Berlin, Germany. Since 1996, he has been with Raumfahrt Systemtechnik GmbH, Germany, where he is the head of the hardware development department. His work is focused on radar systems for spaceborne, airborne and ground penetrating applications.*


CLASSICAL DETAIL
"Our designs are timeless, functional, simple—no more, no less."
–FERENC. A. MARKI
Mixers | High Intercept | Doublers | Amplifiers | Multipliers | Bias Tees
Marki microwave
215 Vineyard Court, Morgan Hill, CA 95037 USA
Ph +1.408.778.4200 | Fax +1.408.778.4300
info@markimicrowave.com | www.markimicrowave.com
ISO 9001

AN IMPROVED THERMAL DESIGN FOR III-N HEMTs ON SILICON SUBSTRATES

Thermal design is a primary concern for enabling electronic devices to reach their potential to operate at high power densities. Heat must be removed efficiently in order to keep the channel temperature below a desired limit. Elevated operating temperatures result in lower carrier mobility, lower sheet charge density, lower effective saturation velocity and higher leakage currents, effectively limiting the ability of the device to produce high RF output powers. Furthermore, most of the failure mechanisms in semiconductor devices are accelerated by elevated temperature, resulting in a reduced mean time to failure (MTTF). The intrinsic carrier concentration of a silicon substrate can be a limiting factor for the microwave and radio frequency (RF) performance at elevated temperatures, due to the loss of RF isolation from the ground plane when the conductivity of the high resistivity substrate increases with temperature. In this study, simulation is used in combination with infrared (IR) thermal imaging and RF electrical measurement to compare two III-N high electron mobility transistors (HEMT) on silicon substrates with different thermal designs. It is shown that significant improvements in thermal performance can be gained by layout, substrate thinning and package design.

The power density of large periphery III-N HEMTs can be as high as 5 W/mm,[1–3] much greater than GaAs (1 W/mm) and Si LDMOS (0.8 W/mm). These devices can generate more power per unit area of chip, or equivalent power in a much smaller package. All power that is not delivered to the load is dissipated locally in the device as heat. The source of the heat generation is Joule heating at the intersection of the high electric field and current found in the channel on the drain side of the gate. In general, the channel temperature should be kept to a minimum while under operation at peak performance for a particular application. The two main drivers in minimizing channel temperature are the RF efficiency and the thermal resistance. The RF efficiency determines how much of the power is dissipated as heat, while the thermal resistance is a measure of a transistor's thermal design and determines the device's ability to remove the heat. In this article, the focus is on improved thermal design

A. EDWARDS, C. PARK, S. SINGHAL, Q. MARTIN, K.J. LINTHICUM AND I.C. KIZILYALLI
Nitronex Corp.
Durham, NC

in order to minimize the thermal resistance. Readily available factors that influence the thermal resistance include device layout, substrate thickness and packaging material. All three of these areas are explored in this work.

The choice of desired mean time to failure (MTTF) is a primary limit on the peak allowable channel temperature. Device designs typically target a 150° to 200°C channel temperature under operation, which results in an MTTF comparable to existing technologies, such as Si LDMOS and GaAs PHEMTs.[4] The thermal limitation due to the onset of intrinsic conduction in the silicon substrate occurs above this range of channel temperature.

EXPERIMENT

The two devices considered in this study consist of undoped III-N heterostructures, grown by metal organic chemical vapor deposition on high resistivity Si (III) substrates. The details of the epitaxial structure and processing have been described elsewhere.[5]

▲ *Fig. 1 Top view of the unlidded CPC package with a device A and its input matching network.*

The packaged parts consist of a 36 mm transistor die attached to a high thermal conductivity Cu-Mo laminate (CPC) or a pure Cu single-ended, ceramic package, using a AuSi or AuSn eutectic attach process, respectively. The sources are grounded to the package base through backside vias etched in the silicon die. A two-stage internal matching network is used to transform the input impedance, while no intentional internal matching exists on the output.[3] Two different thermal designs, labeled devices A and B, with the same total gate width are compared in this study. A top-down view of a standard die in a typical CPC package (without a lid), which corresponds to device A, is shown in ***Figure 1***. Device B has the same overall appearance, but has a Cu package, a thinned Si substrate and a thermally enhanced device layout on the transistor die. The detailed characteristics of the two devices are listed in ***Table 1***.

Finite element analysis (FEA) has been used to assist in the determination of the thermal resistance from the channel to the heatsink in a realistic operating situation. The entire thermal environment relevant to the device is included, neglecting radiation into the air. The simulation consists of the packaged part mounted to a 1 cm thick aluminum application board. The temperature of this aluminum block is held at 80°C. Both the aluminum block and elevated base plate temperatures are included to mimic the configuration used during IR measurement. The use of FEA was necessary in order to simulate the full large periphery device, including the relatively large package and fixture. The model covers four orders of magnitude from the micron scale gates to the centimeter thick fixture. Effects such as long range gate coupling, and the 3D extent of the package and fixture are included. The CFD-ACE+ multiphysics solver, commercially available from ESI Group

TABLE I

COMPARISON OF DEVICE CHARACTERISTICS

Quantity	Device A	Device B
Layout	standard	tiled
Total gate width (mm)	36	36
Unit gate width (μm)	200	200
Gate-to-gate pitch (μm)	30	50
Package thermal conductivity (W/m-k)	240 (CPC)	400 (Cu)
Package thickness (mil)	40	40
Si thickness (mil)	6	4
Attach material	AuSi	AuSn
Die size (mm)	1 × 6	1.2 × 6
R_{JC} (°C/W)	1.95	0.85

Inc.,[6] was used in this work. The standard layout and the thermally improved layout were simulated and correlated to measurement.

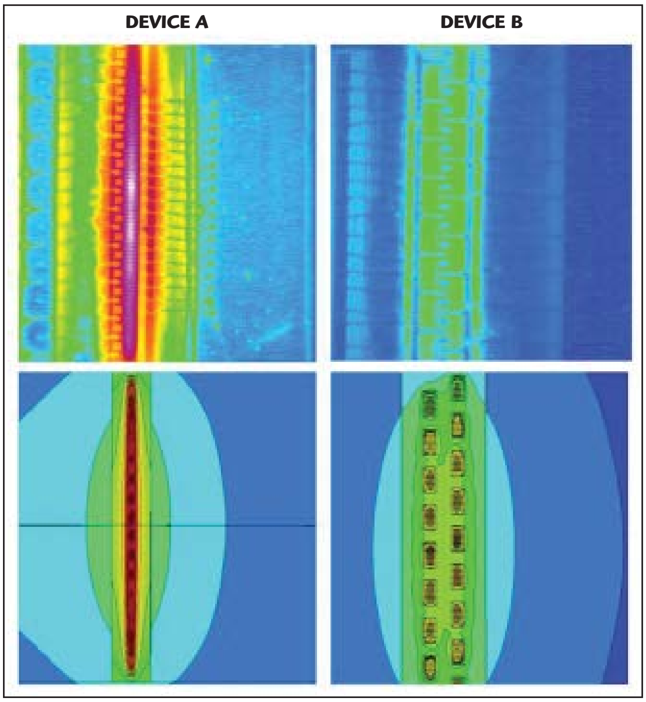


Fig. 2 Simulated and IR temperature profiles for the devices A and B.

An infrared (IR) measurement was used to calibrate the FEA model and to verify the designs. All the measurements are made with a Quantum Focus Instruments (QFI) InfraScope II thermal imaging system.[7] The dissipated power was produced by a direct current (DC) bias. The drain voltage was held at 28 V and the gate voltage was varied to achieve different drain current levels and hence different power dissipations. The heatsink temperature is maintained at 80°C to reduce the background radiant energy. First, an image using the 1x lens was taken to determine the location of the peak channel temperature and to check the thermal distribution across the entire device. A 15x lens with approximately 2.5 µm spatial resolution was then used to obtain the peak channel temperature. The temperature at the back of the package is measured using a thermocouple passing through an aperture in the fixture and contacting the bottom of the package. The thermal resistance is calculated from the channel to the back of the package/case (R_{JC}).

RF measurements were made at 2.14 GHz with a standard load pull system using tuners from Focus Microwaves Inc. The RF characteristics were taken at a drain voltage of 40 V. The devices were biased in class AB with approximately 27.5 mA/mm quiescent drain current, and the input and output impedances were optimized to obtain maximum RF output power.

DISCUSSION AND RESULTS

Thermal simulations were used to investigate the heat removal from the device in order to lower the channel temperature. A model of the packaged device and fixture, as described above, has been used to investigate the effect of substrate thickness, package materials and device layout changes. As an outcome of the simulation effort, a next generation device was developed using a Cu package, a thinned 4-mil Si substrate and an alternative layout, based on interleaving tiled cells. The cells are arranged in two rows, which provide room to increase the gate-to-gate spacing to 50 µm, reducing thermal coupling, or interaction between adjacent heat sources. In addition, there is room to leave a 300 µm gap between cells to additionally reduce coupling. Devices

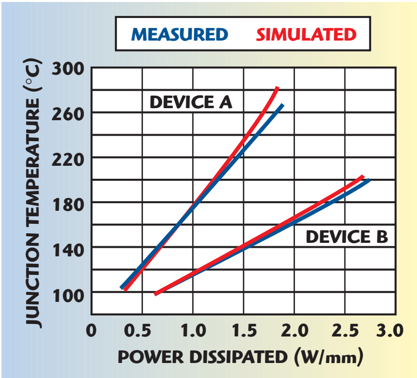


Fig. 3 Measured (blue) and simulated (red) junction temperature.


Military • Commercial
Wireless • Space

with this layout have been fabricated and tested in Cu packages and are labeled device B in this study. Device B represents a tradeoff between thermal performance, RF performance and manufacturability. ***Figure 2*** shows the simulated and measured temperature images of the two devices. The top pictures show the IR images of the devices under DC bias to achieve a dissipated power density of 1.09 W/mm, while the bottom pictures show the simulated devices at the same power density. The thermal stage is held at 80°C for the measurement, but the case temperature is higher and varies with power dissipation level. A graph of the junction temperature versus power dissipated for devices of both varieties is shown in ***Figure 3***. The base plate temperature is maintained at 80°C for both cases. From this graph, excellent correlation between the simulation and measured values is seen for both devices A and B. Additionally, the improvement in thermal performance for device B is evident. Device A can only dissipate approximately 1.25 W/mm (45 W) before reaching a junction temperature of 200°C, while device B can dissipate approximately 2.5 W/mm (90 W) before reaching a 200°C junction temperature. Frequently, the maximum operating temperature limit of the device is obtained from the requirement for MTTF. Using a three-temperature DC life-test, a MTTF greater than 10^7 hours has been extrapolated at 150°C for devices of the same variety as device A of this study.[8,9] The MTTF is greater than 10^5 hours at 200°C. Both of these results can be seen in ***Figure 4***. When the peak channel temperature exceeds 225°C, the RF performance is noticeably affected. At this point, the heat generated at the channel is sufficient to raise a significant portion of the Si substrate to 175° to 200°C. The intrinsic carrier concentration, ni, of Si at 200°C is 8.9×10^{13} cm^{-3}. This carrier concentration corresponds to an n-type resistivity of approximately 50 Ω-cm. As a large enough portion of the substrate becomes less resistive, the onset of significant RF loss is seen. In ***Figure 5***, a clear example of thermally limited performance, which is explained by the onset of substrate loss, is shown in device A. On the other hand, it also shows that the improved thermal design in device B does not reach this limitation. ***Figure 6*** shows the corresponding calculated channel temperature for each device. The temperature is calculated at each point using the measured output power, gain, efficiency and thermal resistance (1.95°C/W and 0.85°C/W) obtained from IR measurement and simulation.

A primary consideration of the RF design is the efficiency with which the device utilizes its power input (DC and RF). All waste power is dissipated locally as heat. Other key RF

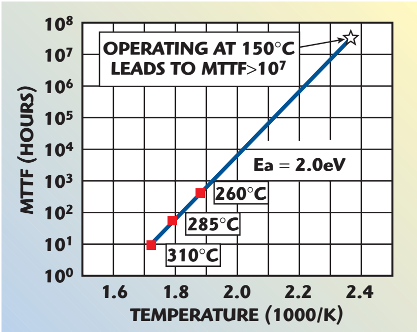


Fig. 4 Arrhenius plot generated from a three-temperature life test.

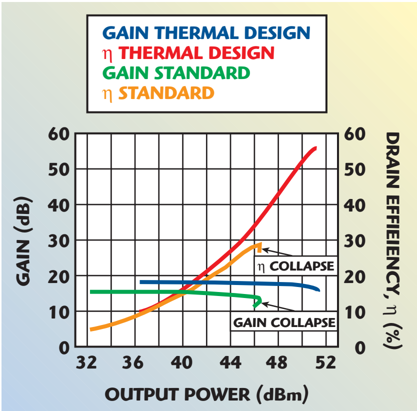


Fig. 5 RF performance of devices A and B.

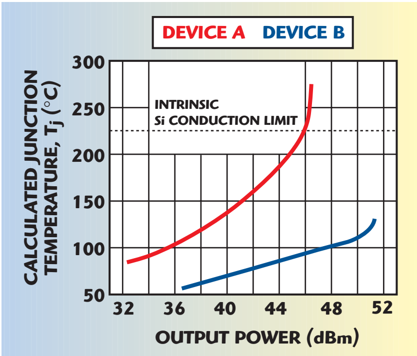


Fig. 6 Calculated channel temperature of devices A and B.

design metrics are low parasitic resistance and output capacitance, both of which will increase the device output impedance and aid in high efficiency design. Of course, a wide variety of considerations in the RF design can lead one to sacrifice efficiency for other performance criteria. Device A in this study, a design intended to meet WiMAX application specific linearity requirements, is operated in a severely backed-off condition producing only 18 percent drain efficiency (DE) and 6 W of output power (P_{OUT}) under operation. The typical power gain, G, is 12 dB for the WiMAX design, or 15.83 on a linear scale. The dissipated power (P_D) is thus $P_D = P_{OUT}$ (1/G + 1/DE–1) = 27.7 W. Using the maximum rated thermal resistance of 1.95°C/W for this part, the temperature drop from channel to case, $\Delta T_{JC} = P_D R_{JC}$ = 54°C. Assuming a case temperature of 80°C, this places the channel below the 150°C operating temperature target. If device A is operated with a continuous waveform (CW), it is capable of 65 W with 45 percent efficiency and 9.5 dB gain. The dissipated power of P_D = 86.7 W results in a temperature rise of ΔT_{JC} = 169°C. When device A is operated in CW with a case temperature of 80°C, the device clearly violates the thermal limit of 225°C and suffers from reduced RF performance. A device, such as device B in this study, which possesses a 0.85°C/W thermal resistance, has a ΔT_{JC} = 73.7°C for the same CW performance levels. Device B would only have a junction temperature of approximately 155°C when operated under CW conditions and with 80°C case temperature. The improved thermal performance of device B allows it to operate with good RF performance and with an acceptable MTTF even under the most stringent conditions of CW operation and elevated case temperature.

CONCLUSION

A primary consideration of RF design is maximizing the efficiency of the device under the actual application usage conditions. Once the best possible efficiency for the application has been obtained, the inevitable waste heat must be removed to the outside environment as effectively as possible to keep self-heating of the device to a minimum. Simulation provides an accurate and predictive support for the design effort. The first thermal limit to be considered is reliability and specifically keeping the operating temperature low enough to meet the application's MTTF goal. A second thermal limitation exists, for devices on Si substrates, at a channel temperature of approximately 225°C for RF applications due to loss of isolation between ground and the RF signal caused by the onset of intrinsic substrate conduction. This article has demonstrated the use of thermal simulation, thermal measurement and RF measurement to optimize the design of a device. The resulting device makes use of substrate thinning, layout changes and Cu packaging to reduce the thermal resistance by a factor of two, thereby enabling a high performing and reliable device capable of operation under CW drive with elevated case temperatures of 80°C. ■

References

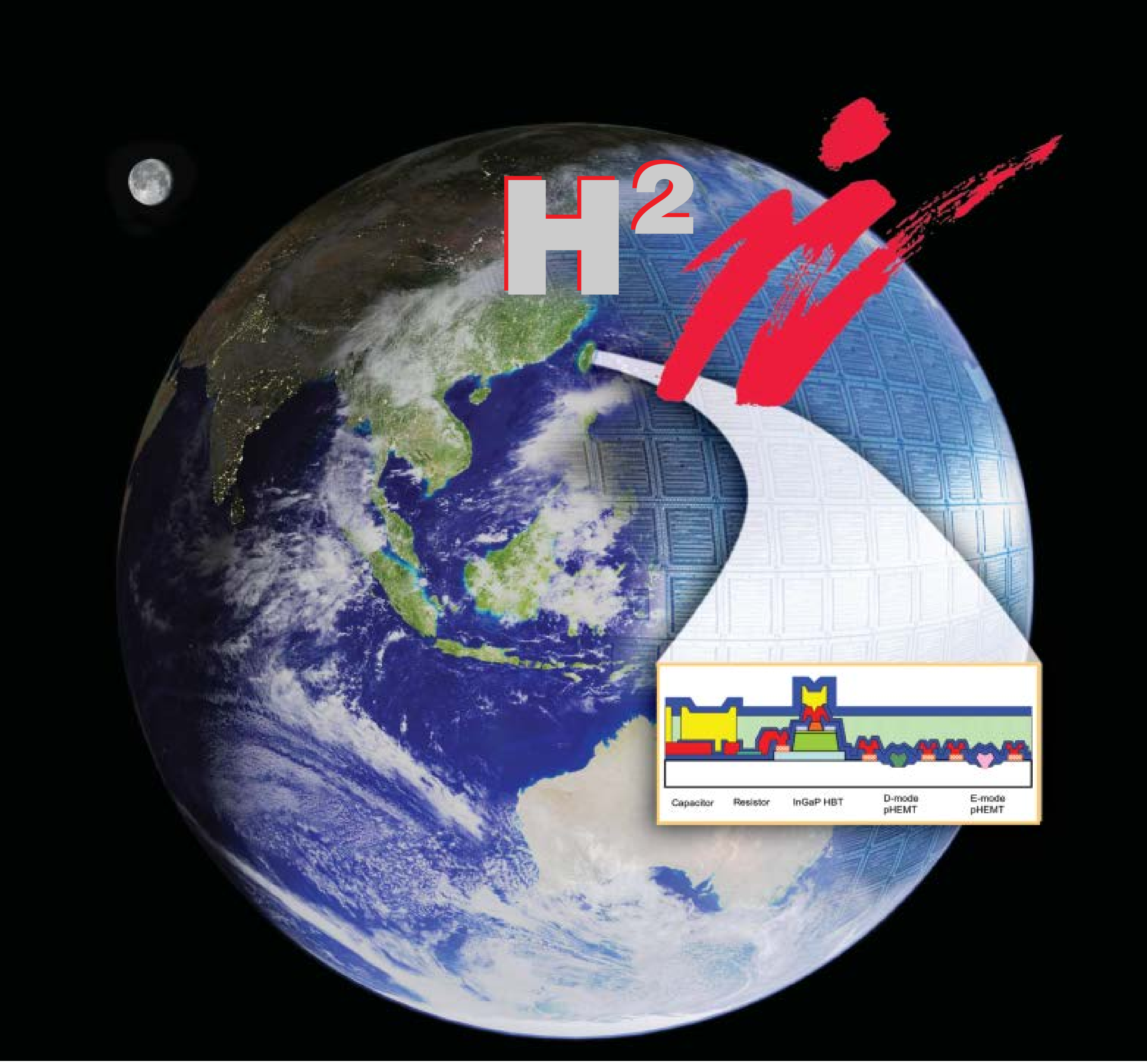
1. T. Kikkawa, T. Maniwa, H. Hayashi, M. Kanamura, S. Yokokawa, M. Nishi, N. Adachi, M. Yokoyama, Y. Tatneo and K. Joshin, "An Over 200 W Output Power GaN HEMT Push-pull Amplifier with High Reliability," *2004 IEEE MTT-S International Microwave Symposium Digest*, Vol. III, pp. 1347–1350.
2. A. Wakejima, K. Matsunaga, Y. Okamoto, Y. Ando, T. Nakayama, K. Kasahara and H. Miyamoto, "280 W Output Power Single-ended Amplifier Using Single-die GAN-FET for W-CDMA Cellular Base Stations," *IEEE Electron Device Letters*, Vol. 41, No. 18, 2005.
3. R. Therrien, S. Singhal, J.W. Johnson, W. Nagy, R. Borges, A. Chaudhari, A.W. Hanson, A. Edwards, J. Marquart, P. Rajagopal, C. Park, I.C. Kizilyalli and K.J. Linthicum, "A 36 mm GaN-on-Si HFET Producing 368 W at 60 V with 70% Drain Efficiency," *2005 IEEE Electron Devices Meeting Technical Digest*, pp. 568–571.
4. S. Singhal, T. Li, A. Chaudhari, A.W. Hanson, R. Therrien, J.W. Johnson, W. Nagy, J. Marquart, P. Rajagopal, E.L. Piner and K.J. Linthicum, "Reliability of Large Periphery GaN-on-Si HFETs," *Microwave Reliability*, Vol. 46, 2006, pp. 1247–1253.
5. J.W. Johnson, et al., "Material, Process and Device Development of GaN-based HFETs on Silicon Substrates," *Electrochemical Society Proceedings*, 21004-6:405-19, 2004.
6. ESI Group Inc., Paris, France.
7. Quantum Focus Instruments Corp., Vista, CA.
8. S. Singhal, J.C. Roberts, P. Rajagopal, T. Li, A.W. Hanson, R. Therrien, J.W. Johnson, I.C. Kizilyalli and K.J. Linthicum, "GaN-on-Si Failure Mechanisms and Reliability Improvements," *2006 IEEE International Reliability Physics Symposium Proceedings*, pp. 95–98.
9. S. Singhal, A.W. Hanson, A. Chaudhari, P. Rajagopal, T. Li, J.W. Johnson, W. Nagy, R. Therrien, C. Park, A.P. Edwards, E.L. Piner, K.J. Linthicum and I.C. Kizilyalli, "Qualification and Reliability of a GaN Process Platform," to be presented at *CS-MANTECH 2007*, Austin, TX.

IMPROVEMENTS IN BAND REJECTION CHARACTERISTICS OF A WIDEBAND ANTENNA USING RESONANT SLOTS

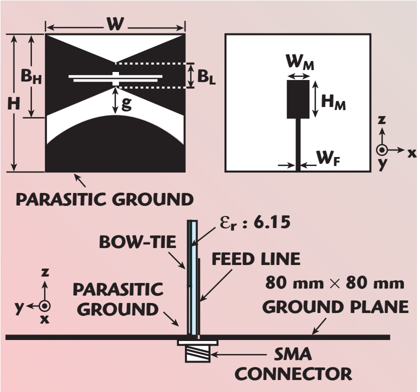
This article presents a method to improve and control the band rejection characteristics of wideband bow-tie patch antennas by using two notch slots. The two-pole band rejection characteristics were obtained by adjusting the mutual coupling values, as in a two-pole band rejection filter (BRF), between two horizontal resonant slots on the main patch of the antenna. The wideband antenna itself is composed of an electromagnetically coupled bow-tie patch and a parasitic semicircular ground patch. By adjusting the dimensions of the slots, the other characteristics of the notch response, such as the center frequency and the band rejection skirt gradient, can also be changed. Therefore, optimized slots can give a wideband patch antenna the required rejection band and sharp skirt characteristic, as is often required for ultra-wideband (UWB) antennas and multi-band antennas, compared to the conventional one with or without a notch slot.

In recent applications of telecommunications and remote sensing at microwave frequencies, the exploitation of UWB antennas is steadily growing.[1] UWB radio can use the frequency band from 3.1 to 10.6 GHz. UWB systems also need to be compatible with other already existing standards.[2] To allow such a wider bandwidth in UWB systems, the Federal Communications Commission (FCC) imposes severe power restrictions. By doing so, UWB devices can make use of an extremely wide frequency band while not emitting enough energy to interfere with narrower band devices nearby, such as Wireless LAN and Hyper LAN devices at approximately 5 GHz. There are also some unlicensed bands in Japan (4.900 to 5.091 GHz) and the United States (5.150 to 5.825 GHz).[3] A similar need also arises from multi-band communication systems. A multi-band system deals with a wide frequency band and needs to filter out non-service bands to avoid interferences. Recently, in order to meet these requirements, several UWB antennas with band rejection characteristics have been proposed.[4–6] The band reject operation is achieved when the length of the embedded slot is approximately one-half wavelength at the desired rejection frequency. In this case, destructive interference for the excited surface currents in the antenna will occur, which causes the antenna

SOO DEOK MOON AND
HEE YONG HWANG
Kangwon National University
Chuncheon, Korea


H2
Capacitor
Resistor
InGaP HBT
D-mode pHEMT
E-mode pHEMT

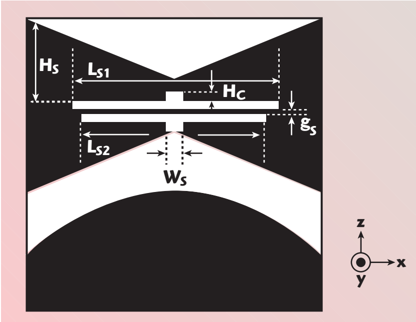
to be non-responsive at that frequency.[7] However, as mentioned in the literature,[8,9] the notch of those antennas can exhibit only a single narrow frequency notch band and cannot provide a satisfactory rejection bandwidth and skirt characteristics for most of the systems requiring the good band rejection response. In order to solve this problem, by embedding two horizontal resonant slots and adjusting the mutual coupling values between them, the band rejection characteristics of a wideband patch antenna has been improved. This technology allows a wideband antenna to be a multi-band antenna, and many systems to be compactly designed without additional components such as notch filters.



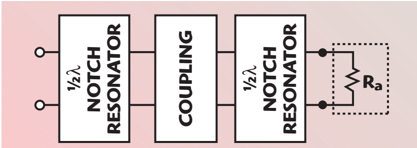
▲ *Fig. 1 Structure of the proposed wideband antenna.*

WIDEBAND ANTENNA DESIGN

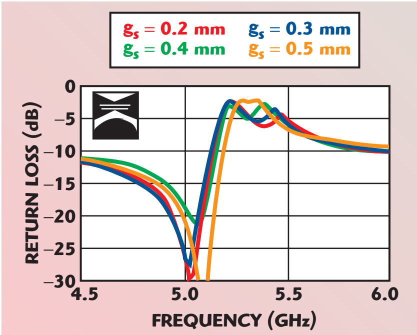
The structure of the proposed wideband bow-tie monopole antenna is shown in ***Figure 1***. It is composed of a bow-tie main patch fed electromagnetically and a parasitic semicircular ground patch. Typically, a bow-tie antenna is fed at its center, the same as for a dipole antenna.[10] The bow-tie patch needs to be fed by direct or proximity coupling. A proximity coupling from an embedded feed line within the substrate gives better bandwidth than a direct coupling.[11] The antenna, with a width W = 22 mm and height H = 22 mm, is constructed on a substrate with a thickness of 0.64 mm, a dielectric constant of 6.15 and a loss tangent of 0.0028. It is fabricated and mounted on a rectangular finite (80 × 80 mm) ground plane. A 50 Ω SMA connector, centrally mounted from the back of the ground plane, is used to excite the antenna. The other antenna dimensions used in this study include: B_L = 4 mm, B_H = 13 mm, W_M = 3.4 mm, W_F = 0.8 mm, H_M = 6.5 mm, R = 15.0 mm and g = 4.5 mm. The proposed wide bandwidth is achieved by inserting a semicircular shaped parasitic ground patch between the bow-tie patch and the ground plane. The



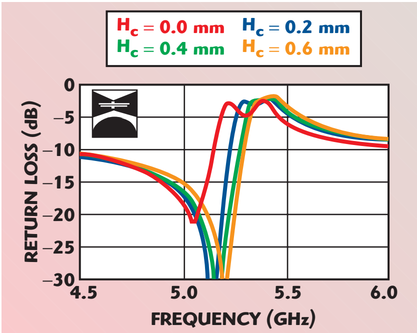
▲ *Fig. 2 Geometry of the proposed band rejection antenna.*



▲ *Fig. 3 Conceptual equivalent circuit of the band rejection antenna.*



▲ *Fig. 4 Return loss for various gaps (g_s) of notch slots.*



▲ *Fig. 5 Return loss for various heights (H_c) of the inserted slots.*

Mission Critical PERFORMANCE

EW System Interconnects from ***TIMES MICROWAVE SYSTEMS***

Integrated Device Assemblies

- Flat, Equalized, Filtered, Attenuated, Amplified
- Platform-Independent System Design
- Dramatically Boosts System Performance
- Broadband Performance

Multi-Port Interconnects

- 38999 size 8, 12; M8; P8; MMP Contacts
- Blind-Mating, ARINC, Rack & Panel, Custom Shells
- Easy Insertion/Removal, Field Replaceable Contacts
- Rugged, Sealed, Extreme Environment Qualified

Vehicle Mounted/Deployed Antenna Feeder Cables

- Excellent Long-Term Electrical Performance
- Resists Harsh Treatment and Environments
- NBC Compliant Ruggedization Options
- Suited to COMM, COMMINT, IED, More

PhaseTrack™ for Critical Phase Applications

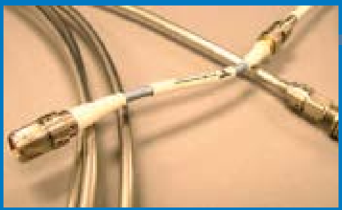
- Superior Electrical Phase Stability (vs LD PTFE)
- <1.5 ppm/°C
- TF4 Dielectric Technology (no PTFE "Knee")
- Ruggedization Options Available

Blind Mate Antenna Solutions

- Convert Antennas to Blind Mate
- Improve Reliability, Maintainability and Serviceability
- Simplify Mission Equipment Role Changes
- Reduce Loss, Eliminate Cable Loop

Military Low Smoke Cables

- Ideal for Shipboard, Vehicle, Manned Area Use
- Low Loss, Light Weight, Superior RF Shielding
- Fire Retardant (non-halogen), Flexible
- MIL-DTL-17H Qualified



SiO2 (Silicon Dioxide) Cable Assemblies

- Exceptional Phase Stability
- Temperature: -273°C to +600°C
- Hermetically Sealed to 10E-9
- Resistance to Harsh/Extreme Environments

MilTech™ Microwave Transmission Lines

- Flexible, Hermetically Sealed Cables
- Low Loss to 20 dB/100 ft. at 18 GHz
- Replaceable Standard and Self-Locking Connectors
- Aircraft Qualified Worldwide

Visit http://mwj.hotims.com/11724-162 or use RS# 162 at www.mwjournal.com/info

TIMES MICROWAVE SYSTEMS

ISO 9001

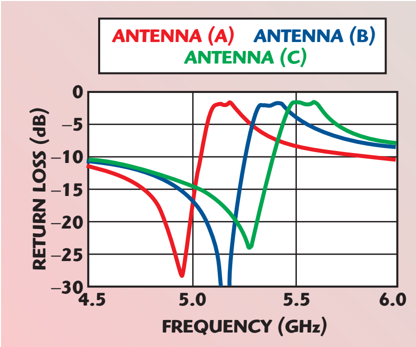
World Headquarters: 358 Hall Avenue, Wallingford, CT 06492 • Tel: 203-949-8400, 1-800-867-2629 Fax: 203-949-8423
International Sales: 4 School Brae, Dysart, Kirkcaldy, Fife, Scotland KY1 2XB UK • Tel: +44(0)1592655428 Fax: +44(0)1592653162
China Sales: 16F, United Plaza, 1468 West Nanjing Road, Shanghai, China 200040 • Tel: 86-21-32224506 Fax: 86-21-62898980

www.timesmicrowave.com

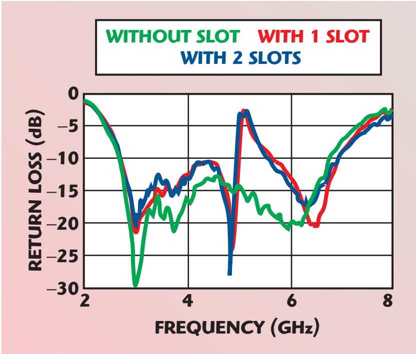
width W of the bow-tie patch is one-half wavelength at the lower resonance frequency, and the widths W_M and W_F of the feed line are important parameters for impedance matching.

BAND REJECTION ANTENNA DESIGN

The aforementioned band reject operation is analyzed as a transmission line when the length of the embedded slot in the radiator is one-half wavelength at the desired rejection frequency.[5] These slots can be modeled as a one-half wavelength short stub. In the proposed antenna, the physical length of the embedded slots varies with their position. In addition, the VSWR at the rejection frequency is increased by locating the slot at the edge of the bow-tie patch near the parasitic ground patch, because there



▲ *Fig. 6 Improved return loss for various frequencies.*

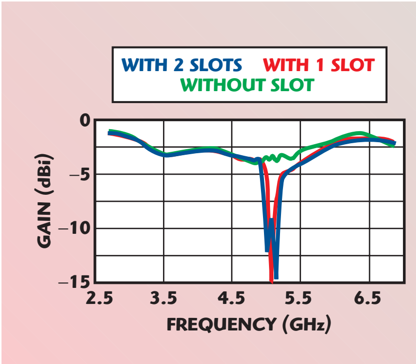


▲ *Fig. 7 Measured return loss with and without slots.*

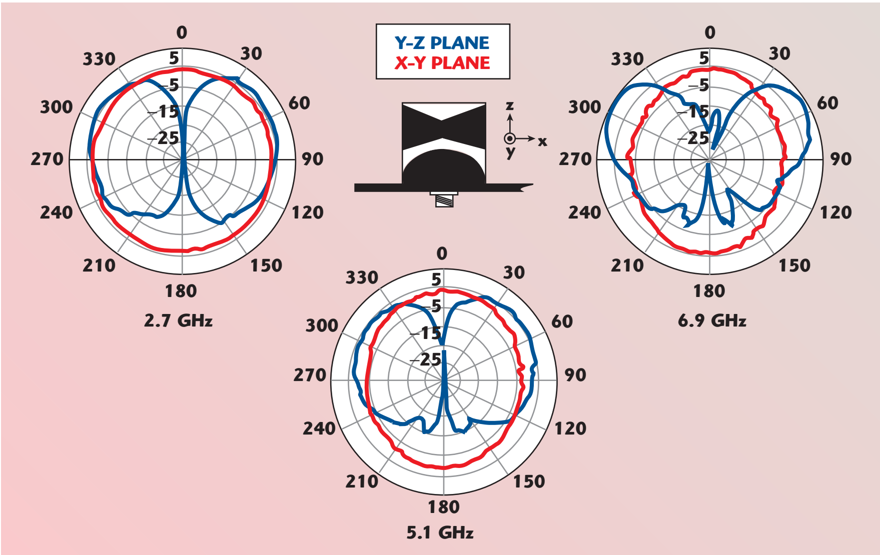
TABLE I

ANTENNA DESIGN PARAMETERS

Parameter	Type A	Type B	Type C
H_s (mm)	6.75	6.80	6.70
L_{s1} (mm)	15.66	15.16	14.56
L_{s2} (mm)	14.30	13.80	13.20
W_s (mm)	1.20	1.20	1.20
H_C (mm)	0.45	0.40	0.50
g (mm)	0.05	0.40	0.10



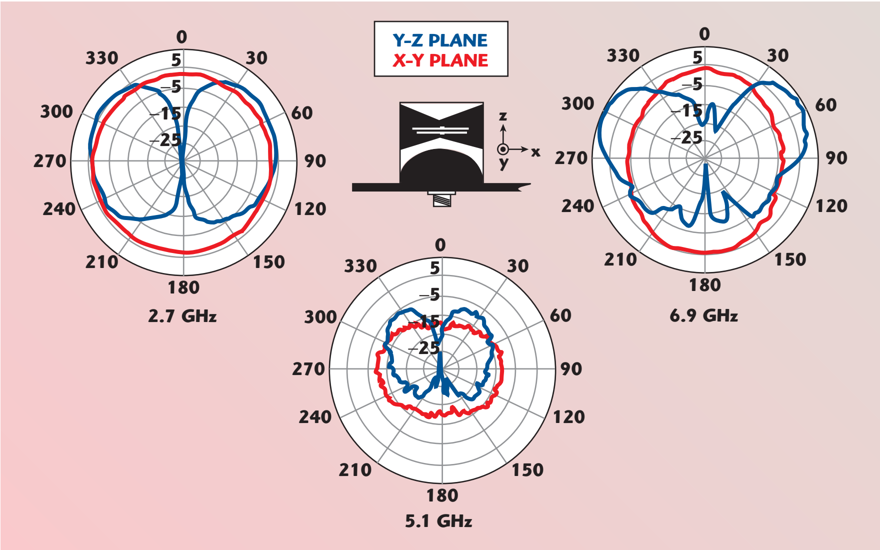
▲ *Fig. 8 Measured average gains of the proposed antennas.*



▲ *Fig. 9 Measured radiation patterns of the reference antenna without a slot.*

Shown with optional equipment.

is greater surface current distribution near the edge. The improved band rejection characteristics are achieved by controlling the mutual coupling between the slots with the same notch frequency. ***Figure 2*** shows the geometry of the proposed band rejection antenna with two horizontal resonant slots. Here, the width of a slot is 0.3 mm. As shown in ***Figure 3***, these slots will be used as notch resonators for band rejection, filter-like characteristics. The conceptual equivalent circuit model for a band rejection antenna has two one-half wavelength notch resonators, coupling and antenna resistance (R_a). EM simulation results were obtained using HFSS™, a full-wave simulator. Considerable enhancement of the coupling between slot resonators and improvement of the magnitude difference of two notch peaks are observed when the slots are closely placed to each other, as shown in ***Figure 4***. The band rejection characteristic is improved by inserting additional small slots in the center of the band-notch slots. The return losses for various heights of inserted slots, when g_s is 0.4 mm, are shown in ***Figure 5***. The coupling decreases as the size of the inserted slot becomes larger. The rejected center frequency barely moves when the gap between resonators is varied, but its movement depends on the height of the inserted slot. Although the rejection characteristics show good performance without the inserted slots, g_s = 0.4 mm was chosen in order to apply two factors for controlling the mutual coupling at the antenna. As shown in ***Figure 6***, the rejection frequency of the antenna can be controlled by the resonance frequencies of the two slots and the rejection characteristic such as bandwidth and flatness is improved by two factors (g_s, HC). The design parameters of the antennas are shown in ***Table 1***. The proposed antenna, with the dimensions of type-B, was fabricated and tested. The measured return losses with and without the notch slots are shown in ***Figure 7***. The measured results were obtained using an Anritsu 37397C vector network analyzer. The rejection band of 4.96 to 5.51 GHz is created by inserting the two notch slots, without any degradation of the required performance in the normal operating frequency band of 2.70 to 6.90 GHz for a return loss below –10 dB (VSWR < 2.0). The average gain of the proposed antennas, measured in the x-y plane, is shown in ***Figure 8*** for a frequency range of 2.7 to 6.9 GHz. The gain of the antenna with two slots has two rejection peaks and is reduced at the broad rejection bandwidth, compared to the antenna using one slot. It is clear that the proposed antenna provides the improved band rejection characteristics with the broad rejection bandwidth and sharp skirt characteristic, compared to the antenna with one notch slot.



▲ *Fig. 10 Measured radiation patterns of the proposed wideband antenna with two slots.*

Figures 9 and *10* show the radiation patterns at 2.70, 5.10 and 6.90 GHz. The frequencies 2.70 and 6.90 GHz are within the radiation band, while 5.10 GHz is in the rejection band. The radiation patterns of the operating frequency band are nearly the same as those of the reference antenna, which is the same antenna except without a slot. On the other hand, within the rejection band the antenna radiation gain is greatly reduced.

CONCLUSION

A method to improve the band rejection characteristics of a wideband patch antenna by embedding two horizontal resonant slots and adjusting their mutual coupling has been presented. To show the method, a wideband bow-tie shaped antenna with improved band rejection characteristics has been proposed and implemented. A broad rejection band, two-pole response and improved notch skirt are obtained. The proposed technique could be useful to improve and/or control the band rejection characteristics of wideband antennas for many applications including UWB and multi-band systems. ■

ACKNOWLEDGMENT

The authors would like to thank Amotech Co. Ltd. and the Kangwon Institute of Telecommunications and Information (KITI) for measurement and other support.

References

1. W.S. Chen and M.K. Hsu, "The Design of a Finite Ground Plane Cross Semi-elliptic Monopole Antenna for UWB Applications," *Microwave Journal*, Vol. 49, No. 5, May 2006, pp. 192–204.
2. G.R. Aiello and G.D. Rogerson, "Ultra-wideband Wireless System," *IEEE Microwave Magazine*, Vol. 4, No. 2, June 2003, pp. 36–47.
3. I.J. Yoon, H. Kim, H.K. Yoon, Y.J. Yoon and J.H. Kim, "Ultra-wideband Tapered Slot Antenna with Band Cut-off Characteristic," *Electronics Letters*, Vol. 41, No. 11, May 2005, pp. 629–630.
4. T. Dissanayake and K.P. Esselle, "Design of Slot Loaded Band-notched UWB Antennas," *2005 IEEE Antennas and Propagation Society International Symposium Digest*, Vol. 1B, pp. 545–548.
5. W.Y. Choi, J.H. Jung, K.H. Chung and H.H. Choi, "Compact Wideband Printed Monopole Antenna with Frequency Band-stop Characteristic," *2005 IEEE Antennas and Propagation Society International Symposium Digest*, Vol. 3A, pp. 606–609.
6. Y.W. Rho, K.H. Kim and J.H. Choi, "Design of a Microstrip-fed Ultra-wideband Monopole Antenna Having Band Rejection Characteristic," *2005 IEEE Antennas and Propagation Society International Symposium Digest*, Vol. 2B, pp. 556–559.
7. W.S. Lee, D.Z. Kim, K.J. Kim and J.W. Yu, "Wideband Planar Monopole Antennas with Dual Band-notched Characteristics," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 54, No. 6, June 2006, pp. 2800–2806.
8. S.D. Moon, K. Choi and H.Y. Hwang, "A Wideband Bow-tie Monopole Antenna with Improved Band Rejection Characteristic," *2006 KEES Korean Conference*, Vol. 16, No. 1, pp. 203–207.
9. S.D. Moon, K. Choi and H.Y. Hwang, "A Wideband Bow-tie Monopole Antenna with Improved Band Rejection Characteristic," *The Journal of the Korea Electromagnetic Engineering Society*, Vol. 17, No. 12, December 2006, pp. 1199–1205.
10. F. Soldovieri, A. Brancaccio and G. Leone, "Characterization of Ultra-wideband Bow-tie Antennas for Ground Penetration Radar Systems," *Microwave Journal*, Vol. 49, No. 8, August 2006, pp. 186–194.
11. L. Le Coq, S. Von der Mark, M. Drissi and J. Citerne, "Printed Bow-tie Antenna Fed by Electromagnetic Coupling," *1999 IEEE Antennas and Propagation Society International Symposium Digest*, Vol. 4, pp. 2710–2713.

Soo Deok Moon *received his BS and MS degrees in electrical and electronic engineering from Kangwon National University in 2005 and 2007, respectively. His research interests include microwave antennas and RF systems.*

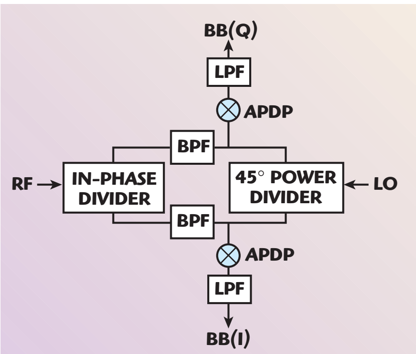
Hee Yong Hwang *received his BS degrees in biology and electronic engineering from Seoul National University in 1988 and 1992, respectively, and his MS and PhD degrees in electronic engineering from Sogang University in 1995 and 1999, respectively. From March 2000 to February 2001, he was with the department of electronic engineering, Sogang University, as a research professor. From March 2001 to April 2002, he was with the department of ECE, University of Maryland, College Park, MD, as a Visiting Researcher. Since March 2003, he has been with the department of electrical and electronics engineering at Kangwon National University, Chuncheon, Korea, where he is an associate professor. His research interests include microwave passive and active components and RF systems.*

A SUB-HARMONIC QUADRATURE MIXER USING APDPS FOR UWB SYSTEMS

This article presents an ultra-wideband (UWB) sub-harmonic mixer comprising anti-parallel diode pairs (APDP), a miniaturized bandpass filter (BPF) and a wideband 45° Wilkinson power divider. The proposed UWB mixer operates over the 3.1 to 4.8 GHz band and offers excellent conversion loss, linearity, and phase and amplitude balances for quadrature outputs.

A great deal of attention has recently been paid to ultra-wideband (UWB) technologies for short-range and high data-rate wireless personal area networks (WPAN). By supporting data rates up to several hundred megabits per second (Mbps), these technologies are expected to be used in multimedia consumer electronic products in the near future. Multi-band orthogonal frequency division multiplexing (OFDM), which is employed for this research, was one of the proposed high rate WPAN standards managed by the IEEE 802.15.3a.[1] Direct conversion receivers (DCR) mainly utilize various types of sub-harmonic mixers, such as a resistive mixer,[2] a double-balanced active mixer,[3] a cascode FET mixer,[4] or an anti-parallel diode-pair (APDP) mixer.[5] Among these mixers, the APDP sub-harmonic mixer is the most likely to be used for a DCR because it requires no DC power, consists of a simple circuit and shows excellent isolation at the RF, LO and baseband (BB) frequencies. The APDP sub-harmonic mixer can also overcome two serious DCR problems. One is the DC offset created by self-mixing of the LO and RF signals and the other is the even-order distortion created by the second-order intermodulation (IM2).[5]

Fig. 1 Schematic of the direct conversion and sub-harmonic quadrature mixer for UWB systems.



This article describes the design and implementation of a new sub-harmonic quadrature mixer for the UWB Mode 1 that operates over the 3 to 5 GHz band. The proposed mixer comprises APDPs, an in-phase power divider, miniaturized bandpass filters (BPF), low pass filters (LPF) and a wideband 45° Wilkinson power divider. The mixer design is presented in detail, along with a discussion of the measured results.

DESIGN

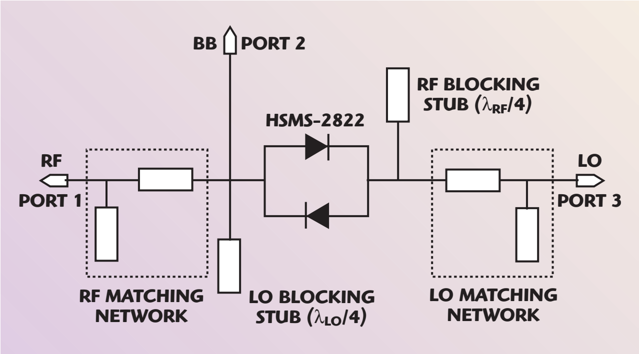
Sub-harmonic Quadrature Mixer

There are two ways of generating in-phase/quadrature-phase (I/Q) signals, that is implementing a quadrature of the phase shift for an either RF or LO port.[6] In this article, the quadrature of the LO signal is done at the second sub-harmonic frequency, due to the presence of a non-information signal at a frequency lower than that of the RF signal. As shown in **Figure 1**, the proposed hybrid microwave inte-

GOO-YOUNG JUNG AND
TAE-YEOUL YUN
Hanyan University
Seoul, Korea

grated-circuit (HMIC) mixer needs BPFs, LPFs, an in-phase power divider and a 45° power divider. Among these, the BPF and 45° power divider are novel components that greatly contribute to the RF-LO isolation and I/Q mismatch of the circuit; consequently, they are discussed in detail.

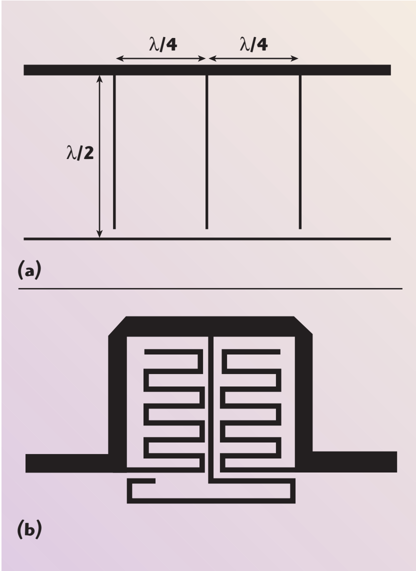
In addition, the APDP circuit has impedance matching and isolation blocks for RF and LO, as shown in ***Figure 2***. To isolate the RF port from the LO port, the mixer adopts $\lambda_{RF}/4$ and $\lambda_{LO}/4$ open-stubs between the APDP and matching networks. The matching circuits were simply designed with a single-stub matching technique to improve the conversion loss. The complete mixer circuit is fabricated on a Taconic CER-10 substrate with a dielectric constant of 9.5 and a thickness of 0.635 mm. The high dielectric constant of the substrate affords a compact circuit structure. An Agilent Schottky diode pair (HSMS-2822) is used as the mixing component.



▲ *Fig. 2 Matching circuits for anti-parallel diodes.*

Bandpass Filter

Figure 3 shows a general microwave BPF using transmission-line stubs in a parallel configuration. The BPF was employed to accommodate a high rejection of the LO from 1.55 to 2.4 GHz and a low insertion loss at RF from 3.1 to 4.8 GHz. The design procedure of the BPF follows three steps. First, a distributed high pass filter comprises a cascade of short-circuited stubs for UWB filters.[7,8] The characteristic impedances of each short-circuited line are initially calculated as described by Hong and Lancaster.[9] Second, to minimize the



▲ *Fig. 3 A small size BPF; (a) the basic structure and (b) the meandered and reduced size structure.*

90% of the time spent measuring

is in setting up the measurement.

Agilent N6705A DC power analyzer

- *View critical multiple-bias-supply turn-on/turn-off sequences*
- *Display voltage and current versus time*
- *Generate DC bias supply transients*
- *Log data from seconds to days*

LXI

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

www.agilent.com/find/dcpoweranalyzer

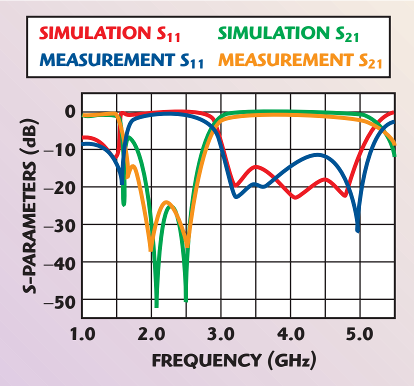
Setting up and programming multiple test instruments is holding you back. Free yourself and get right to your DC bias testing with the new Agilent N6705A DC power analyzer.

The N6705A integrates the capabilities of up to four power supplies, a DMM, an arbitrary waveform generator, a scope, and a data-logger into a single instrument.

Every function is controlled from the front panel, and a single graphical display reveals all your measurements. Even the controls are designed to save you time. The N6705A includes an easy and intuitive interface, with color-coded controls and convenient button placement to give you quick access to the functions you need.

Don't be held back. Time savings are within reach.

Agilent Technologies

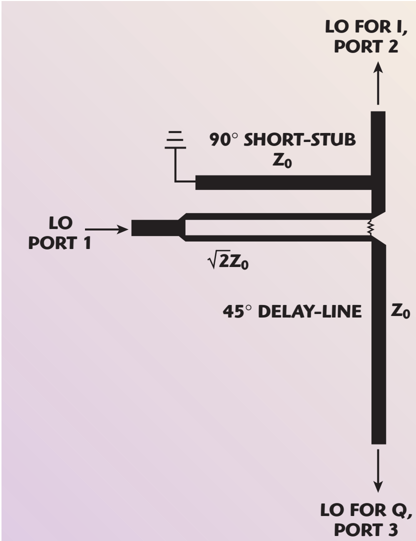


▲ *Fig. 4 Simulated and measured S-parameters of the BPF.*

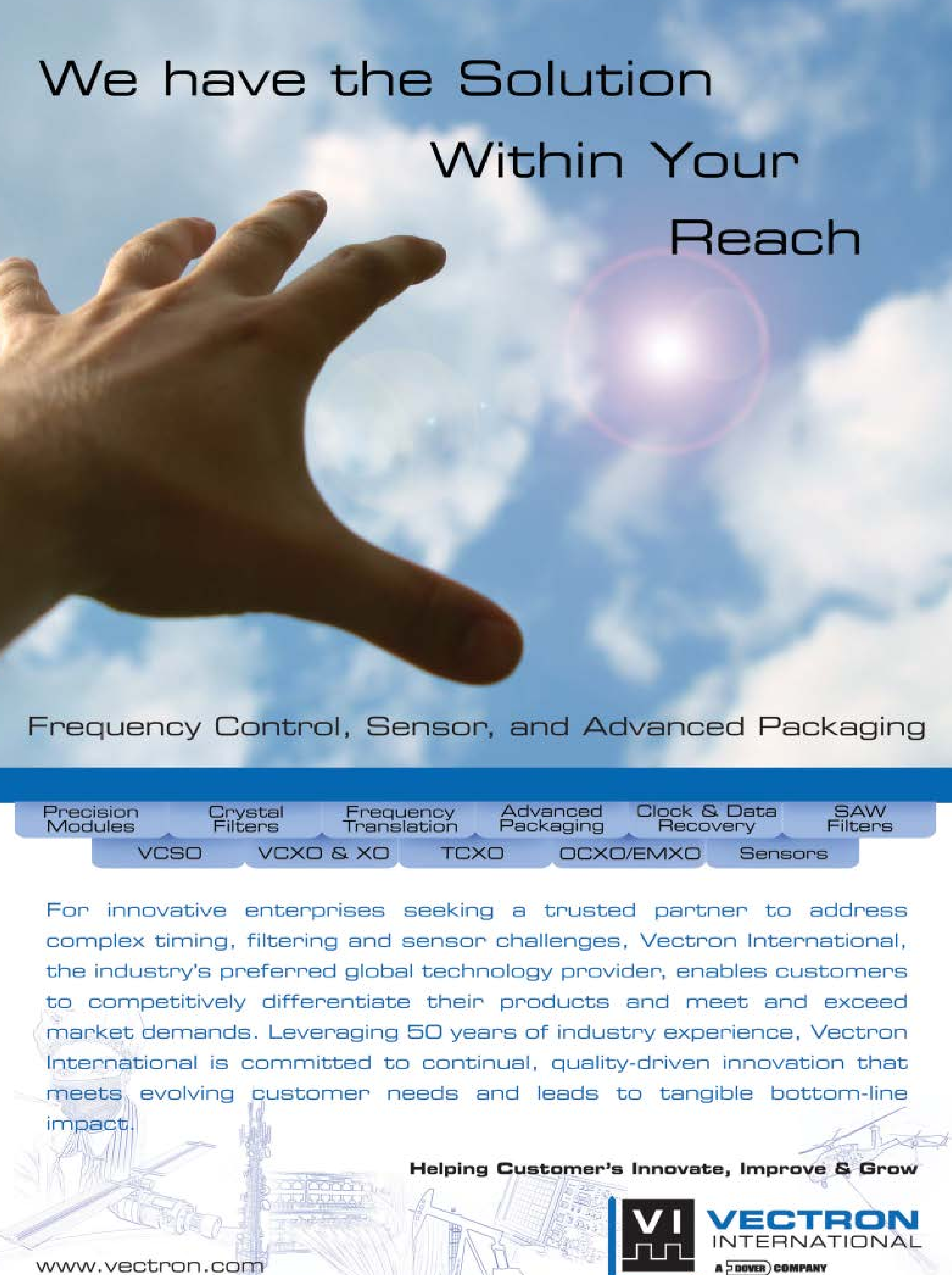
parasitic effects of the via holes used as a short circuit, the short-stub is replaced with a double length open-stub. Finally, the shunt open-circuited stubs are meandered to widen the bandwidth of the LO rejection frequency using the coupling between the stub-lines[10] and to reduce the filter size to 13 × 7 mm. ***Figure 4*** shows the simulated and measured results of the new BPF. An insertion loss (S_{21}) of 1 ±0.5 dB and a return loss (S_{11}) of less than –15 dB are obtained in the RF band between 3.1 and 4.8 GHz. A LO rejection of more than 10 dB is measured at the LO band between 1.55 and 2.40 GHz. The UWB BPF results in a wide bandwidth, low insertion loss, small size and sharp attenuation.

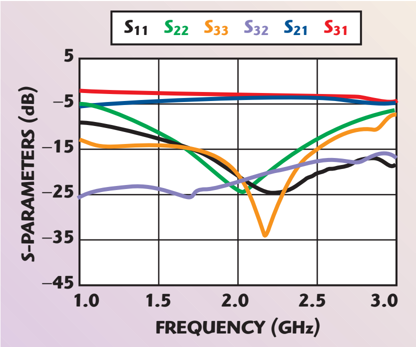
Wideband 45° Wilkinson Power Divider

Most wideband quadrature mixers have phase- and amplitude-imbalances of the LO quadrature signals which significantly influence the I/Q mismatch of the mixer.[11,12] As shown in ***Figure 5***, to maintain the phase difference of 45° at the output ports over the wideband, a short-stub with an electrical length of 90° at the LO center frequency is inserted into the opposite side of the 45° delay-line. The 90° short-stub compensates the phase deviation between S_{21} and S_{31} because the phase variations of the delay-line are nearly identical to those of the short-stub over the LO band.[12] The measured characteristics of the wideband 45° Wilkinson power divider are illustrated in ***Figure 6***. Insertion losses (S_{21} and S_{31}) of 3.75 ±0.25 dB, return losses (S_{11}, S_{22} and S_{33}) of less than –15 dB and isolations (S_{32} and S_{23}) of less than –20 dB are obtained at the LO over the 1.55 to 2.4 GHz band. ***Figure 7*** shows that the two outputs differ in phase by 45 ±1.5°. ***Table 1*** summarizes the measured results of the mixer components such as the LPF, the BPF, the in-phase power divider and the 45° power divider. All the return losses, insertion losses and isolations are suitable for the passive UWB mixer.



▲ *Fig. 5 A wideband 45° Wilkinson power divider.*


We have the Solution
Within Your
Reach
Frequency Control, Sensor, and Advanced Packaging
Precision Modules
Crystal Filters
Frequency Translation
Advanced Packaging
Clock & Data Recovery
SAW Filters
VCSO
VCXO & XO
TCXO
OCXO/EMXO
Sensors
For innovative enterprises seeking a trusted partner to address complex timing, filtering and sensor challenges, Vectron International, the industry's preferred global technology provider, enables customers to competitively differentiate their products and meet and exceed market demands. Leveraging 50 years of industry experience, Vectron International is committed to continual, quality-driven innovation that meets evolving customer needs and leads to tangible bottom-line impact.
Helping Customer's Innovate, Improve & Grow
VI
VECTRON INTERNATIONAL
A DOVER COMPANY
www.vectron.com



▲ *Fig. 6 Measured S-parameters of the wideband 45° Wilkinson power divider.*

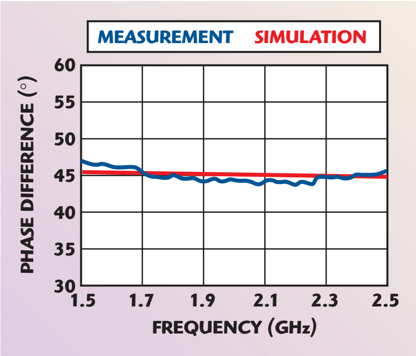
TABLE I

MEASURED S-PARAMETERS OF THE WIDEBAND MIXER COMPONENTS

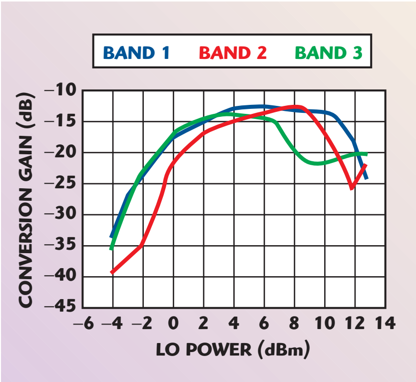
Parameters	LPF	BPF	In-phase Divider	45° Phase Divider
Frequency (GHz)	0 ~ 0.26	3.1 ~ 4.8	3.1 ~ 4.8	1.55 ~ 2.40
S_{11} (dB)	< –12	< –12	< –15	< –15
S_{21} (dB)	> –0.5	> –1	> –3.5	> –4
Isolation (dB)	–	–	< –20	< –20

RESULTS AND DISCUSSION

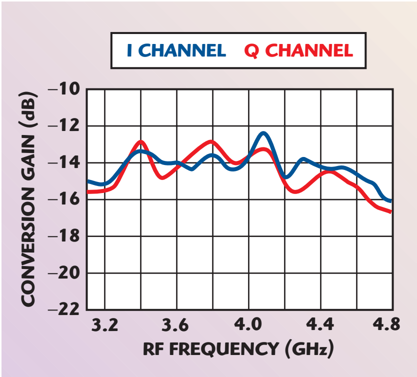
The proposed mixer is characterized by return losses, conversion gains, I/Q imbalance, an input-referred 1 dB compression point (P1dB) and an input-referred third-order intercept point (IIP3). The



▲ *Fig. 7 Phase difference between the output ports of the wideband 45° Wilkinson power divider.*

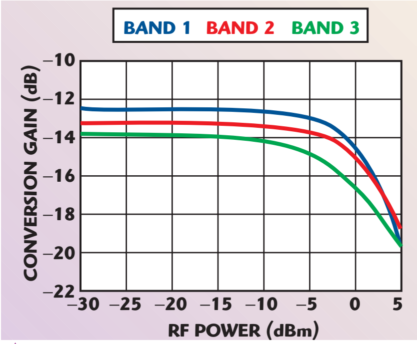


▲ *Fig. 8 Measured conversion gains vs. LO power.*

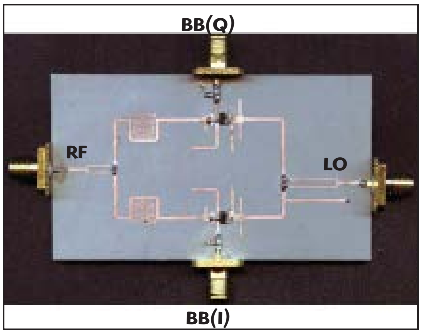


▲ *Fig. 9 I/Q conversion gains vs. frequency.*

center frequency of Band 1 of the UWB system is 3.432 GHz, while Band 2 is 3.960 GHz and Band 3 is 4.488 GHz. ***Figure 8*** compares the measured conversion gain as a function of LO power to determine its optimal value. The optimal LO power is 6 dBm with a RF input power level of -30 dBm. For brevity, the simulated and measured RF and BB (I/Q) input return losses are not shown, but it should be noted that they agreed well and are less than approximately –10 dB over each band. ***Figure 9*** shows the conversion losses and flatness of I and Q outputs at 3.1 to 4.8 GHz (UWB mode 1). The measured conversion losses were 13 to 15 dB, including the insertion loss of the in-phase power divider of 3 dB. Therefore, the measured conversion loss of the mixer can be estimated as 10 to 12 dB if the LO quadrature signals are directly supplied outside of the



▲ *Fig. 10 Measured conversion gain vs. RF power.*



▲ *Fig. 11 The fabricated UWB mixer.*

TABLE II

PERFORMANCE SUMMARY OF THE PROPOSED SUB-HARMONIC QUADRATURE MIXER

Parameters	*Band 1*	*Band 2*	*Band 3*
RF frequency (GHz)	3.168 ~ 3.696	3.696 ~ 4.224	4.224 ~ 4.752
LO frequency (GHz)	1.584 ~ 1.848	1.848 ~ 2.112	2.112 ~ 2.376
Conversion loss (dB) I/Q	13.42/13.66	13.85/13.97	14.35/14.64
I/Q gain difference (dB)	0.24	0.12	0.29
I/Q phase difference (°)	2.4	1.6	2.0
P1dB (dBm)	–4	–4	–5
IIP3 (dBm)	7	6	6
RF-BB isolation (dB)	< –40	< –40	< –40
RF-LO isolation (dB)	< –70	< –70	< –70

mixer. ***Figure 10*** shows the linearity of the proposed mixer with the measured input-referred P1dB to be approximately –4 dBm at each band. ***Figure 11*** shows a photograph of the fabricated UWB quadrature mixer with a size of 80 × 45 mm.

Important parameters such as conversion losses, linearity, I/Q gain difference, I/Q phase difference and port isolations of the proposed mixer are summarized in ***Table 2***. These results confirm that the proposed mixer is useful for UWB applications with a direct conversion architecture.

CONCLUSION

This article has presented a sub-harmonically pumped mixer for UWB systems using anti-parallel diode pairs with a new miniaturized BPF and a new wideband 45° Wilkinson power divider. The proposed mixer has shown good performance in, and agreement between, simulations and measurements. The mixer should be suitable for UWB systems and other wideband direct conversion applications because it provides a low and flat conversion loss, small I/Q imbalance, high port-to-port isolation and moderate linearity over the 3 to 5 GHz band. ■

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-2006-C1090-0603-0019).

References

1. http://www.ieee 802.org.5/pub/TG3a.html.
2. K.S. Ang, M. Chongcheawchamnan, D. Kpogla, P.R. Young, I.D. Robertson, D. Kim, M. Ju and H. Seo, "Monolithic Ka-band Even-harmonic Quadrature Resistive Mixer for Direct Conversion Receivers," *2001 IEEE Radio Frequency Integrated Circuits Symposium Digest*, pp. 169–172.
3. M. Goldfarb, E. Balboni and J. Cavey, "Even Harmonic Double-balanced Active Mixer for Use in Direct Conversion Receivers," *IEEE Journal of Solid-State Circuits*, Vol. 38, 2003, pp. 1762–1763.
4. D. An, S. Kim, W. Sul, H. Han, H. Park and J. Rhee, "High Conversion-gain Millimeter-wave λ4 Sub-harmonic Mixer with Cascode 4^{th}-harmonic Generator," *Microwave and Optical Technology Letters*, Vol. 41, 2004, pp. 490–493.
5. M. Cohn, J.E. Degenford and B.A. Newman, "Harmonic Mixing with an Anti-parallel Diode Pair," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 23, No. 8, August 1975, pp. 667–673.
6. B. Razavi, *RF Microelectronics*, Prentice Hall Inc., Upper Saddle River, NJ, 1998.
7. P. Cai, Z. Ma, X. Guan, X. Yang, Y. Kobayashi, T. Anada and G. Hagiwara, "A Compact UWB Bandpass Filter Using Two-section Open-circuited Stubs to Realize Transmission Zeros," *2005 IEEE Asia-Pacific Microwave Conference*.
8. C.L. Hsu, F.C. Hsu and J.T. Kuo, "Microstrip Bandpass Filters for Ultra-wideband (UWB) Wireless Communications," *2005 IEEE MTT-S International Microwave Symposium Digest*, pp. 679–682.
9. J.S. Hong and M.J. Lancaster, *Microstrip Filters for RF/Microwave Applications*, John Wiley and Sons Inc., Somerset, NJ, 2001.
10. K. Sachse, A. Sawicki and G. Jaworski, "Novel, Multi-layer, Coupled-line Structures and Their Circuit Applications," *2000 IEEE Microwaves, Radar and Wireless Communications International Conference Digest*, pp. 131–155.
11. T. Nakagawa, M. Kawashima, H. Hayashi and K. Araki, "A 0.9 to 2.5 GHz Wideband and Direct Conversion Receiver for Multi-band Applications," *2001 IEEE Gallium Arsenide Integrated Circuits Symposium Digest*, pp. 37–40.
12. H. Hayashi and B. Piernas, "Miniaturized 45° Power Divider Using Three-dimensional MMIC Technology," *IEE Electronics Letters*, Vol. 36, 2000, pp. 1785–1787.


IMAGINE YOUR WORKDAY
35x FASTER
TESLA
ASK US HOW WE CAN TRANSFORM YOUR SIMULATION TIMES
Our products redefine the possibilities of invention & data analysis. From complex data processing to large-scale simulations, Acceleware super-charges your technical applications to run up to 35X faster.
Visit http://mwj.hotims.com/11724-1 or use RS# 1 at www.mwjournal.com/info
www.acceleware.com
acceleware
PROCESSING SUPERPOWER

APPLICATIONS AND ANTENNA SELECTION IN THE 4.9 GHz BAND

This article will begin with a review of various applications and uses for the 4.9 GHz band (4.40 to 4.99 GHz) and then focus on applications and antenna selection for the "new" 4.940 to 4.990 GHz public safety band allocated by the Federal Communications Commission (FCC).

A variety of commercial, governmental and military applications utilize the 4.40 to 4.99 GHz band. In the US and NATO countries, the 4.4 to 4.5 GHz band is designated for military fixed and mobile communications such as point-to-point microwave links and telemetry applications such as unmanned aerial vehicles (UAV), commonly known to the general public as drones. In the 4.635 to 4.685 GHz band the United States Navy operates the Cooperative Engagement Capability (CEC) network, which is a radar information distribution network. There is also a radio astronomy service (RAS) globally allocated on a secondary basis in the 4.80 to 4.94 GHz band. More recently, the FCC allocated 50 MHz in the 4.940 to 4.990 GHz band for public safety applications. Any state or local government agency including municipal utilities can utilize this "new" band on a shared basis. Communication networks deployed in the 4.940 to 4.990 GHz band must be related to the protection of life, health or property and cannot provide services that are otherwise commercially available to the public. These communication networks specifically serve state and local governmental organizations such as police, fire, and search and rescue. ***Figure 1*** is a diagram showing these frequency allocations.

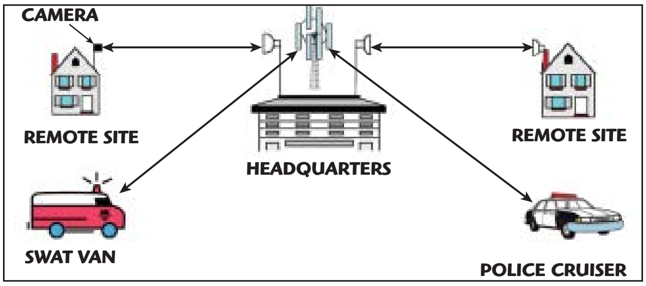
Fig. 1 Frequency allocations for state and local government communication networks.

Driven by a growing public awareness for the need to have better emergency communication systems, the 4.9 GHz band is experiencing a rapid increase in available radio products that can be deployed. Thus far, most of the deployments in the 4.9 GHz band have been utilizing the 4.940 to 4.990 GHz spectrum for microwave backhaul link activity with less activity occurring on the access side. These links serve several communication networks including building-to-building, linking temporary stations to a base station and linking remote devices such as video surveillance cameras or SWAT vans to a headquarters. These networks can also be utilized for temporary monitoring of large events, homeland security and for border control activities. Municipal utilities can utilize these networks for remote monitoring and communications. A diagram showing some of these applications can be seen in ***Figure 2***.

Meanwhile, this new 4.9 GHz band is very attractive to public safety communications users for numerous reasons. As a licensed

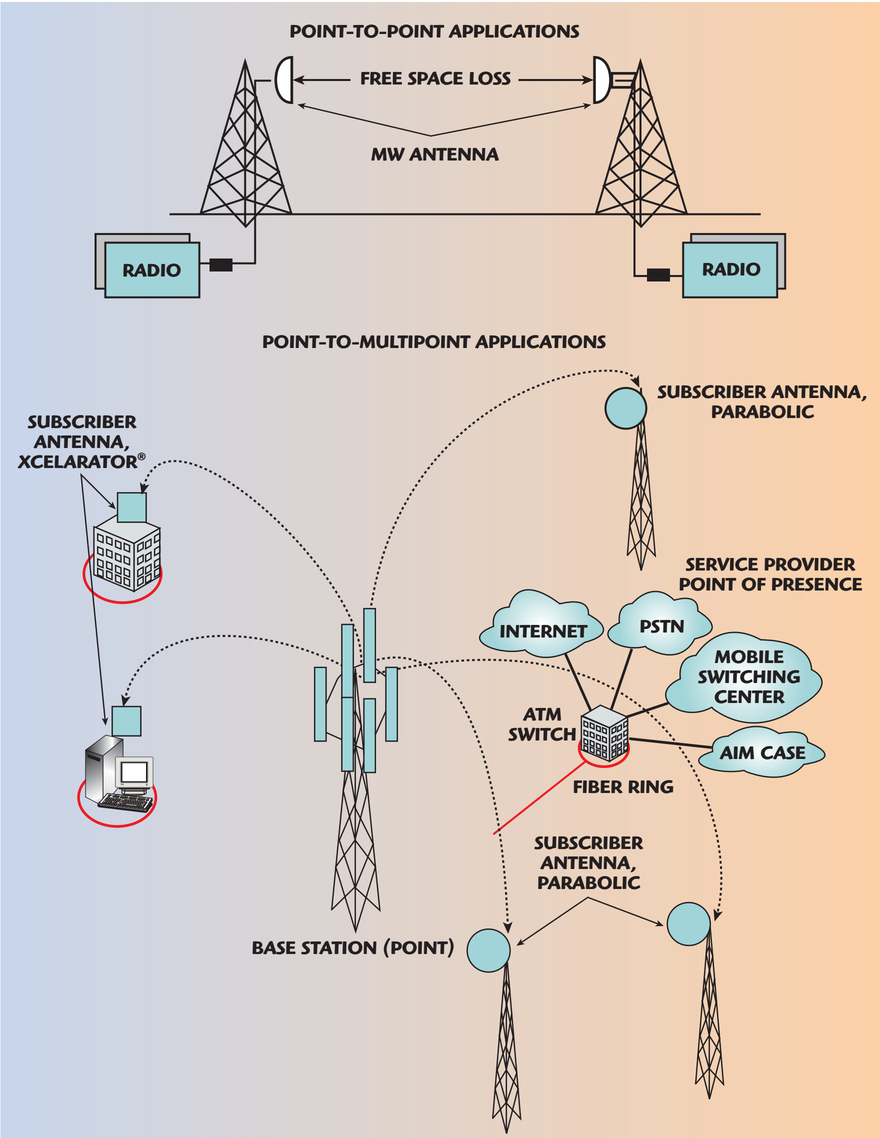
ANDY SINGER
Radio Waves Inc.
Billerica, MA

band, one of the greatest advantages to the 4.9 GHz allocation is the minimal interference for public safety users relative to the level occurring in the unlicensed bands such as 5 GHz. Additionally, these networks are easy and fast to deploy with a wide selection of equipment already available. This new FCC allocation of 4.940 to 4.990 GHz permits public safety agencies to implement on-scene wireless networks for video, Internet and database access, transfer of data and files such as maps, building layouts, medical files, police records and missing person images. This allocation also allows public safety agencies to establish temporary (up to one year) fixed microwave links to support surveillance operations and emergency communications.



▲ *Fig. 2 4.9 GHz applications include command center links to temporary stations, remote sites and devices.*

The FCC licensing rules grants a public safety agency authorization to use the total 50 MHz of spectrum within its jurisdiction. Fixed point-to-point operation requires an individual license for each station, allowing for temporary operations (up to one year) on a primary basis, or for permanent operations on a secondary basis. The FCC has concluded that Part 90 (FCC specifications governing private land mobile radio services) will guide this allocation and declined to adopt any standard for broadband technology.



▲ *Fig. 3 Network configurations for point-to-point and point-to-multipoint applications.*

ANTENNA IMPACT ON NETWORK PERFORMANCE

From an equipment perspective, the technical specifications are favorable to the development of networks based largely on the existing inventory of commercially available radio equipment. While there are a number of good radios available from companies for the 4.940 to 4.990 GHz public safety band, antenna selection is by far the most critical decision relative to network performance. Because the antenna cost is a fraction of the radio cost, the antenna system offers perhaps the best return on investment (ROI) of any network component. Selecting and deploying the optimum antenna is critical to ensuring maximized network performance. In fact, choosing the right mix of antennas can lead to significant cost savings in a network. Designers can maximize the coverage for each antenna and minimize interference, thus minimizing the number of radio points required. For point-to-point links the focus will be on microwave parabolic dishes and for point-to-multipoint networks the focus will be on sector antennas. ***Figure 3*** is a diagram showing the two applications.

For the public safety band, a sliding scale power limit depending on signal bandwidth is specified. The antenna gain limit is specified at 9 dBi. However, high power devices used for point-to-point or point-to-multipoint (both fixed or temporary) may use transmit antennas with directional gain up to 26 dBi at maximum transmitter output power. Directional gain may exceed 26 dBi if both power transmitted and spectral density are reduced by the amount that the directional antenna gain exceeds 26 dBi.

ANTENNA CONSIDERATIONS

There are four basic styles or types of antennas utilized for the 4.9 GHz

▲ *Fig. 4 Basic antenna types utilized for the 4.9 GHz band include: sector, parabolic, flat panel and grid.*

band. These four can be seen in ***Figure 4***. The sector (hub) antenna is designed to provide segmented coverage over a selected area. They typically provide a wider beamwidth than parabolic antennas and are commonly manufactured in beamwidths of 40°, 60°, 90° and 120°. The flat panel antenna is ideal when aesthetics are critical. They are light in weight and visually appealing, allowing for easy concealment. They are generally available in several sizes and for all broadband wireless bands. Network developers should be aware that parabolic antennas will have more gain for the same size flat panel. This is due to the inherent higher efficiency of the parabolic antenna design.

The standard in microwave antennas is the parabolic or "dish" antenna. The parabolic antenna consists of a parabolic shaped reflector, which focuses energy at the feed point of the antenna. They have a very narrow beamwidth that focuses energy at a specific point, making them ideal for point-to-point communications. Due to the narrow beam, they have a relatively high gain compared to other types of antennas. There are also high performance versions that utilize a shroud and absorber material to improve sidelobe performance and the front-to-back ratio of the antenna. At lower frequencies, that is, below 5 GHz, the behavior of a parabolic reflector can be simulated using a "grid" of reflective elements. This arrangement reduces wind loading, but does not provide the pattern performance or gain as can be achieved with a solid reflector. Additionally, grid antennas are limited to a single polarization.

Different system applications each require a different antenna type to ensure optimum network performance. A point-to-point application requires an antenna with a narrow beamwidth in both planes and high gain. This capability allows for longer paths, as well as minimization of interference. Thus, a parabolic is the best choice. A high performance (HP) parabolic should be utilized whenever interference may be present and the best possible communications path is called for. Due to the crowded nature of spectrum these days, increasing numbers of network designers must utilize HP dishes on microwave links even in the 4.9 and 5.2 GHz bands. These HP dishes allow


In times of change, you can rely on DLI.
Consistent focus on your special, high Q MLC needs

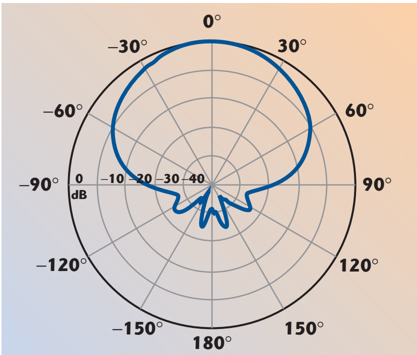
more links to co-exist in the same geographic area.

IMPROVING ANTENNA PERFORMANCE

A common technique to minimize interference is to simply utilize a larger diameter antenna. The larger the antenna, the lower the back lobe and sidelobes will be relative to the main lobe. Additionally, the larger the antenna the higher the gain provided by the antenna. This will lead to a higher received level for the desired signal and a reduced level for the interfering signals. There have been cases where users have resolved interference problems simply by replacing an existing antenna with a larger diameter antenna at a site. Given the expenses associated with the deployment of a microwave link, utilization of a larger diameter antenna is a relatively low cost method to improve network performance. Network developers will need to consider a number of factors including performance, size, weight and cost in their antenna selection process. Users should also always consider the use of radomes to protect their investment for years to come from the elements.

A point-to-multipoint hub (base station) application requires an antenna with a wide horizontal beamwidth and high gain to properly illuminate the coverage area, which is best provided by a sector antenna. A typical sector antenna horizontal pattern can be seen in ***Figure 5***. A point-to-multipoint subscriber application requires a small antenna that can be easily installed and is aesthetically pleasing. This can best be accomplished with a small 1' or 2' parabolic. When selecting the beamwidth for the hub (base) antenna users should consider 90° horizontal beamwidth antennas as the optimum choice with at least 16 dBi of gain or more. Intuitively, it may seem that a network covering 360° would require three 120° antennas. This actually turns out to be inefficient. If a network were to "overlay" three 120° antennas, there would be significant overlap in the three beam patterns. By utilizing three 90° antennas, the area is fully covered, there is less wasted overlap and the higher gain of the 90° antennas helps the system to work over longer distances. Thus, 90 degree sectors are the ideal choice for most hub antenna applications in this frequency range.

Network designers need to be careful if selecting sector antennas that make use of PC board material for the radiating elements or feed system. Typically, low cost antennas have poor or unreliable performance characteris-



▲ *Fig. 5 A horizontal beam pattern for a typical sector antenna type.*

tics such as high loss and interference as well as inappropriate beam widths. All too common in low cost PCB antennas is the usage of lower quality board material that has higher losses. As the RF signal travels through the board, more energy is converted to heat and less energy passed through the circuit to eventually be radiated as energy from the antenna system. A higher quality board material will lower the losses and have higher antenna efficiency ultimately providing more energy that is radiated out of the antenna system as true gain.

When selecting antennas, one should also be careful of "paper specs" in a catalog, as there is no agency or industry organization that monitors and qualifies that a manufacturer's data is correct. It is not uncommon to find antennas that do not meet the gain specified by the manufacturer. It is advisable to visit the manufacturer's facility and actually witness the antenna gain being measured. Designers should also be careful to check the manufacturer's warranty. Considering the potentially harsh conditions that the public service band equipment is expected to operate in without failure, equipment quality needs to be adequately addressed. Equipment reliability in the field should be backed by a minimum five-year warranty.

Dual-polarized antennas may be utilized to offer system capacity enhancement with a radio such as Motorola's Canopy Backhaul PTP400 and PTP600 series or polarization diversity to enhance the link performance. In the case of the radio produced by Exalt Communications, the polarization can actually be switched remotely with a software controlled RF switch. Either of these radios would ideally be matched with an antenna such as the HPD4-5.2, which is a high performance, 4' dual-polarized parabolic dish. By utilizing the combination of one of these radios and a high performance dual-polarized antenna, network performance is thus greatly enhanced and susceptibility to interference greatly reduced.

CONCLUSION

Radio links in the 4.9 GHz band have many interesting applications in the commercial, government and military sectors. The newly licensed public service band is critical to assisting agencies tasked with dealing with man-made and natural disasters. Antenna selection is often the most cost-effective tool for enhancing system performance. Choosing an antenna that focuses energy to the desired area is key to assuring minimal interference. Higher gain (larger diameter) antennas have narrower beamwidths that help to reduce interference from unwanted sources and maximize desired signal. Choosing an antenna with good efficiency is also critical to assuring optimized performance. As the most significant performance improvements are achieved by optimizing performance of antenna systems, it is imperative that designers consider the choice of antennas carefully. Antenna manufacturers such as Radio Waves are ready to provide an arsenal of antennas to solve complexities facing designers in optimizing their networks at 4.9 GHz and beyond. ■

A Highly Efficient 7 to 14 GHz Monolithic Class-E Power Amplifier

This article describes the design and fabrication of a highly efficient broadband monolithic class-E power amplifier utilizing a new distributed class-E load topology. The amplifier maintains a simultaneous high power-added efficiency (PAE) and output power over a 7.0 GHz bandwidth. The HPA's measured performance shows a PAE range of 82 to 50 percent and an output power of greater than 25 dBm across a 7 to 14 GHz band. The new broadband load also allows the HPA to have an excellent, spectrally pure frequency response demonstrated by its low AM and PM noise. A single 0.25 × 720 µm GaAs PHEMT device is used in this circuit.

Highly efficient monolithic power amplifiers, such as those operating under switching-mode conditions, that is class-E, -F, are suitable for the realization of large-scale phased-array radar systems.[1] In these systems, the number of radiators can easily reach 100,000 or more. Such large-scale arrays are ideal for applications in space or mobile ground systems. By utilizing highly efficient, single chip, T/R modules that are based on class-E power amplifier technology, significant savings in cost, weight and volume for these aforementioned systems can be attained.

The concept of switching-mode power amplifiers was originally introduced by Sokal[2] and subsequently by the work of Raab,[3] who introduced comprehensive design methodologies for a broad family of RF switching-mode power amplifiers. However, the first monolithic version of a class-E switching-mode amplifier operating at 835 MHz was reported in 1994,[4] followed by the work of several authors pushing the operating frequency of these circuits to ever-higher frequencies,[5–8] albeit over a rather limited frequency band.

DESIGN METHODOLOGY

Class-E Load Network

In previous publications, methodologies for the design of monolithic class-E amplifiers having lumped[7] or distributed[8] output loads were described in detail. In these designs, the load topologies were of the inverted "L" type (series L, shunt C). Furthermore, little design efforts were made to optimize these circuits for broadband operation. Hence, in the previous amplifier designs, the drain bias line was treated independent of the load circuit, merely acting as a choke realized by a quarter-wavelength transmission line, as shown in ***Figure 1***. It is worth mentioning that the function of the load network in a class-E amplifier is to shape the voltage and current waveforms. Therefore, in the design of a broadband class-E amplifier, care should be taken to ensure that class-E waveforms exist over the entire

R. Tayrani
Raytheon Space & Airborne Systems
El Segundo, CA

UP TO 100 Watt AMPLIFIERS 20 MHz TO 2 GHz

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

Heavy duty, ruggedness and reliable operation to meet your demanding communication applications describe ***Mini-Circuits collection of 5, 10, 20, 50 and 100 Watt ZHL high power amplifiers!*** Covering 20 MHz up to 2 GHz, these broadband solutions are available with or without integrated heat sink/fan to fit your system requirements. Each amplifier operates with low current consumption and is designed to work off a single +24 V DC supply, including the fan! Plus, each model can withstand and open or short output load without damage under full CW output power. They also offer built-in protection against over-voltage, thermal overloads, and an internal regulated power supply to handle fluctuations from the supply source and *still* deliver high performance. Need a ***robust*** power amplifier solution? Then come to Mini-Circuits where quality and reliability is built into every unit.

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

Model	Freq. (MHz) f_L - f_U	Gain (dB) Typ.	Max. P_{OUT} (dBm) @ Compression 1 dB	3 dB	Dynamic Range NF (dB) Typ.	IP3 (dBm) Typ.	DC Pwr. Volt (V) Nom.	Current (A) Max.	Price $ea. Qty. 1-9
With Heat Sink/Fan									
ZHL-5W-2G	800-2000	49	+37	+38	8.0	+44	24	2.0	995.00
ZHL-10W-2G	800-2000	43	+40	+41	7.0	+50	24	5.0	1295.00
• ZHL-20W-13	20-1000	50	+41	+43	3.5	+50	24	2.8	1395.00
• ZHL-50W-52	50-500	50	+46	+48	4.0	+55	24	9.3	1395.00
• ZHL-100W-52	50-500	50	+47	+48.5	6.5	+57	24	9.3	1995.00
▲ ***Without Heat Sink/Fan***									
ZHL-5W-2GX	800-2000	49	+37	+38	8.0	+44	24	2.0	945.00
• ZHL-10W-2GX	800-2000	43	+40	+41	7.0	+50	24	5.0	1220.00
• ZHL-20W-13X	20-1000	50	+41	+43	3.5	+50	24	2.8	1320.00
• ZHL-50W-52X	50-500	50	+46	+48	4.0	+55	24	9.0	1320.00
• ZHL-100W-52X	50-500	50	+47	+48.5	6.5	+57	24	9.0	1920.00

• *Patent Pending*

▲ *With heat sink/fan removed, customer must provide adequate cooling to ensure that the base plate temperature does not exceed 85°C.*
See data sheets on Mini-Circuits web site.

ZHL-5W-2 GX ZHL-10W-2 GX ZHL-50W-52X ZHL-100W-52X ZHL-20W-13X

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

YONI2™ Patent Pending ***The Design Engineers Search Engine*** *Provides ACTUAL Data Instantly From MINI-CIRCUITS At:* ***www.minicircuits.com***

RF/IF & MICROWAVE COMPONENTS

416 Rev D

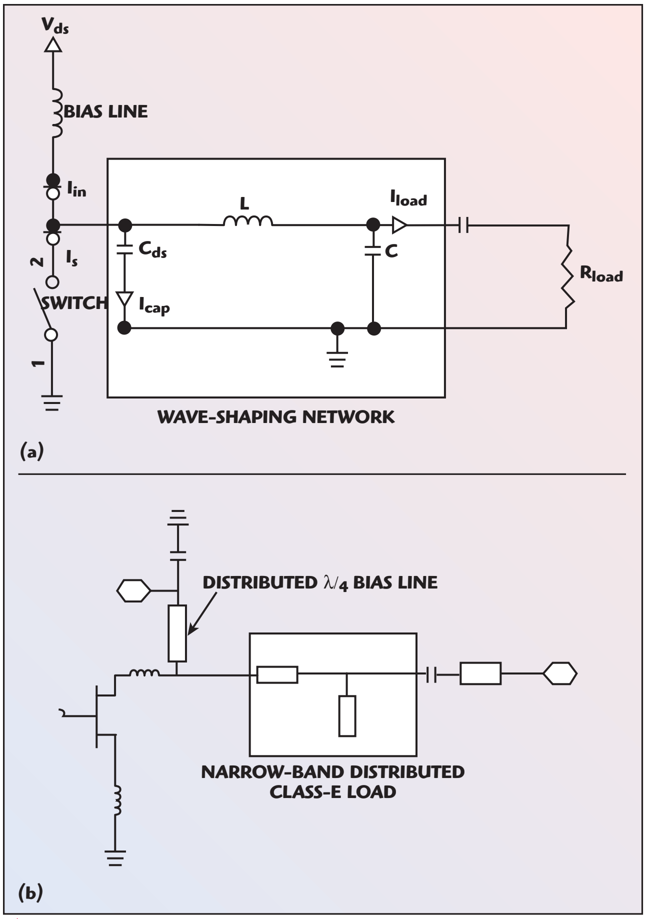


Fig. 1 Ideal class-E load; (a) topology and (b) distributed version.

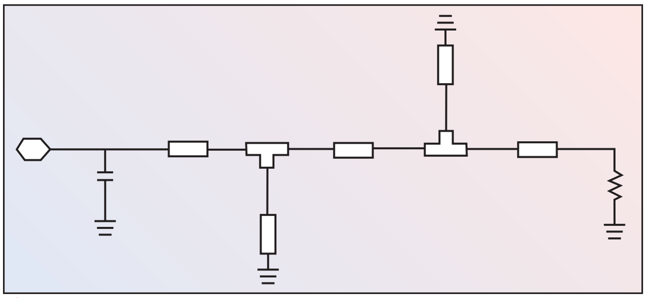


Fig. 2 Broadband distributed class-E load.

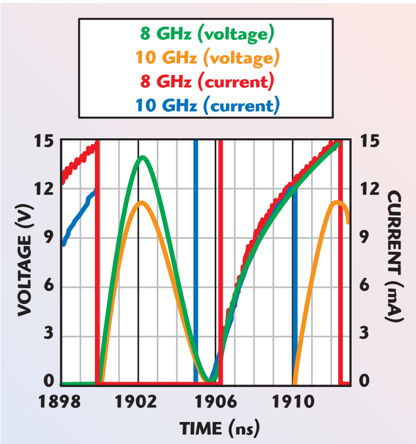


Fig. 3 Simulated waveforms for broadband load.

frequency band. Choices of a suitable device nonlinear modeling tool as well as a design environment tool capable of time domain analysis, robust harmonic balance and envelope simulation, are critical for the successful design of highly nonlinear circuits such as switching-mode amplifiers. All aspects of the nonlinear device modeling and circuit simulations were successfully performed by using Agilent CAD tools, namely ICCAP[9] and ADS,[10] respectively.

In this article, a new distributed broadband class-E load topology is presented, as shown in **Figure 2**. The load offers superior performance over an octave bandwidth (7 to 14 GHz) when compared with the classical class-E load network. Using the time domain simulation capability of ADS,[10] the load network was optimized to obtain near ideal class-E current and voltage waveforms over several frequency points, as shown in **Figure 3**. The voltage waveform across the switch rises slowly at switch-off and falls to zero at the end of the half-cycle. It also has a zero rate of change at the end of the half-cycle, thereby ensuring a "soft" turn-on condition. Furthermore, it is shown that the switch current has dropped to zero by the end of the half-cycle, all indicative of class-E operation for the distributed load at 8 and 10 GHz. Similar simulated waveforms were obtained over the entire desired 7 GHz frequency band. The integral of the capacitor (C_{ds}) current over the half-cycle was also simulated to ensure a zero net current during the switch-off period.

Device Modeling and Circuit Simulation

For accurate and robust nonlinear simulation of switching-mode amplifiers, the device nonlinear model should include the following important parameters:

- Bias dependency of the drain-to-source $C_{ds}(V_{ds}, V_{gs})$ and gate-to-drain $C_{gd}(V_{ds}, V_{gs})$ capacitances.
- Bias dependency of the input channel resistance $R_I(V_{ds}, V_{gs})$.
- Bias dependency of the output channel resistance $R_{ds}(V_{ds}, V_{gs})$.

The device model should also be able to accurately describe the dispersion associated with the drain current, gm and R_{ds}. Obviously, if a pulsed DC IV technique is used for the model development, this requirement becomes unnecessary. In previous work[7,8] and in current studies, the EEHEMT model available in ICCAP[9] and ADS[10] was used. It is believed that this is a robust model, suitable for the simulation of class-E amplifiers. The amplifier performance goal was tailored for application in very large (more than 100,000 T/R elements) space-based phased-array radars, requiring simultaneous broadband power (200 mW, 20 dBm

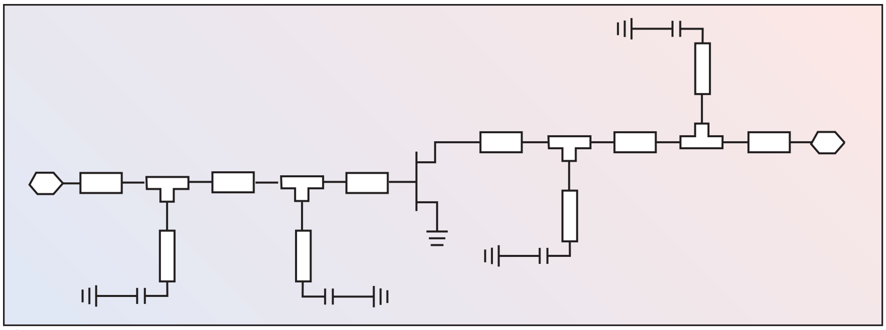
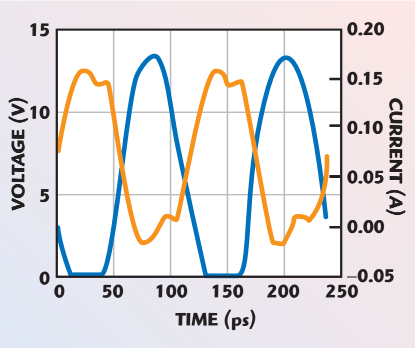


Fig. 4 Class-E amplifier circuit.

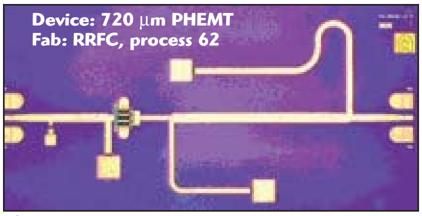

ARJ109
BEO USA
AC264
A2CP6008
IN USA
15 VDC
001-001
OUT

minimum) and high PAE over the 7 to 14 GHz band. A 0.3 × 6 × 120 µm PHEMT device, having a gate-drain breakdown voltage greater than 18 V, was found to meet the amplifier's performance goals. The details of the amplifier design steps are the same as those described previously.[7,8] ***Figure 4*** shows the final schematic circuit of the monolithic class-E amplifier, depicting the new broadband class-E load topology. Great care was taken in the design of the reactive input matching network to ensure a broadband response under large-signal input drive conditions.

Figure 5 depicts the simulated voltage and current waveforms at the PHEMT output terminals. The waveforms confirm the switching-mode behavior of the PHEMT at 8.5 GHz. Similar waveforms were observed over the 7 to 14 GHz band, thereby confirming the class-E operation of the new distributed broadband load.



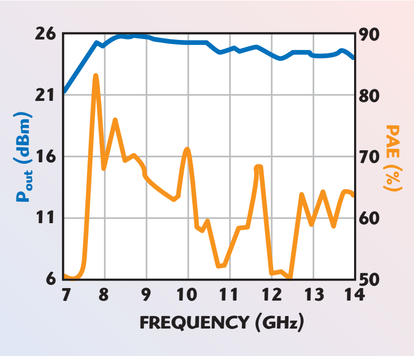
▲ *Fig. 5 Class-E simulated voltage and current waveforms.*



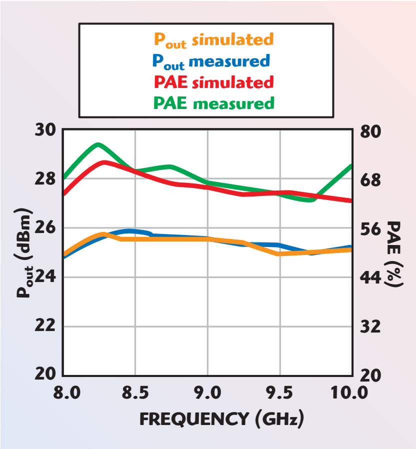
▲ *Fig. 6 MMIC amplifier chip (2.5 × 1.0 mm).*

MEASURED PERFORMANCE

A typical fully fabricated monolithic amplifier chip is shown in ***Figure 6***, while the measured amplifier performance is shown in ***Figure 7***,



▲ *Fig. 7 P_{out} and PAE versus frequency.*



▲ *Fig. 8 Simulated and measured P_{out} and PAE of the amplifier.*

demonstrating the widest bandwidth for a class-E power amplifier reported so far. As shown, the HPA possesses simultaneous high PAE and P_{out} over the 7 to 14 GHz bandwidth, when excited by an input drive of 14 dBm. The PHEMT is biased at V_{ds} = 6 V and V_{gs} = –0.8 V. The measured maximum and minimum PAE are shown to be greater than 80 and 50 percent, while the measured output power is greater than 24 dBm over the entire 7 GHz bandwidth. Over the sub-band of 8 to 10 GHz, which is of great interest for space-based radar systems, the HPA has a measured maximum and minimum PAE and output power of 75 and 63 percent and 25.8 and 25.0 dBm, respectively. As can be seen in ***Figure 8***, good agreement between simulated and measured performance has been obtained. Although not shown, similar agreement is also obtained over the 7 to 14 GHz range. ***Figure 9*** shows the measured output power, PAE and gain versus input power at 10 GHz. A maximum PAE greater than 70 percent and an output power of 25 dBm are obtained at P_{in} = 14 dBm.

The new broadband class-E load also allows the HPA to have a spectrally pure frequency response when operated under linear or compressed power conditions. During extensive AM and PM noise measurements, no bias and/or RF input dependent subharmonic oscillations, nor any spurious parametric oscillations were observed. These critical performance attributes are extremely desirable for pulsed linear FM chirp phased-array radars, where the HPAs should avoid introducing any significant amplitude and/or phase distortions. ***Figures 10***

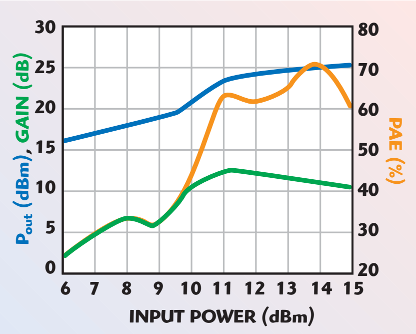


Fig. 9 Measured P_{out}, PAE and gain versus P_{in} at 10 GHz.

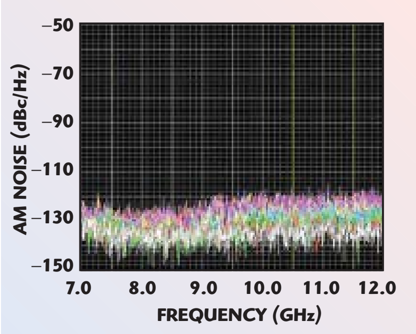


Fig. 10 Swept AM noise at 10 kHz offset from the carrier for 6 to 14 dBm drive levels.

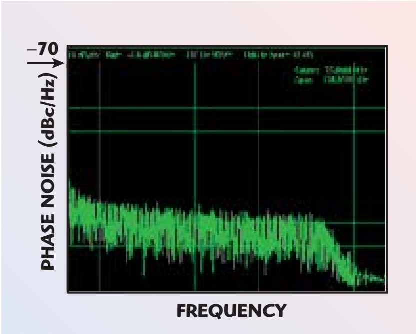


Fig. 11 PM noise response at 10 GHz carrier frequency and 14 dBm drive level.

and **11** illustrate a typical AM and PM noise response of the HPA, respectively. The swept (7 to 12 GHz) AM noise data is obtained at a 10 kHz offset from the carrier over 6 to 14 dBm input RF drive levels. As can be seen, the HPA has a spurious free AM response of less than –130 dBc over the entire frequency and input drive levels. The HPA's PM noise response shows less than –130 dBc/Hz at 15 kHz offset from 10 GHz for a 14 dBm input drive level. The measured system noise floor is close to –140 dBc/Hz. The HPA's DC bias for all noise measurements was set to V_{ds} = 6 V and V_{gs} = –0.8 V.

CONCLUSION

In this article, a new broadband distributed class-E load topology is presented, which is suitable for implementation in both hybrid and monolithic technologies. The load allows a broadband class-E performance, showing a nearly frequency independent response over the 7 to 14 GHz band. The monolithic amplifier contains a single GaAs PHEMT of 0.3 × 6 × 120 µm, having a gate-drain breakdown voltage greater than 18 V. The fabrication was performed at the Raytheon foundry using process 62. The measured PAE and output power over the 7 to 14 GHz band are 82 to 50 percent and 25.8 to 24.0 dBm, respectively, showing simultaneous high PAE and power over the entire 7.0 GHz frequency bandwidth. The new broadband class-E load also allows the HPA to have a spectrally pure, spurious free output response. The observed low AM and PM noise responses are less than –130 dBc at 10 kHz offset from the carrier and less than –130 dBc/Hz at 15 kHz offset from 10 GHz, respectively. ■

References

1. T. Quach, et al., "Broadband Class-E Power Amplifier for Space Radar Application," *2001 IEEE GaAs IC Symposium Digest*, pp. 209–212.
2. N.O. Sokal, et al., "Class-E – A New Class of High Efficiency Tuned Single-ended Switching Power Amplifier," *IEEE Journal of Solid State Circuits*, Vol. 10, No. 6, June 1975, pp. 168–176.
3. F.H. Raab, et al., *Solid State Radio Engineering*, John Wiley & Sons Inc., Somerset, NJ, 1980.
4. T. Sowlati, et al., "Low Voltage, High Efficiency Class-E GaAs Power Amplifiers for Mobile Communications," *1994 IEEE GaAs IC Symposium Digest*, pp. 171–174.
5. T. Mader, E. Bryerton, M. Markovic, M. Forman and Z. Popovic, "Switched-mode High Efficiency Microwave Power Amplifiers in a Free-space Power Combiner," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 46, No. 10, October 1998, pp. 1391–1398.
6. P. Watson, et al., "Ultra-High Efficiency Operation Based on an Alternative Class-E Mode," *2000 IEEE GaAs IC Symposium Digest*, pp. 53–56.
7. R. Tayrani, "A Broadband Monolithic S-band Class-E Power Amplifier," *2002 IEEE RFIC Symposium Digest*, pp. 255–258.
8. R. Tayrani, "A Monolithic X-band Class-E Power Amplifier," *2001 IEEE GaAs IC Symposium Digest*, pp. 205–208.
9. Agilent ICCAP, V.5.1.
10. Agilent Advanced Design Systems (ADS), V. 2005A.

A BROADBAND MEANDER LINE MONOPOLE ANTENNA WITH VERTICAL LINES

A meander line monopole antenna with vertical lines is presented for broadband operation. The impedance and radiation characteristics of the antenna are investigated. For the proposed antenna, a bandwidth of approximately 38 percent, which covers the DCS (1.71 to 1.88 GHz), PCS (1.85 to 1.99 GHz), UMTS (1.92 to 2.17 GHz), WiBro (2.3 to 2.4 GHz) and WLAN (2.45 to 2.485 GHz) bands with S_{11} less than –10 dB, is achieved. Omni-directional radiation patterns are obtained for the frequencies across the operating bands and the peak antenna gain is approximately 2.8 dBi. Experimental results from the constructed prototype are presented and discussed. The electrical characteristics of the proposed antenna make it attractive for mobile terminals and repeater applications.

Until recently, conventional commercial antennas in the worldwide market have been external ones, because they provide omni-directional radiation patterns for optimum coverage in all circumstances. In addition, stubby antennas are shorter, more robust and, arguably, more aesthetically appealing than the retractable antenna. Most of the stubby antennas reported are of the helical type or a modified one.[1–6] A meander-type structure is generally used in monopole antennas due to its simplicity and adaptability to miniaturization. However, meander line antennas are often limited by a narrow impedance bandwidth. To achieve broadband characteristics, the proposed antenna incorporates vertical lines in a meander line antenna (MLA). A parametric study has been carried out using HFSS software. The proposed antenna, which has omni-directional radiation characteristics and operates in the DCS (1.71 to 1.88 GHz), PCS (1.85 to 1.99 GHz), UMTS (1.92 to 2.17 GHz), WiBro (2.3 to 2.4 GHz) and WLAN (2.45 to 2.485 GHz) bands, has potential applications in mobile terminals and repeaters. Details of the antenna design and the experimental results obtained are presented and discussed in the subsequent sections of this article.

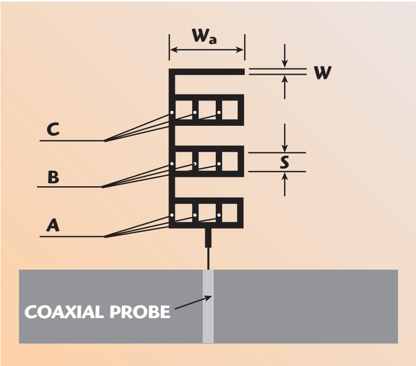
ANTENNA DESIGN

An MLA has a high current density in accordance with geometrical characteristics; therefore, its operating impedance bandwidth is generally narrow. A representative method

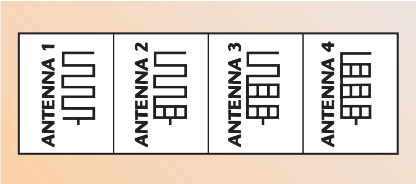
JINWOO JUNG AND YEONGSEOG LIM
Chonnam National University
Yongbong-Dong, Gwangju, Korea
HYEONJIN LEE
Dongkang College
Doam-Dong, Gwangju, Korea


contact

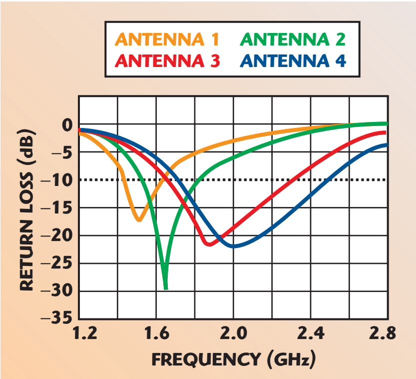
to extend the impedance bandwidth is to widen the surface area of an antenna and thereby broaden its current distribution. The proposed monopole antenna incorporates vertical lines within the MLA to broaden the current distribution. As a result, the proposed antenna has an extended impedance bandwidth.



▲ *Fig. 1 Geometry of the proposed antenna.*



▲ *Fig. 2 Antenna configurations used in the study.*

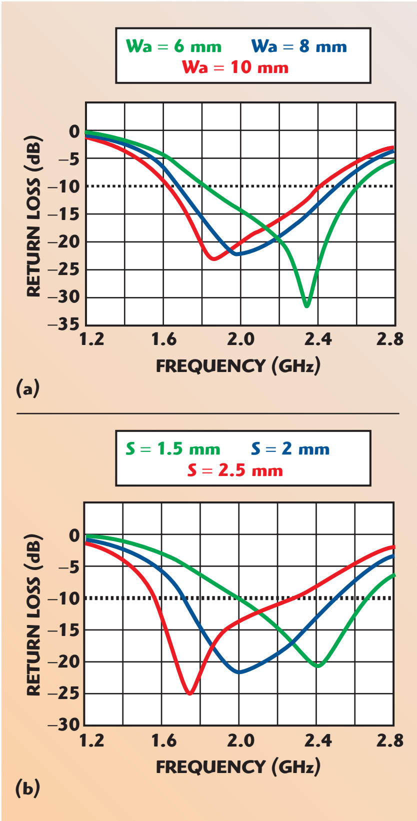


▲ *Fig. 3 Return loss vs. frequency for the prototype antennas.*

The geometry of the proposed antenna is shown in ***Figure 1***. It consists of the MLA and the vertical lines A, B and C. The dimensions of the MLA, which are optimized to operate in the DCS to WLAN bands, are as follows: the width of the meander is Wa = 8 mm, the pitch S = 2 mm and the width of the line w = 0.7 mm. Each vertical line is located so as to divide the meander section into three equal parts; the distance between each vertical line is 1.733 mm. Additionally, each vertical line has a width equal to the line width of the antenna (w). The antenna is printed on an FR-4 substrate with a thickness t = 0.8 mm and a relative permittivity ε_r = 4.6. The external dimensions of the antenna are 8 × 18.9 × 0.8 mm. The ground plane, with dimensions 40 × 50 mm, can be considered to be the circuit board of a practical mobile terminal. The antenna is excited through a coaxial probe. There is a gap of 2.2 mm between the antenna and the ground plane. This gap is usually required for a monopole above a ground plane in order to achieve good impedance matching.

DISCUSSION AND EXPERIMENTAL RESULTS

To design the proposed antenna, the simulation was carried out using Ansoft High-Frequency Structure Simulator (HFSS) simulation software to understand the behavior of the antenna model and determine the suitable parameters. ***Figure 2*** shows the configurations of the antennas studied. The return loss versus frequency of the MLAs, when the vertical lines A, B and C are added, is shown in ***Figure 3***. ***Table 1*** lists the performance of the antennas. It is seen that for Antenna 4, which is the proposed antenna, a bandwidth of 38.66 percent (approximately 810 MHz, from 1.69 to 2.5 GHz) is achieved, which covers the DCS, PCS, UMTS, WiBro and WLAN bands. This bandwidth is greater than the 32.91 percent of Antenna 3 and much greater than the 17.42 percent of Antenna 2. This behavior is largely due to the much broader current distribution that was achieved in the antenna. The proposed antenna is a modified MLA. Therefore, the operating frequencies are basically determined by the values of Wa and S.[7] ***Figure 4*** shows the return loss for the antenna with various widths (Wa) and pitches (S). ***Table 2*** shows the performance of the antennas. By varying Wa from 6 to 10 mm, while maintaining S = 2 mm, the center frequency can be decreased from 2.225 to 2.025 GHz and the impedance bandwidth is not varied. By varying S from 1.5 to 2.5 mm, while maintaining Wa = 8 mm, the center frequency can be decreased from 2.32 to 1.855 GHz and the impedance bandwidth is increased from 720 to 910 MHz. The significant reason for the decrease in the impedance bandwidth, and the increase in the operating frequency exhibited when the meander



▲ *Fig. 4 Return loss of the antenna as a function of Wa (a) and S (b).*

TABLE I
PERFORMANCE OF THE ANTENNAS SHOWN IN FIGURE 2

	Antenna 1	*Antenna 2*	*Antenna 3*	*Antenna 4*
Geometry	MLA	MLA with A	MLA with A and B	MLA with A, B and C
Lower, upper frequency (GHz)	1.43 1.63	1.52 1.81	1.65 2.30	1.69 2.50
Bandwidth S_{11} < −10 dB (MHz) (%)	200 13.07	290 17.42	650 32.91	810 38.66

FIRST-PASS SYSTEM SUCCESS

APPLICATION WORKSHOPS FOR HIGH-PERFORMANCE ELECTRONIC DESIGN

Explore design techniques and simulation technologies for IC, packaging, RF & microwave, system signal integrity, system-level EMI, low power and much more.

Discover how to design systems that integrate RF/Analog/Digital SoC solutions with memory, graphics, storage, antennas, displays, cameras, and MP3 players.

Learn how to integrate electromagnetic components, power electronic circuits, and controllers into high-performance electromechanical systems.

Discuss with industry leaders how to achieve first-pass system success!

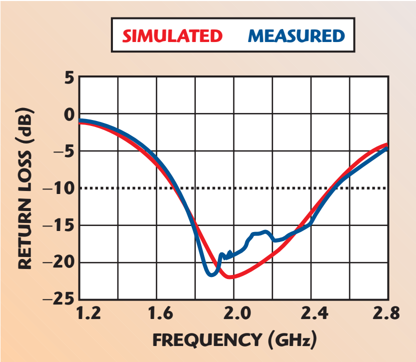
Get more information and register online: **ansoft.com/firstpass**

TABLE II

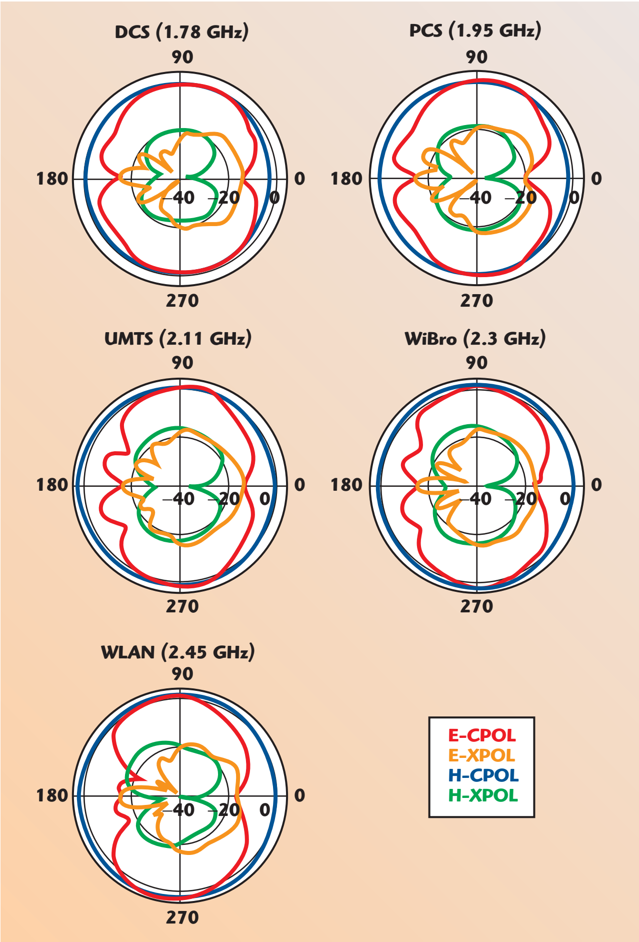
PERFORMANCE OF THE ANTENNAS WHEN Wa AND S ARE VARIED

Value	Various (mm)	Low/High Frequency (GHz)		Bandwidth (MHz)
Wa	6	1.82	2.63	810
	8	1.69	2.50	810
	10	1.62	2.43	810
S	1.5	1.96	2.68	720
	2.0	1.69	2.50	810
	2.5	1.40	2.31	910

sections are brought closer together, becomes evident when examining the current vectors on the radiating elements.[8,9] The antenna was fabricated and measured using an Anritsu 37325A network analyzer. The measured and simulated return loss for the aforementioned dimensions are shown in ***Figure 5***. Good agreement between the simulated and measured results is achieved. The predicted and measured 10 dB return loss bandwidths are 38.66 percent (1.69 to 2.5 GHz) and 38.22 percent (1.704 to 2.509 GHz), respectively. The radiation characteristics of the proposed antennas were also measured using STARGATE 32. ***Figure 6*** plots the measured radiation patterns at 1.78 (DCS), 1.95 (PCS), 2.11 (UMTS), 2.3 (WiBro) and 2.45 (WLAN) GHz, respectively. It is important to note that the radiation patterns are shown in four planes: vertical and horizontal polarizations in both the E- and H-planes. The patterns obtained were generally close to monopole-like patterns. The maximum gain of the proposed antenna, shown in ***Figure 7***, is 2.78 dBi at 2.11 GHz. The gain variations are less than 1.86 dBi for each of the operating frequencies.



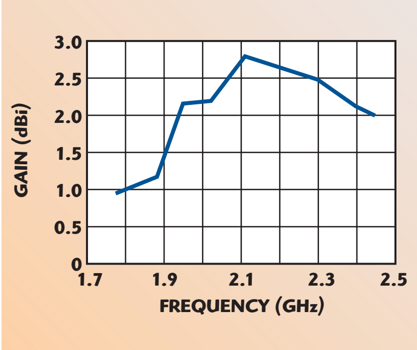
▲ *Fig. 5 Simulated and measured return loss of the prototype antenna.*



▲ *Fig. 6 Measured radiation patterns.*

CONCLUSION

A novel broadband meander line monopole antenna with vertical lines for the DCS, PCS, UMTS, WiBro and WLAN bands has been proposed and investigated. The proposed antenna



▲ *Fig. 7 Antenna gain vs. frequency.*

has compact dimensions of 8 × 18.9 × 0.8 mm. The obtained 10 dB return loss bandwidth is 38.22 percent (805 MHz) and the measured maximum gain is 2.78 dBi. The radiation patterns are similar to those of a monopole antenna. These features make the proposed antenna attractive for mobile terminals and repeater applications. ■

References

1. H. Nakano, N. Ikeda, W.Y. Yuan, R. Suzuki, H. Mimaki and J. Yamauchi, "Realization of Dual Frequency and Wideband VSWR Performance Using Normal-model Helical and Inverted-F Antennas," *IEEE Transactions on Antennas and Propagation*, Vol. 46, No. 6, June 1998, pp. 788–793.
2. S.C.K. Ko and R.D. Murch, "A Diversity Antenna for External Mounting on Wireless Handsets," *IEEE Transactions on Antennas and Propagation*, Vol. 49, No. 5, May 2001, pp. 840–842.
3. J.C. Louvigne and A. Sharaiha, "Broadband Tapered Printed Quadrifilar Helical Antenna," *Electronic Letters*, Vol. 37, 2001, pp. 932–933.
4. P. Eratuuli, P. Haapala and P. Vainikainen, "Dual Frequency Wire Antennas," *Electronic Letters*, Vol. 32, 1996, pp. 1051–1052.
5. O. Leisten, J.C. Vardaxoglou, P. McEvoy, R. Seager and A. Wingfield, "Miniaturized Dielectrically-loaded Quadrifilar Antenna for Global Positioning System (GPS)," *Electronic Letters*, Vol. 37, 2001, pp. 1321–1322.
6. D.U. Sim, J.I. Moon and S.O. Park, "A Wideband Monopole Antenna for PCS/IMT-2000/Bluetooth Applications," *IEEE Antennas and Wireless Propagation Letters*, Vol. 3, 2004, pp. 45–47.
7. T. Endo, Y. Sunahara, S. Satoh and T. Katagi, "Resonant Frequency and Radiation Efficiency of Meander Line Antennas," *Electronics and Communications in Japan*, Part 2, Vol. 83, No. 1, 2000.
8. S.R. Best and J.D. Morrow, "The Effectiveness of Space-filling Fractal Geometry in Lowering Resonant Frequency," *Antennas and Wireless Propagation Letters*, Vol. 1, 2002, pp. 112–115.
9. S.R. Best, "On the Performance Properties of the Koch Fractal and Other Bent Wire Monopoles," *IEEE Transactions on Antennas and Propagation*, Vol. 51, 2003, pp. 1292–1300.

i2S® INTELLIGENT INTERACTIVE SYNTHESIZERS

FEATURES:

- Exceptional Phase Noise Performance
- Interactive Communication
- Selectable Interface
- Standard Programming Interface
- Single or Dual Supply Options
- Small Size, Surface Mount
- Lead Free - RoHS Compliant
- Patent Pending REL-PRO® Technology

RoHS COMPLIANT

FSW & FSH Series

LFSW Series

Model #	Frequency (MHz)	Step Size (KHz)	Typical Phase Noise (dBc/Hz)	
			@10 kHz	@100 kHz
Compact size				
FSW511-50	50 - 115	500	-112	-127
FSW1125-50	110 - 250	500	-105	-130
FSW1545-50	150 - 450	500	-98	-120
FSW1857-100	180 - 570	1000	-100	-126
FSW2476-50	240 - 760	500	-93	-120
FSW60135-50	600 - 1350	500	-90	-117
FSW60170-50	600 - 1700	500	-90	-117
FSW80210-50	800 - 2100	500	-90	-113
FSH9496-20	940 - 965	200	-109	-134
FSW150290-10	1500 - 2900	100	-79	-101
FSW150320-50	1500 - 3200	500	-85	-107
FSW190410-50	1900 - 4100	500	-82	-107
FSW190410-100	1900 - 4100	1000	-85	-110
FSH196225-50	1960 - 2250	500	-94	-119
FSW200400-100	2000 - 4000	1000	-85	-110
FSW215265-50	2150 - 2650	500	-90	-120
FSH250300-1M	2500 - 3000	10000	-98	-122
Single Supply (Buffered Output)				
LFSW514-50	50 - 140	500	-112	-127
LFSW1129-50	110 - 290	500	-108	-133
LFSW1545-50	150 - 450	500	-98	-120
LFSW1857-50	180 - 570	500	-94	-120
LFSW1857-100	180 - 570	1000	-98	-120
LFSW2476-50	240 - 760	500	-94	-119
LFSW35105-50	350 - 1050	500	-108	-130
LFSW35105-100	350 - 1050	1000	-102	-132
LFSW50120-50	500 - 1200	500	-97	-120
LFSW60170-50	600 - 1700	500	-90	-117
LFSW110250-50	1100 - 2500	500	-95	-118
LFSW150320-25	1500 - 3200	250	-82	-107
LFSW150320-50	1500 - 3200	500	-85	-110
LFSW190410-50	1900 - 4100	500	-82	-107
LFSW190410-100	1900 - 4100	1000	-85	-110
LFSW290342-100	2900 - 3420	1000	-87	-107
Contact us for other frequency bands not listed.				

SYNERGY® MICROWAVE CORPORATION

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

Visit Our Website At WWW.SYNERGYMWAVE.COM

A COMPACT WIDE STOP-BAND KOCH-SHAPED ELECTROMAGNETIC BANDGAP MICROSTRIP LOW PASS FILTER

A novel compact wide stop-band electromagnetic bandgap microstrip low pass filter using a Koch shape is presented. The Koch-shaped configuration of the low pass filter not only can reduce the size of the structure, but can also widen the stop-band width. In this article, a pass-band with a less than –25 dB return loss and a stop-band width of 8.6 GHz were achieved by the presented Koch-shaped dual-planar electromagnetic bandgap microstrip low pass filter. The occupied area of the filter is only 25 × 20 mm².

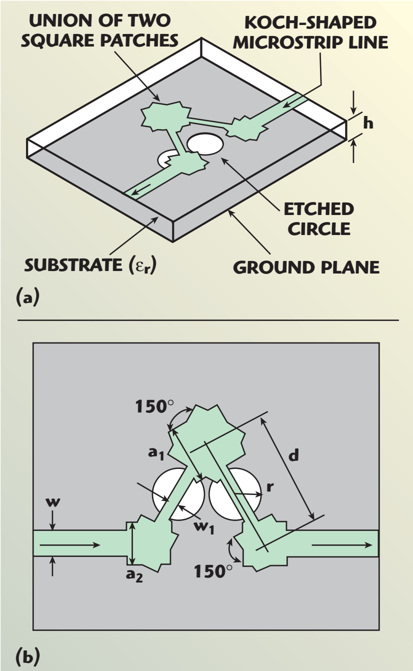
The practical application of an electromagnetic bandgap (EBG) structure usually presents difficulties in accommodating its physical size, since the period of an EBG lattice has to be a half-wavelength at the stop-band center frequency. Simple increments of the EBG cells and the wave impedance difference will result in inherent problems of increasing size and pass-band degradation.[1] Several authors have recently focused on achieving a compact and wide stop-band design.[2-4] Although these structures are relatively small and have a wide rejection frequency bandwidth, their pass-band performances are not meeting the required performance well. The space-filling properties of certain fractal curves, in order to obtain resonant elements that occupy a small volume and at the same time provide wideband performances, have been reported.[4,5] In this article, a novel Koch-shaped EBG microstrip low pass filter is presented. The upper microstripline of the presented Koch-shaped EBG microstrip low pass filter was configured as a Koch curve of the first iteration order, inserted with novel patches. The FDTD simulation results and experimental results show that the proposed novel Koch-shaped EBG microstrip low pass filter achieved excellent pass-band and stop-band performances within a small area.

FILTER DESIGN

Figure 1 shows the 3-D and top views of the proposed Koch-shaped EBG microstrip low pass filter. As can be seen, the proposed Koch-shaped EBG microstrip low pass filter has only two EBG cells, so it is highly compact compared with the size of other EBG structures. The patches are produced by superposing two rectangular patches, which are inserted in the microstripline with a period d. Bends of 60° and 120° are placed alternatively, according to the shape of the first iteration order Koch curve with a period d. The period d satisfies the Bragg reflection condition, which

WEN-LING CHEN, GUANG-MING WANG AND YI-NA QI
Missile Institute of Air Force Engineering University
Xi'an, China

results in d = $\lambda_g/2$ at the center frequency. The F4B-2 substrate has a dielectric constant ε_r = 2.65 and a thickness h = 0.8 mm. When the center frequency of the stop-band is set at 10 GHz, the period d of the structure can be determined as 10 mm, according to the Bragg reflection condition. The width of the microstrip line was set to be 2.2 mm, corresponding to a characteristic impedance of 50 Ω.

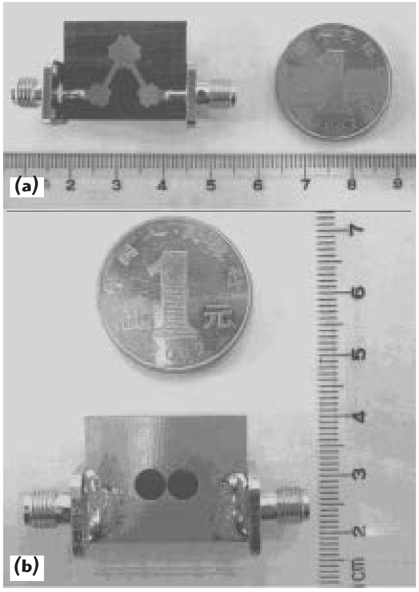


▲ *Fig. 1 Schematic of the Koch-shaped EBG microstrip low pass filter; (a) 3-D view and (b) top view.*

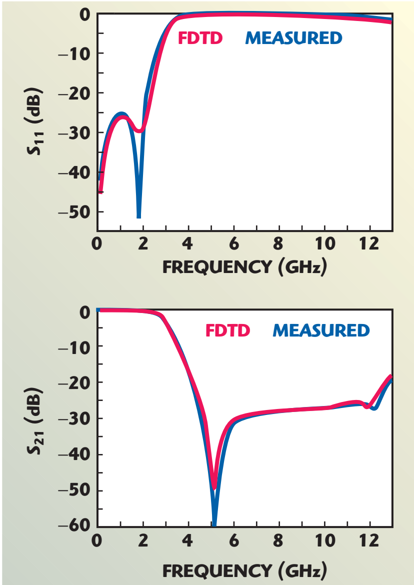
Two circular holes are etched in the ground plane, exactly below the microstriplines with their centers located at the mid-point between the two adjacent inserted patches. The circle radius is r = d/4. The relative location of the inserted patches and the etched circles are shown in the figure. A Chebyshev square distribution is adopted to taper the inserted patches, and a Chebyshev linear distribution is adopted to taper the microstriplines between two adjacent patches. For more information about Chebyshev square distribution and linear distribution, please refer to Karmarkar and Mollah.[6] Three- and four-Chebyshev arrays, with a major-to-minor ratio of 25 dB, are used for the proposed design, and the normalized coefficients are shown in ***Table 1***. Based on the proposed structure and the Chebyshev coefficients shown in the table, the parameters of the proposed low pass filter can be calculated and are given in ***Table 2***.

NUMERICAL AND MEASUREMENT RESULTS

The performance of the proposed low pass filter was simulated with the finite-difference time-domain method (FDTD), and a prototype 20 mm wide by 25 mm long was constructed for measurements. ***Figure 2*** shows photos of the fabricated prototype, while ***Figure 3*** shows the simulated and measured S-parameters of the proposed Koch-shaped EBG microstrip low pass filter. Based on these results and the structure parameters given above, comparisons can be made among the performances of the proposed structure and the structures published previously.[2–4] ***Table 3*** shows that the performance of the proposed structure is better than that of the other three structures. Although the stop-band narrows a little because of fewer EBG cells (only two cells), the Koch-shaped EBG low pass filter occupies a smaller area and achieves a better pass-band performance.



▲ *Fig. 2 The designed Koch-shaped EBG microstrip low pass filter; (a) top view and (b) ground view.*



▲ *Fig. 3 Simulated and measured S-parameters of the proposed low pass filter.*

TABLE I

NORMALIZED COEFFICIENTS OF THE CHEBYSHEV ARRAY

Chebyshev Array	*Normalized Coefficients*
3 elements	0.56, 1, 0.56
4 elements	0.48, 1, 1, 0.48

TABLE II

PARAMETERS OF THE PROPOSED LOW PASS FILTER

Parameter	*Dimension (mm)*
d	10.00
a_1	5.00
a_2	3.74
r	2.45
w	2.20
w_1	1.06

TABLE III

PERFORMANCE OF DIFFERENT COMPACT AND WIDE STOPBAND LOW PASS FILTERS

LPF Types	*Size of Occupied Area (mm²)*	*3 dB Passband Performance (dB)* Return Loss	*3 dB Passband Performance (dB)* Insertion Loss	*−20 dB Stopband Width (GHz)*
LPF in [2]	33 × 30	< −15	< 0.33	7.6
LPF in [3]	40 × 20	< −10	< 0.75	10.0
LPF in [4]	40 × 30	< −18	< 0.50	8.8
Koch-EBG LPF	25 × 20	< −25	< 0.25	8.6


NEVER
COMPROMISE
YOUR
CONNECTION

VCOs

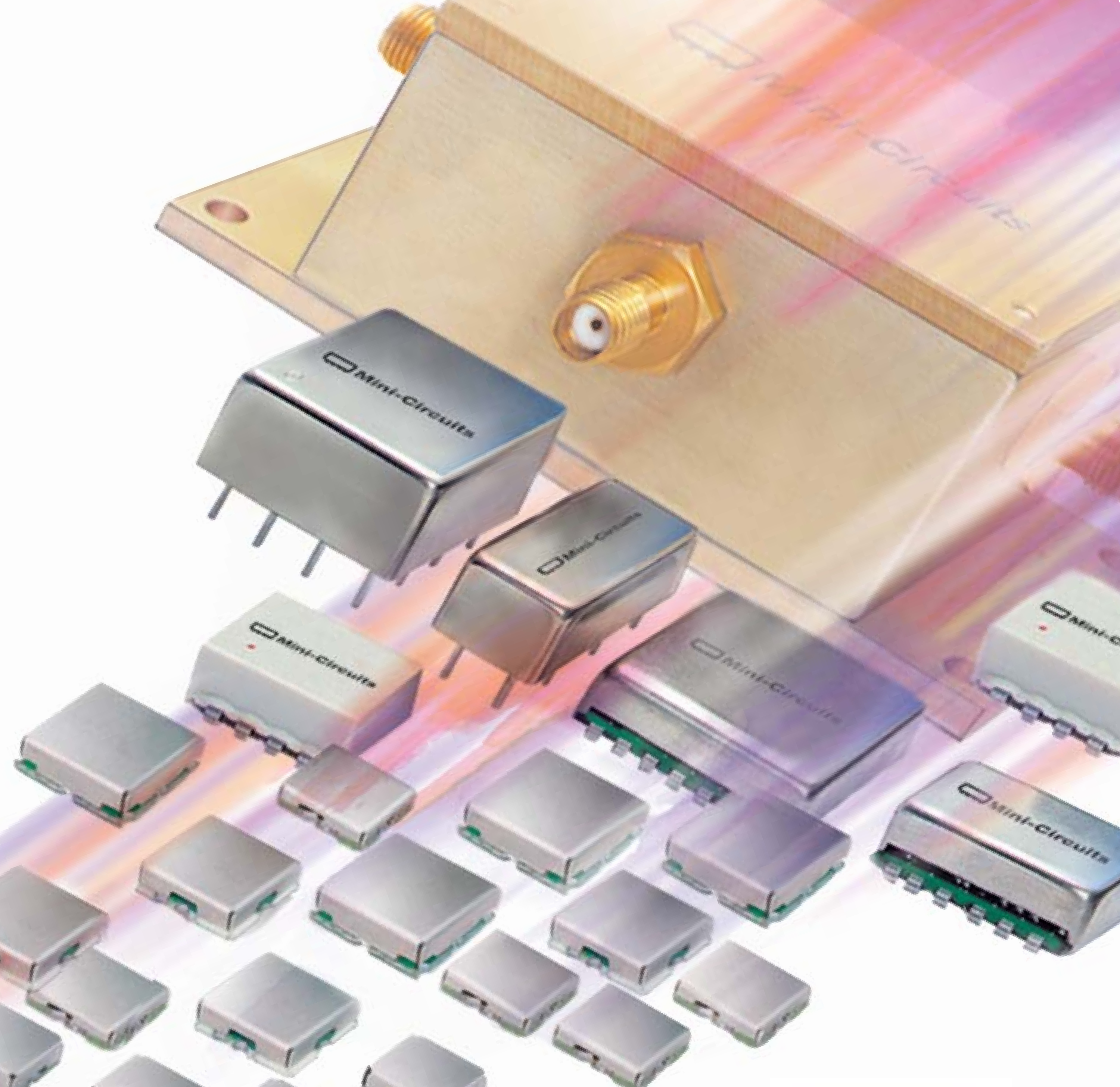
10 to 5150 MHz from $11.95 ea. (qty. 5)

RoHS COMPLIANT™

RoHS models available, consult factory.

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!


Mini-Circuits
Mini-Circuits
Mini-Circuits
Mini-Circuits
Mini-Circuits

CONCLUSION

In this article, a novel compact wide stop-band Koch-shaped electromagnetic bandgap microstrip low pass filter is presented. The structure is highly compact with a size of 25 by 20 mm. The structure achieved a stop-band width of 8.6 GHz ($S_{21} \leq -20$ dB) and a pass-band return loss of less than –25 dB. This structure can be easily applied to microstrip circuits and can also be used to enhance their compactness. ■

ACKNOWLEDGMENT

This research has been supported by the National High Technology Development Program of China under Grant 2003AA00 5044. The authors would also like to thank the 206th Institute of CWI Group for the fabrication and measurement supports.

References

1. I. Rumsey, M. Picket-May and P.K. Kelly, "Photonic Bandgap Structures Used as Filters in Microstrip Circuits," *IEEE Microwave and Guided Wave Letters*, Vol. 8, No. 10, October 1998, pp. 336–338.
2. S.Y. Huang and Y.H. Lee, "Compact U-shaped Dual Planar EBG Microstrip Low Pass Filter," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 53, No. 12, December 2005, pp. 3799–3805.
3. J.Y. Kim and H.Y. Lee, "Wideband and Compact Bandstop Filter Structure Using Double-plane Superposition," *IEEE Microwave and Wireless Components Letters*, Vol. 13, No. 7, July 2003, pp. 279-280.
4. W.L. Chen, G.M. Wang and Y.N. Qi, et al., "Size-reduced Fractal-shaped Dual Planar PBG Microstrip Low Pass Filter," ISAPE2006, October 2006, Guilin, China.
5. W.L. Chen, G.M. Wang and Y.N. Qi, et al., "Fractal-shaped Stepped-impedance Transformers for Wideband Application," *Microwave and Optical Technical Letters* (accepted for publication).
6. N.C. Karmakar and M.N. Mollah, "Investigations into Non-uniform Photonic-bandgap Microstripline Low Pass Filters," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 51, No. 2, February 2003, pp. 564–572.

Wen-Ling Chen *received his BS degree in radar engineering from the Missile Institute of Air Force Engineering University, Xi'an, China, in 2004, where he is now pursuing his PhD degree. His current interests include passive microwave circuits, antennas and propagation, and the application of fractal theory in microwave engineering.*

Guang-Ming Wang *received his BS and MS degrees from the Missile Institute of Air Force Engineering University, Xi'an, China, in 1982 and 1990, respectively, and his PhD degree from the Electronic Science and Technology University, Chengdu, China, in 1994. In 1994, he joined the Air Force Engineering University as an associate professor and was promoted to full professor in 2000. He is now the head of the Microwave Laboratory Center, Missile Institute of Air Force Engineering University. His current interests include passive and active microwave circuits, antenna and propagation, and electromagnetic computation.*

Yi-Na Qi *received her BS and MS degrees in computer engineering from the Missile Institute of Air Force Engineering University, Xi'an, China, in 2004 and 2007, respectively. Her current interests include fractal theory and computer programming.*

GAINING SPECTRAL EFFICIENCY WITH OFDM

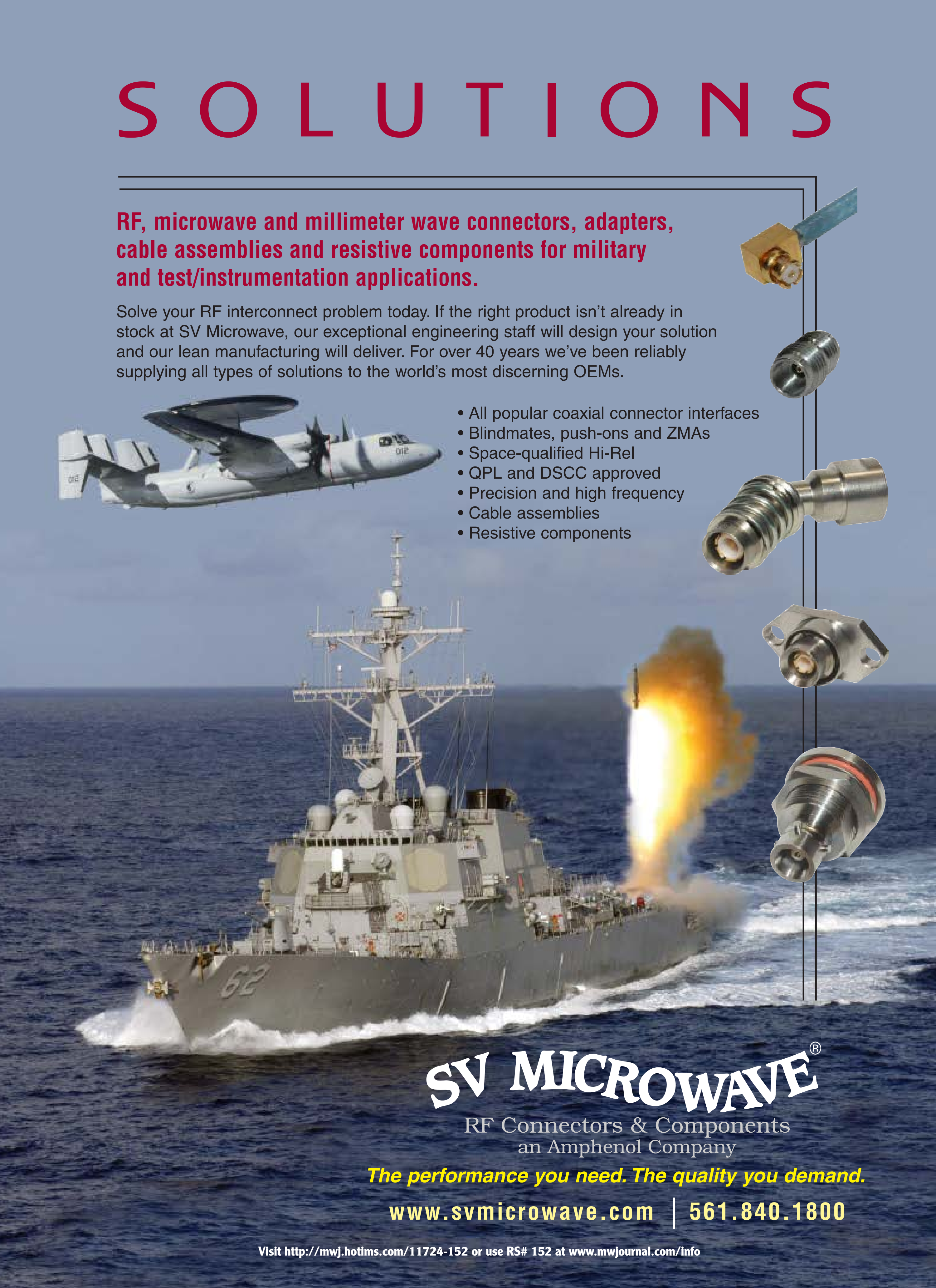
Orthogonal frequency division multiplexing (OFDM) is a multi-carrier transmission technique whose history dates back to the mid-1960s. Although the concept of OFDM has been around for a long time, it has only recently been recognized and adopted as an effective technique for high speed bi-directional wireless data transfer. WiMAX, DAB and DVB-T are some of the new emerging standards that use OFDM. This is because of the following reasons: First, OFDM is very immune to channel imperfections; second, OFDM uses bandwidth very efficiently, that is it uses less bandwidth than traditional modulation schemes to transmit at a particular rate; lastly, OFDM can be implemented using DSP techniques on fast and low cost embedded devices, which have become easily available over the last few decades.

Due to OFDM's immunity to many channel imperfections, it is the ideal modulation scheme for many applications that transmit signals in hostile environments.

A GENERAL OVERVIEW OF OFDM AND ITS GENERATION

OFDM spreads the data to be transmitted over a large number of carriers—typically in the range of 50 to 1000, but sometimes in thousands. For example, DVB-T has options for using either 1705 or 6817 carriers. The effective data rate to be conveyed by each of these carriers is therefore correspondingly reduced. They have equal, precisely chosen, frequency spacing. This is the reciprocal of the duration, called the active symbol period, over which the receiver will examine the signal. This choice of carrier spacing ensures orthogonality (the 'O' in OFDM) of the carriers. The demodulator for one carrier does not 'see' the other carriers even though there is no explicit filtering and their spectra overlap. There is therefore no crosstalk between carriers. Fortunately, what seems to be a very complex process of modulating (and demodulating) hundreds of carriers simultaneously is equivalent to a discrete Fourier transform operation, for which efficient fast Fourier transform (FFT) algorithms exist. Integrated circuit implementations of OFDM modulators and demodulators are thus feasible for affordable mass-produced transmitters and receivers. To generate OFDM, the relationship between all the carriers must be carefully controlled to maintain the orthogonality of the carriers. For this reason, OFDM is generated by first choosing the spectrum required, based on the input data and modulation scheme used. Each carrier to be produced is assigned some data to transmit. The required amplitude and

ASHWIN PRASAD
National Instruments
Bengalore, India


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 | 561.840.1800
Visit http://mwj.hotims.com/11724-152 or use RS# 152 at www.mwjournal.com/info

phase of the carrier is then calculated based on the modulation scheme (typically BPSK, QPSK, or QAM). The spectrum is constructed using the calculated amplitudes and phases of the carriers. The required spectrum is then converted back to its time domain signal using an inverse Fourier transform. In most applications, an inverse fast Fourier transform (IFFT) is used. The IFFT performs the transformation very efficiently, and provides a simple way of ensuring that the carrier signals produced are orthogonal. The FFT transforms a cyclic time domain signal into its equivalent frequency spectrum. The IFFT performs the reverse process, transforming a spectrum (amplitude and phase of each component) into a time domain signal. An IFFT converts a number of complex data points, which represent a signal in the frequency domain, into the equivalent time domain signal with the same number of points. Each data point in the frequency spectrum used for an IFFT is called a bin. The orthogonal carriers required for the OFDM signal can be generated easily by setting the amplitude and phase of each frequency bin, then performing the IFFT. Since each bin of an IFFT corresponds to the amplitude and phase of a set of orthogonal sinusoids, the process guarantees that the carriers generated are orthogonal. This is explained in more detail in the next section. A further refinement adds a guard interval to each OFDM symbol. Each modulated carrier is transmitted for a total symbol period, which is longer than the active symbol period by a period called the guard interval. This means that the receiver will experience neither inter-symbol nor inter-carrier interference, provided that any echoes present in the signal have a delay that does not exceed the guard interval. Naturally, the addition of the guard interval reduces the data capacity by an amount dependent on its length. The concept of a guard interval could in principle be applied to a single-carrier system, but the loss of data capacity would normally be prohibitive. However, with OFDM, the loss of data capacity is not so high due to the presence of many carriers. The insertion of guard time is also called cyclic prefix insertion.

The Use of OFDM in Modern Communication Systems

Most present day communication systems transmit signals over wireless channels that are far from ideal. Due to OFDM's immunity to many channel imperfections, it is the ideal modulation scheme for many applications that transmit signals in hostile environments. By dividing the channel into many narrowband flat fading channels, OFDM makes it easier to reverse the effects of frequency selective fading. This is because fades can be evaluated and reversed in each of the narrowband channels where it can be assumed to be constant. Also, OFDM effectively eliminates intersymbol interference (ISI) by inserting the cyclic prefix. Given OFDM's bandwidth efficiency and the fact that it can be easily implemented on embedded devices, OFDM has found wide spread use in wireless communication systems. As a specific example, consider 802.11a (WiFi), which uses OFDM in the physical layer. It uses 64 orthogonal carriers and a cyclic prefix, which is at most one quarter of the length of the OFDM symbol. Four modulation schemes are supported: BPSK, QPSK, 16-QAM and 64-QAM. Not all the 64 carriers are used for data transmission. Some of them are always zero (these serve as the guard band) and some carriers always carry known data. These carriers are called pilots and are used to estimate the effects of the channel. In the following section, the working of an OFDM system is considered in more detail. The mathematics presented is not meant to be a formal proof of concepts. It is meant to provide an intuitive understanding of the working of an OFDM system.

THE THEORY OF OFDM

Orthogonality of Carriers

As stated earlier, orthogonality of carriers is a necessary condition for the proper functioning of an OFDM system. Two functions f(x) and g(x) are said to be orthogonal in the period [a, b] if

$$\int_a^b f(x)\,g^*(x)\,dx = 0 \qquad (1)$$

Physically, if f(x) and g(x) are signals, then the left-hand side of Equation 1 is a measure of how much common energy the spectra of these two signals have. In the case of OFDM, the carriers are sinusoidal. Consider two sinusoidal functions $e^{j2\pi mft}$ and $e^{j2\pi nft}$. Then

$$\frac{1}{T}\int_{\langle T\rangle} e^{j2\pi mft} e^{-j2\pi nft}\,dt = \begin{cases} 0, & m \neq n \\ 1, & m = n \end{cases} \qquad (2)$$

where

T = 1/f

Equation 2 shows that all harmonics of a sinusoid of frequency f are orthogonal to each other. This property is used in the generation of orthogonal carriers for OFDM signals.

Generation and Demodulation of an OFDM Signal

The OFDM signal is formed by modulating these orthogonal carriers using a sequence of symbols generated by mapping the input bit stream into complex symbols (IQ symbols) based on an m-ary constellation. By doing this, the bit stream is reduced to a sequence of complex symbols. The OFDM symbol, formed by modulating N orthogonal sinusoidal carriers using N symbols generated by mapping the input bit stream, is given by

$$s(t) = \sum_{k=0}^{N-1} m[k]\, e^{j\frac{2\pi}{T}kt} \qquad (3)$$

where

m[k] = k^{th} symbol in the message symbol sequence for k in [0, N–1]
N = number of carriers
T = active symbol period

Given this representation of an OFDM symbol and the fact that all the carriers are orthogonal to each other, all that needs to be done at the receiver to recover a symbol that was used to modulate a particular carrier, say the i^{th} harmonic of the fundamental frequency, is to perform an "integrate and dump" demodulation at that carrier frequency.

$$\frac{1}{T}\int_{\langle T\rangle} \left\{ \sum_{k=0}^{N-1} m[k]\, e^{j\frac{2\pi}{T}kt} \right\} e^{-j\frac{2\pi}{T}it}\,dt = m[i] \qquad (4)$$

Equation 4 shows that symbols can be extracted from the carriers they modulate even though the spectra of

the carriers overlap. In discrete time, the OFDM symbol s(t) in Equation 3 can be represented as

$$s\left[n\right]=\sum_{k=0}^{N-1} m\left[k\right]e^{j\frac{2\pi}{N}kn} \qquad (5)$$

where T (the active symbol period in continuous time) has been replaced by N and t (continuous time) has been replaced by n (discrete time). Equation 5 can be identified as the inverse discrete Fourier transform (IDFT). Thus, the IDFT can be used to generate an OFDM symbol from a sequence of IQ symbols. Similarly, by replacing T by N, t by n and the integral by a summation in the "integrate and dump" equation, one obtains

$$\frac{1}{N}\sum_{n=0}^{N-1} s\left[n\right]e^{-j\frac{2\pi}{N}in}=\widehat{m[i]} \qquad (6)$$

where $\widehat{m[i]}$ is the estimate of the symbol modulating the carrier whose frequency is i times the fundamental frequency. Equation 6 is the discrete Fourier transform (DFT). Thus, the DFT can be used to demodulate OFDM signals.

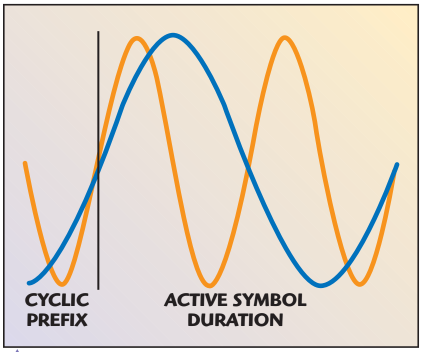


Fig. 1 Cyclic prefix insertion.

Guard Interval or Cyclic Prefix Addition

Consider the transmission of the simple OFDM symbol, which was described earlier. Here, carriers exist only within the OFDM symbol duration T (which is also the correlation period). If the channel has a frequency selective delay, some carriers may be received later than others. This would lead to a situation where some carrier will have a zero amplitude for some part of the correlation interval. For the orthogonality between any two received carriers to be preserved, every carrier must have an integer number of cycles in the correlation (integration) interval. To counter the effect of delay on the orthogonality of the carriers, each of the carriers is extended in time. This is called cyclic prefix or guard interval insertion. The duration of extension is decided based on the root mean squared delay spread of the channel. Another advantage of inserting the cyclic prefix is that the effect of the channel transfer function reduces from a linear convolution (of the signal and the transfer function) to a cyclic convolution. Since a DFT is being used at the demodulator, and the effect of the channel is a circular convolution, the effect of the channel can be equalized by dividing the DFT by the channel transfer function estimate. This is because the circular convolution of two functions is the product of their DFTs. ***Figure 1*** shows the cyclic extension of two orthogonal OFDM carriers.

Spectrum of an OFDM Signal

Consider a simple mapping of one bit onto one carrier. The bit is represented by the presence or absence of the carrier in the OFDM symbol interval T. In the time domain, the OFDM symbol is a sum of N orthogonal sinusoids multiplied by a rectangular pulse of duration T.

$$s(t) = \left(\sum_{k=0}^{N-1} b_k c_k \right) \mathrm{rect}\left(\frac{t}{T} \right) \qquad (7)$$

where

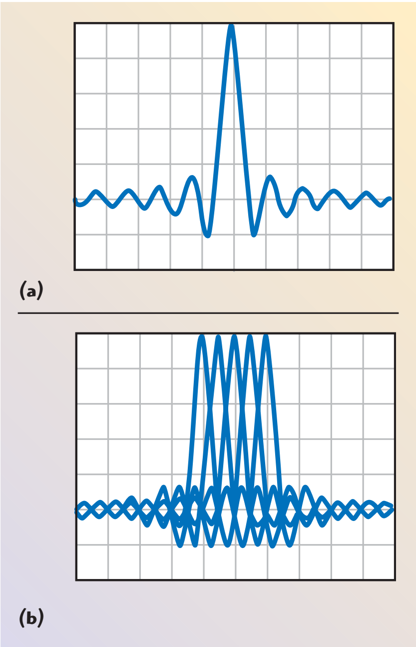
b_k = bit stream
c_k = k^{th} carrier
$\mathrm{rect}\left(\frac{t}{T}\right)$ = rectangular pulse which exists for t in the interval [–T/2, T/2]

The spectrum of the carriers is a set of impulses and the spectrum of the square pulse is a sinc function. The OFDM symbol spectrum is therefore a convolution of the above-mentioned spectra.

$$S(f) = \sum_{k=0}^{N-1} b_k \delta(f - f_k) * T\mathrm{sinc}(fT) \qquad (8)$$

This is a sum of shifted, weighted sinc functions. The sinc function is defined as

$$\mathrm{sinc}(x) = \frac{\sin(\pi x)}{\pi x} \qquad (9)$$



▲ *Fig. 2 Spectrum of an individual carrier (a) and of an OFDM signal (b).*

Figure 2 shows the spectrum of an individual carrier in the OFDM signal and the spectrum of the OFDM signal itself.

Basic OFDM Transmitter

Putting together the various operations explained previously, the block diagram of a basic OFDM transmitter may be drawn, as shown in ***Figure 3***. After the addition of the guard interval, the symbol-shaping block interpolates and low pass filters the basic OFDM signal generated. The output of this stage is the complex baseband of the OFDM signal. This needs to be up-converted to IF by an IQ modulator and then up-converted to RF frequency before it is transmitted.

WRITING A SIMPLE OFDM APPLICATION WITH LABVIEW AND MODULATION TOOLKIT

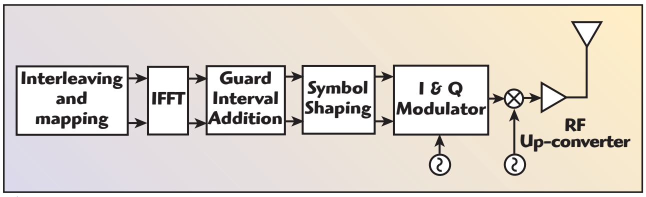
This section describes the implementation of each of the blocks shown in the OFDM transmitter block diagram. In addition, forward error correction (FEC) is also described.

Forward Error Correction

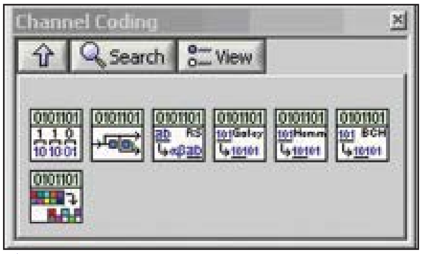
Even though error correction is strictly not a part of the OFDM system itself, every system that uses OFDM needs some form of forward error correction (FEC) to achieve reasonable bit error rates (BER). Modulation Toolkit (MT) provides several error-coding options. Therefore, to incorporate FEC into an OFDM application in LabVIEW, one just needs to drop the appropriate virtual instrument (VI) from the Modulation Toolkit error-coding palette (see ***Figure 4***). Modulation Toolkit has the following error coding options: Reed-Solomon, Golay, Hamming, BCH and Convolutional encoders.

Mapping Bits to Symbols

In an OFDM system, bits are mapped to complex (IQ) symbols, which are then used to modulate one carrier in the OFDM symbol, that is the IQ symbol decides the phase and/or amplitude of the carrier. Bits are converted into IQ symbols by mapping sets of bits onto points on the IQ plane based on an m-ary symbol map. Modulation Toolkit provides a VI, which converts a stream of bits to a stream of complex symbols based on a symbol map, which may either be one used for a standard IQ modulation scheme or a user defined one. ***Figure 5*** shows how a bit stream may be mapped to complex symbols based on a standard m-ary QAM constellation. Custom symbol maps may also be generated and used to map bits to symbols. Custom maps may either be rectangular (such as m-QAM) or circular (such as m-PSK). ***Figure 6*** shows that the polymorphic VI may be used to generate arbitrary symbol maps. The symbol map output of the VI needs to be wired to the MT Map Bits to Symbols VI as in the previous case.



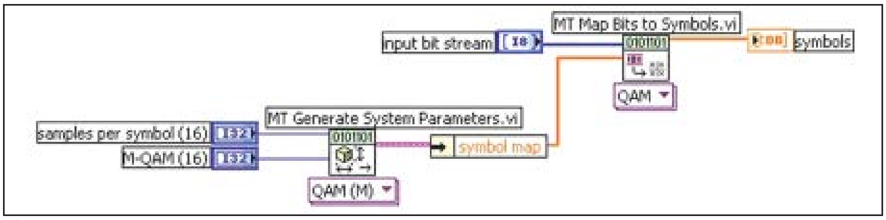
▲ *Fig. 3 Basic OFDM transmitter.*



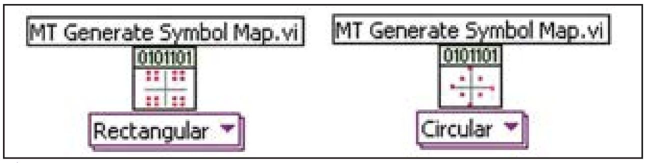
▲ *Fig. 4 MT channel coding palette.*

Interleaving Bits/Symbols

Many applications require interleaving of data—both bits and symbols generated after mapping. Modulation Toolkit provides VIs to perform block and convolutional interleaving (see ***Figure 7***). However, if the application re-



▲ *Fig. 5 Mapping bits to symbols.*

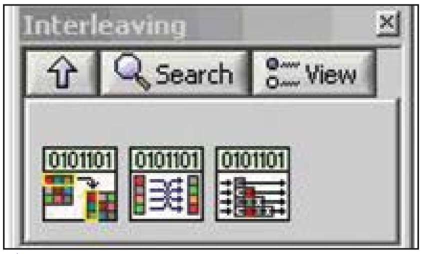


▲ *Fig. 6 MT VIs to generate arbitrary symbol maps.*

quires a different interleaver, MT provides a generic VI, which may be used to permute input arrays (bits or symbols) into any required order.

Inverse Fast Fourier Transform

The IFFT is used to generate and modulate a set of n orthogonal sinusoidal carriers. LabVIEW has an IFFT block in the Signal Processing palette, shown in ***Figure 8***, which can be used. The output of the IFFT is scaled by the constant multiplier 1/n. Some applications may require additional scaling so as to change the amplitude of the generated OFDM time domain signal.

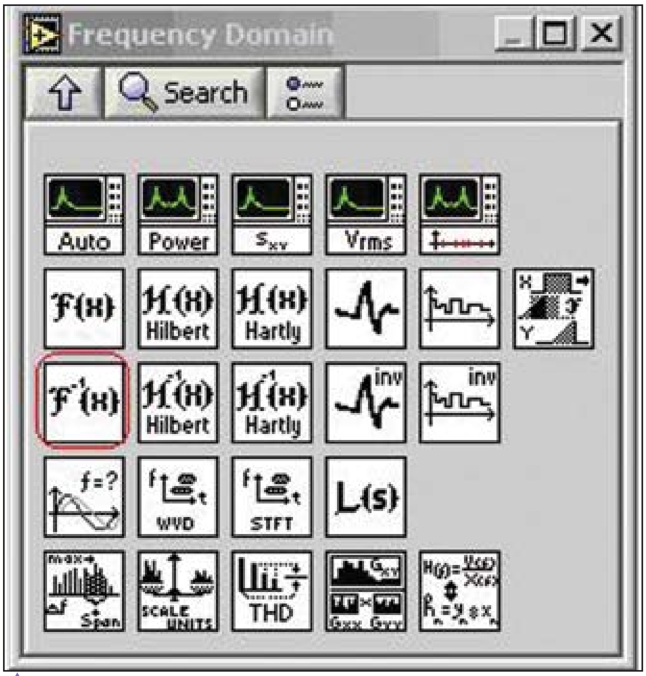


▲ *Fig. 7 MT interleaving palette.*

Guard Interval Addition

As mentioned earlier, a guard interval (cyclic prefix) is added to every OFDM symbol, as shown in ***Figure 9***. The OFDM symbol generated using the IFFT is extended cyclically to reduce the effects of ISI and also to make equalization at the receiver easier.

While programming in LabVIEW, samples are represented as arrays. Therefore, replicating the last n samples



▲ *Fig. 8 LabVIEW frequency domain processing palette.*


Value Added Here:
www.DeltaRF.com/value
Save your valuable time by using one of our innovative and unique web-based tools: The Connector Finder to quickly search for a standard product by characteristic; The Connector Designer to visually assemble and specify custom receptacles; and The Cable Designer to design and specify cable assemblies...all with your Web browser, with no plug-ins or special software required.
GLOBAL MANUFACTURER
ISO 9001:2000 CERTIFIED
RoHS COMPLIANT
DELTA
ELECTRONICS MFG. CORP.
Connect Here.

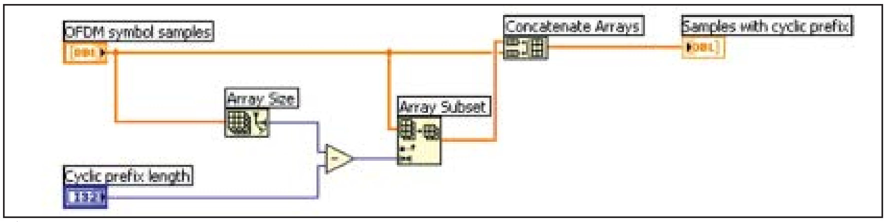


Fig. 9 Cyclic prefix insertion.

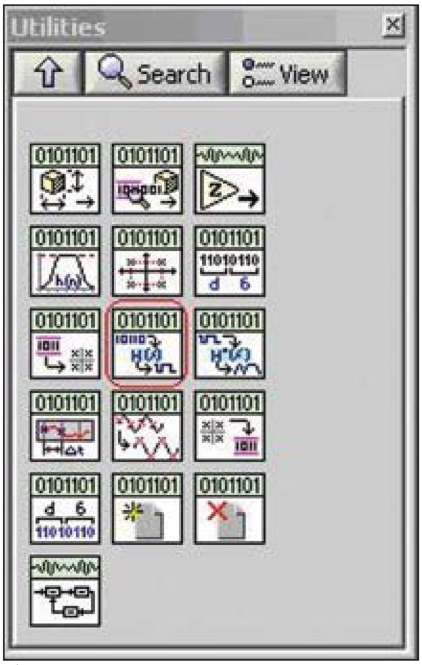


Fig. 10 MT utilities palette.

Fig. 11 NI-RFSG palette.

of an array representing one OFDM symbol at the beginning of the array adds a cyclic prefix to the symbol. This is possible because each carrier in an OFDM symbol has an integer number of cycles in the active symbol period.

Symbol Shaping

The IQ signal, which is obtained after the previously described steps, needs to be interpolated and filtered to be able to generate a real world signal. Modulation Toolkit provides a VI that interpolates and filters the critically sampled signal (see ***Figure 10***). The toolkit provides various choices for the filter to be used; currently raised cosine, root raised cosine and Gaussian filters are available. The effect of interpolating and filtering is that a signal, which is "better described" by its samples, is obtained and also the signal is band-limited. These characteristics make it easier to actually generate the signal.

Generating the OFDM Signal with NI-RFSG

The complex baseband representation of the OFDM signal, obtained after filtering and up-sampling, can be used to generate a real OFDM signal using the NI-RFSG palette shown in ***Figure 11***. The complex baseband signal can be written to the arbitrary waveform generator (ARB) memory, generated and up-converted using the NI-RFSG VIs.

CONCLUSION

OFDM is a modulation technique that is widely used for high speed data transfer. Because of this, many OFDM-based transmitters and receivers, with different designs and specifications, are being built. With LabVIEW and NI Modular instruments, these devices can be prototyped and tested quickly and easily. Also, LabVIEW provides the flexibility needed to quickly change a system design to test several different designs with very little effort. ■

Ashwin Prasad *received his BS degree in communications and signal processing from the RV College of Engineering, Bengalore, India, in 2005. He is now a software engineer in the RF and communications group at National Instruments, India. He is currently working on means of improving the performance of communication algorithms on PCs, using commercially available technologies, including multi-core processors and stream processors, such as GPUs. His other interests include compilers, graph visualization and applied mathematics.*

High Reliability
Military and Aerospace applications require materials with excellent electrical and physical properties, and above all, a history of proven performance.
C-RAM LOSSY AND MULTI-BAND FOAM ABSORBERS
C-RAM ELASTOMERIC ABSORBERS
Cuming Microwave offers RF and dielectric materials for microwave applications, from electronic assembly, antenna design, to turn-key construction of anechoic test facilities. We allow the design engineer to meet tight performance specifications, on time and within budget.
DESIGN, BUILD TURN-KEY ANECHOIC CHAMBERS
Solid Solutions For...... Tomorrows Applications
C-RAM Anechoic Absorbers
ABSORBERS FABRICATED TO YOUR SPECIFICATION
Our experienced Engineers can assist you with your design requirements
CUMING MICROWAVE CORPORATION
Credit: US NAVY
Raptor photo: Rick Llinares www.dash2.com
225 Bodwell St. Avon, Ma. 02322
(T) 800-432-6464(F) 508-584-2309
www.cumingmw.com
mwsales@cumingcorp.com

A SOFTWARE SUITE TO AID WORKFLOW

All companies need to see increasing income year on year to please investors and to fund their growth. A mounting need for microwave design, combined with skilled worker shortages, make seamless growth challenging. As a result, engineers in rapidly growing companies are faced with increased workloads, more diverse work and the requirement to work with other, perhaps unfamiliar parts of the company to achieve design goals.

To make growth easier to manage, seamless workflow between software design tools has become critical. For example, different departments in a company, which may be geographically separated, could be designing handset antennas, PCB layout, antenna drive circuits and interconnects. They may all need to communicate layout, circuit and EM data and, due to mergers, they may all have different tool vendors. So, how does a company ensure that an overstretched engineer does not have to redesign the wheel every time he works on a new or updated design?

CST has addressed these issues. Traditionally the company has supplied point tools for full wave microwave/RF design and optimization, but in recent years it has made its products fit centrally into the much wider design flow to address current requirements. Thus, the newly released CST STUDIO SUITE™ version 2008, incorporating CST MICROWAVE STUDIO® (CST MWS), is the most open and easily integrated tool ever released by the company.

Its customer centric approach is designed to focus on the company's core 3D EM specialization and provide easy workflow to other 'best in class' tools. The following reveals how

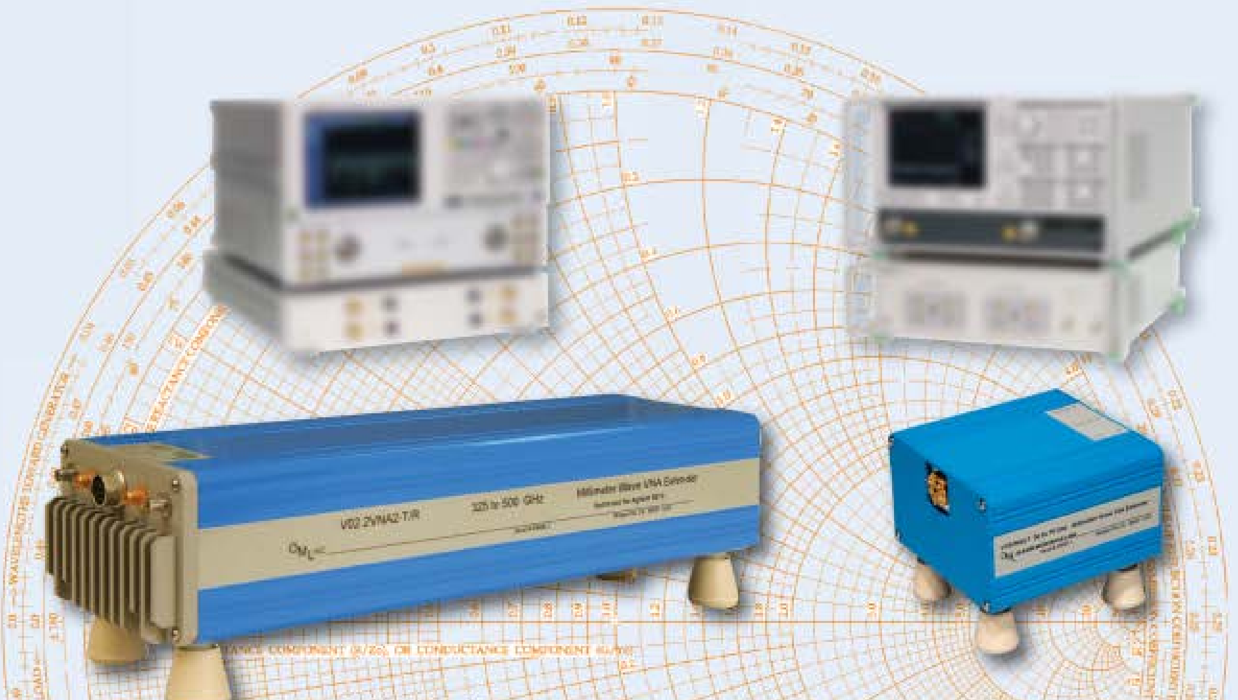
EXECUTIVE INTERVIEW SERIES

MWJ SPEAKS WITH DR. BERNHARD WAGNER, MANAGING DIRECTOR, CST. VISIT WWW.MWJOURNAL.COM TO READ THIS IN-DEPTH INTERVIEW.

CST OF AMERICA
Framingham, MA

Budget Limited?

An *economic solution* to millimeter two port "S" parameter measurements



T/R Module

T Module

- One Path Two Port – Reflection and Transmission Measurement
  - Obtain the other two "S" parameters by reversing the DUT

As future budgets allow
the T Module can be upgraded to a T/R Module for

full two port "S" parameter measurements

OML modules are available from 50 to 500 GHz and are compatible with:

- Agilent 20 GHz or higher PNA (E836xx) or PNA-X (N5242A) with N5260A Controller
- Agilent N5250A Millimeter Wave System
- Anritsu 20 GHz or higher Lightning (37xxxx) with 3738A Controller
- Anritsu ME7808B/C Panorama System

OML Inc.

300 Digital Drive • Morgan Hill, CA 95037 • Tel: (408) 779-2698 • Fax: (408) 778-0491 • email: info@omlinc.com • www.omlinc.com
Outside US: Radar Systems Technology • Tel: (650) 949-8041 • Fax: (650) 949-8082 • email: sales@rst-radar.com

the suite has become not only a central part of the overall design process, but also a powerful tool with its own well defined internal workflow for solving multiple applications with the best turnaround times possible.

EXTERNAL WORKFLOW

Figure 1 shows a typical workflow situation. Inputs may come from layout tools such as those supplied by Cadence (see ***Figure 2***) or new in version 2008, Mentor Graphics. It may come from planar EM simulators such as Momentum or Sonnet or it may be in an interchange format like ODB++ or multilayer Gerber. Virtually all other mechanical formats are supported and, new to this version, other 3D EM formats are accepted.

Poor mechanical geometry and fault intolerant meshing have plagued the workflow in this sector for many years, causing frustration and delay at the first hurdle. Import healing and fault tolerant meshing have been big areas of research for CST and in the vast majority of cases, complex geometries are effectively healed and meshed without user input. ***Figure 3*** shows the typical automatic healing process on import. The facets are removed on the pad and the trace is joined correctly.

Input may also come from the output of another EM tool. For example, new in version 2008 is the capability to import near field data from Sigrity's Speed2000 or PowerSI tools. This means that a highly complex PCB stack-up can be simulated in Sigrity's tool and the surrounding near field data exported to CST MWS. At this point radiation, coupling or proximity simulations can be carried out. A similar link is included to Simlab's PCBmod tool, based on surface currents.

As well as importing layouts from external planar/circuit simulators, CST MWS allows co-simulation and co-optimization with circuit tools from AWR and Agilent. This essentially means that a block appears in the circuit schematic, greatly simplifying circuit/EM co-design. Workflow has also been improved to the closely coupled circuit tool CST DESIGN STUDIO™, with a new layout viewer and editor as well as tuning bars, time domain simulation, eye diagram tools and IBIS import.

On the output side, the company has always been strong in post-processing of data with clear and intuitive visualization and post-processing templates allowing automated dataset manipulation. Some new features in version 2008 are HSPICE creation, far field sub-ranges, near field sub-volumes and Smith chart table creation.

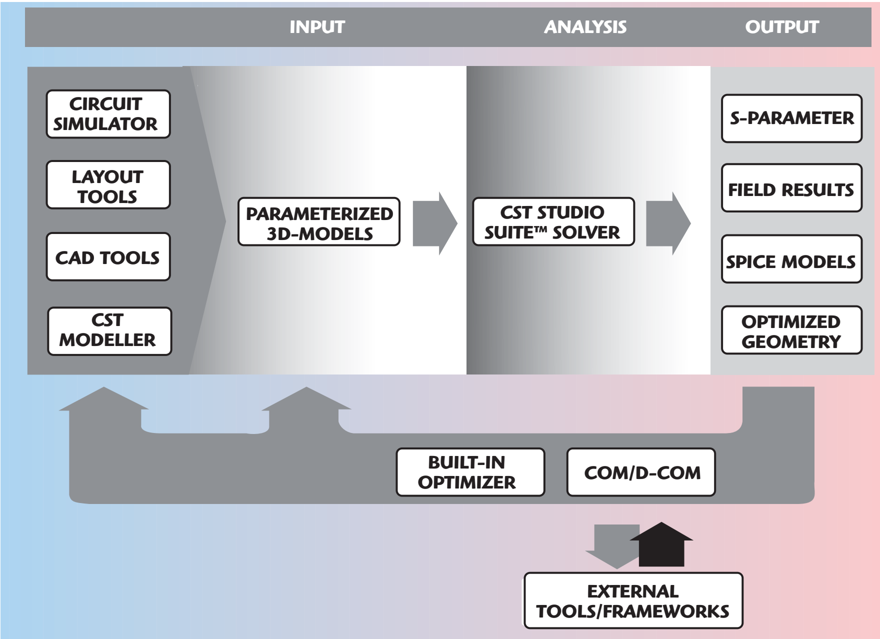
INTERNAL WORKFLOW

With increasingly diverse product lines and new requirements for EM characterization due to higher signal speeds, higher component densities and miniaturization, the need has arisen for more than one solver to address the vast range of 3D microwave/RF applications. This is because no one solver can solve all applications efficiently and in some cases, a solver will fail on an application entirely. As the solver choice can make significant differences in run time, it becomes essential to offer the choice to speed up overall workflow. Thus, version 8 offers a choice of solver to suit the application, while keeping a unified and class leading interface so that the solver selection is a push of one button.

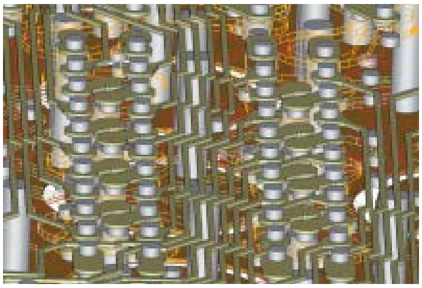
The CST MWS time domain solver is improved in version 2008 and is a consolidation of major improvements made over the last couple of years. As will be described later, hardware acceleration has been introduced. The time domain solver is highly suited to very complex, multiband/broadband structures and is the most general-purpose solver in the suite.

The newer frequency domain solver achieves a high level of performance. For example, frequency domain solvers work by solving single frequency points and for broadband applications they have to solve many samples in order to build up an accurate response. Distribution of those frequency samples to multiple computers is now possible to give a much faster overall solve time. Frequency domain analyses can be done with either direct or indirect methods. CST MWS has both, and exhibits good speed and memory usage.

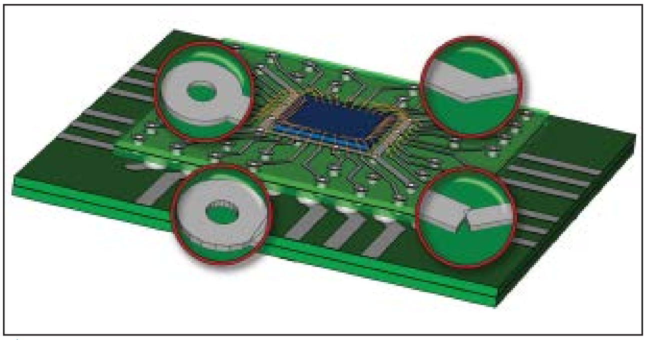
In particular the indirect solver has low memory usage for large models. The direct solver, which has advantages for smaller multiport structures, is now 20 percent faster with a



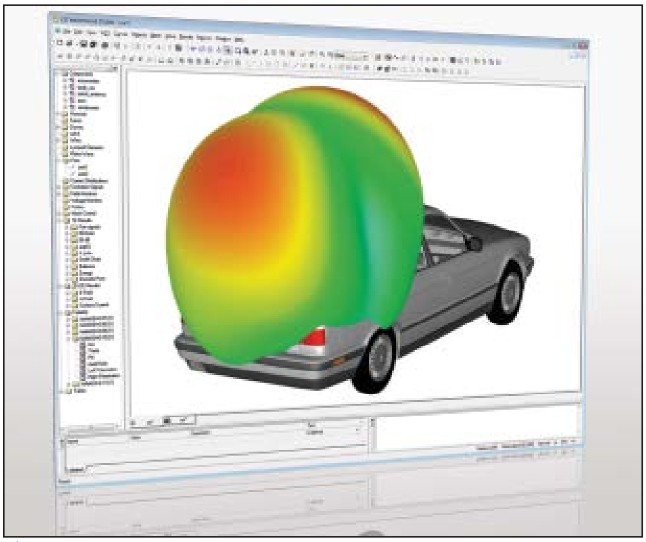
▲ *Fig. 1 Typical workflow in the CST STUDIO SUITE.™*



▲ *Fig. 2 Detail view of a package imported through the Cadence Allegro Interface.*



▲ *Fig. 3 Typical faults that can be healed automatically while importing.*



▲ *Fig. 4 CST MWS GUI on Windows Vista showing the far field of a car glass antenna.*

50 percent memory usage reduction over version 2006B. The frequency domain solver allows repeating unit cells to be created and these offer far field and RCS calculation based on Floquet modes. In general the frequency domain solver is well suited to phased-array design, electrically small and very narrow band devices.

Other solvers available include a fast resonant solver for high Q cavity filter design and a new integral equation solver for electrically very large structures such as airplanes or ships. Improvements to the integral solver in version 2008 include the ability to use a far field source to excite the structure and the implementation of lossy metals.

A thermal solver adds to the internal workflow within version 2008. Besides the thermal analysis of electromagnetic losses (dielectric and conductive) from CST MWS simulations, the deposed particle energy derived from CST PARTICLE STUDIO™ can be used as a heat source.

HARDWARE ACCELERATION

It is accepted that graphics cards (GPU) are significantly faster than CPUs when it comes to rendering extremely large numbers of pixels. What is not so well known is that the same technology can be applied to solve numerical problems to give an order of magnitude speed-up. CST has been working with Acceleware to bring this technology to CST MWS and it is now available in version 2008.

One of the key advances is that the method retains all the accuracy and mesh size reduction that arise from the use of the conformal Perfect Boundary Approximation (PBA)®. The use of a GPU with this technique additionally gives a large speed injection to the most complex industry simulation problems. In other words, the bigger the problem, the greater the speed-up that is achieved.

This GPU hardware acceleration is available either as a PCIe card for the desktop or as a 'cluster in box' comprising two external cards, which bring capacity and speed benefits to those who may have thought their problems were simply too difficult for 3D analysis.

The company has also been working directly with Intel in high performance computing to optimize code performance on the latest generation of multicore Intel processors easily achieving a 200 percent + speed increase against previous generation processors.

MODELER IMPROVEMENTS

Some very useful additions to the main modeling interface have been added to version 2008 to further improve workflow. Windows Vista is fully supported (see ***Figure 4***), as is Linux RedHat Enterprise, both on 32- or 64-bit platforms. A project management tool has been added to allow for easier file management and exchange of data.

▲ *Fig. 5 Horn antenna with reflective metallic surface.*

This includes copy/paste of structure parts either within the same project or to other projects, import of CST DS layouts and sub models, thus allowing the creation of library components. Also, for maintained licenses and those connected to the Internet, automatic updates can be enabled ensuring the latest version is always on hand. As usual all update details are shown in the Help – history of changes menu.

An artistic improvement, but nevertheless one that allows quick recognition of materials, is the addition of true reflective materials. A graphic is reflected in the metal to give the real appearance of a shiny metal (see ***Figure 5***). Other improvements to speed up workflow include arbitrary pickpoints on surfaces and an update to the ACIS modeling kernel.

CONCLUSION

For version 2008 of CST STUDIO SUITE, external and internal workflow improvements have been the key focus. With easy data exchange to and from other software tools, a choice of first class solvers and a range of modeler usability improvements, the engineer is able to leverage the latest developments in 3D electromagnetics to bring designs to market faster and with lower risk.

CST of America,
Framingham, MA
(508) 665-4400, www.cst.com.

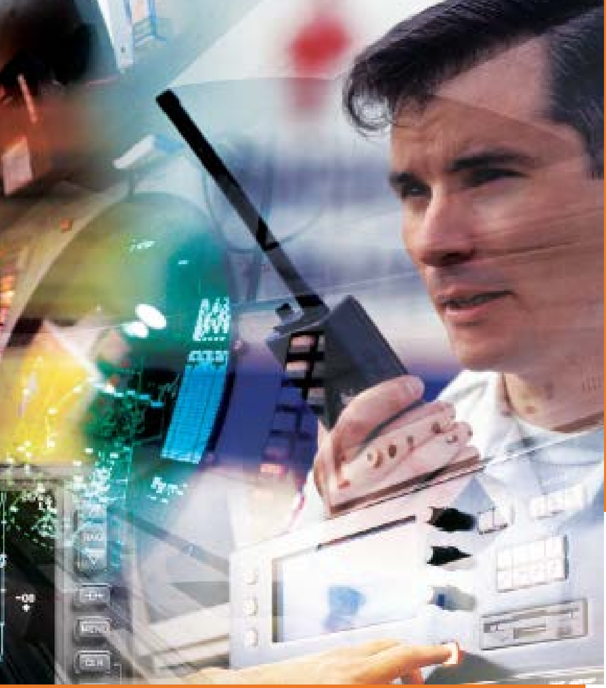
RS No. 300

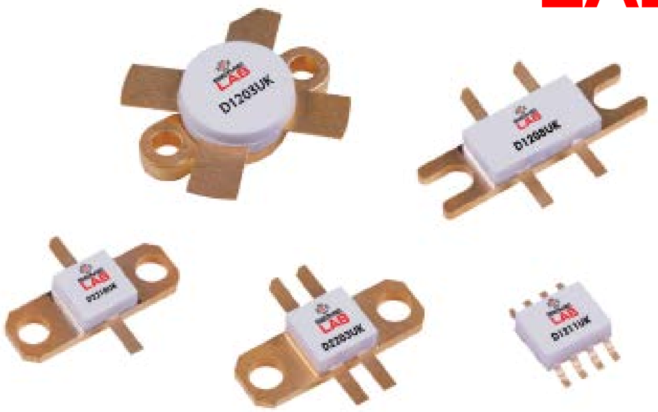
A SiGe BiCMOS RMS Power Detector for High Data Rate Wireless Networks

There has always been a critical need to measure and control RF power in wireless communication networks. Accurate measurement and control aids in the setting of overall cell coverage, and ensures that the RF power amplifiers in the wireless base station are operated for optimum thermal performance. In early cellular networks such as GSM (1G/2G) and AMPS cellular systems, for example, transmitter RF power could be easily measured using a pair of Schottky diodes: one for peak power detection, and the other for temperature compensation. This technique was adequate since the ratio of the peak power to the average power being measured did not vary significantly. Later, various types of logarithmic detectors were used and these were also found to provide acceptable performance in most situations.

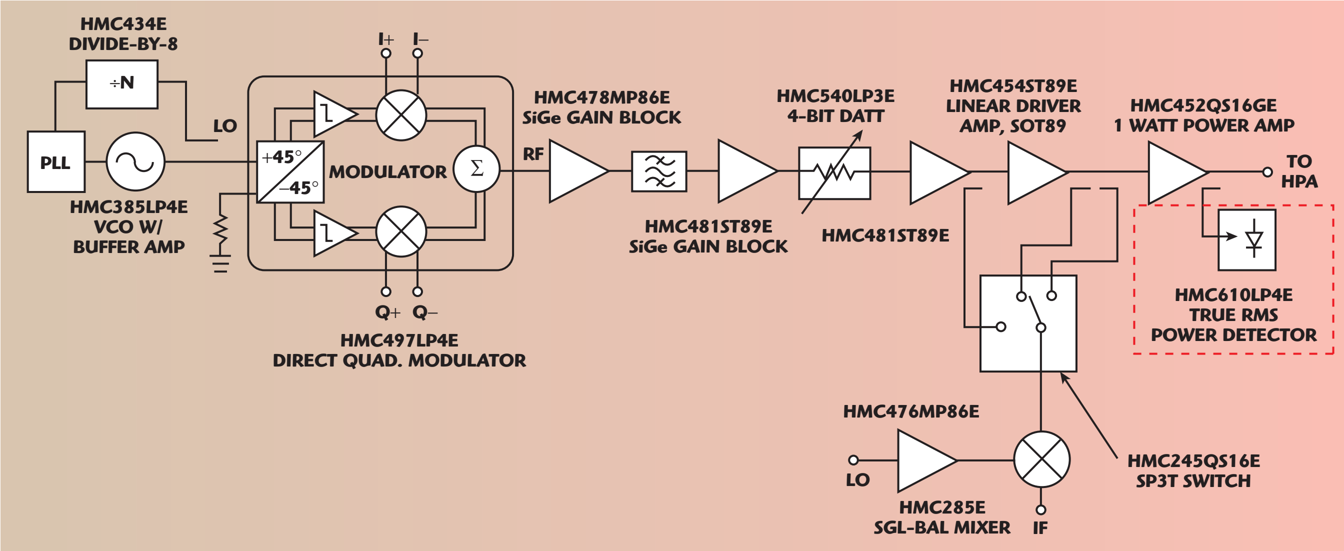
In recent years, the applications for wireless broadband services have continued to expand at a high rate. To keep pace with this demand, wireless communications networks must continue to provide higher data transmission rate capability. In order to do this in an efficient manner, wireless communications technology has relied upon ever more complex bandwidth efficient modulation schemes. The evolution of complex digital modulation schemes such as QPSK, 8PSK, 16QAM and OFDM means that a greater amount of data or bits/second can be transmitted in a given bandwidth, with the disadvantage being that much more complex circuitry in the form of DSP hardware and software algorithms, wide dynamic range modulators and demodulators, and higher linearity RF power amplifiers is required to handle these signals. Another disadvantage of these complex digital modulation waveforms is that RF power measurement and control becomes more difficult. The reason for this is that contemporary wireless base stations are transmitting RF signals whose peak-to-average value (also defined as crest factor) is constantly changing. This varies widely depending on the number of calls being processed by the base station, and also with the differing power levels transmitted by multiple service providers. For example, base

HITTITE MICROWAVE INC.
Chelmsford, MA



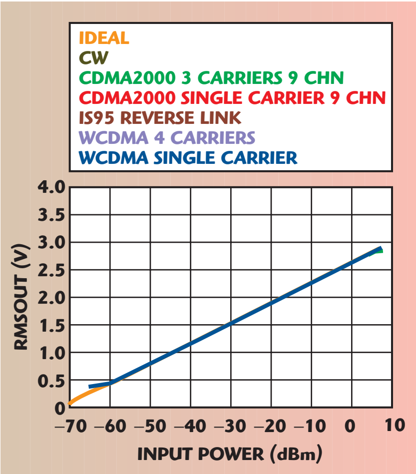


Device	Minimum Output Power (W)	Minimum Efficiency (%)	Minimum Gain (dB)	Test Frequency (MHz)	Package Style
D1203UK	30	50	10	175	DM
D1208UK	40	50	10	400	DK
D1211UK	10	50	10	500	SO8
D2201UK	2.5	40	10	1000	DP
D2203UK	5	40	10	1000	DQ
D2210UK	20	40	10	500	DP
D2212UK	10	40	10	1000	DP
D2213UK	20	40	10	1000	DK
D2219UK	2.5	40	10	1000	SO8
D2220UK	5	40	10	1000	SO8
D2225UK	5	40	10	1000	SO8

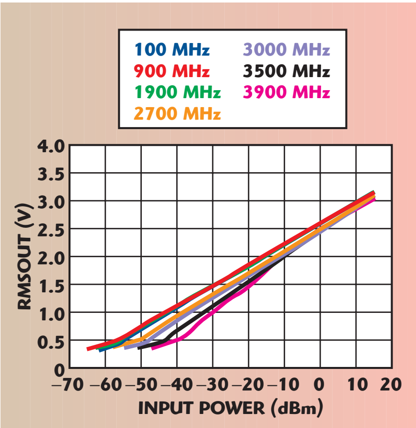


▲ *Fig. 1 A wireless base station transmitter implementation using Hittite standard components.*

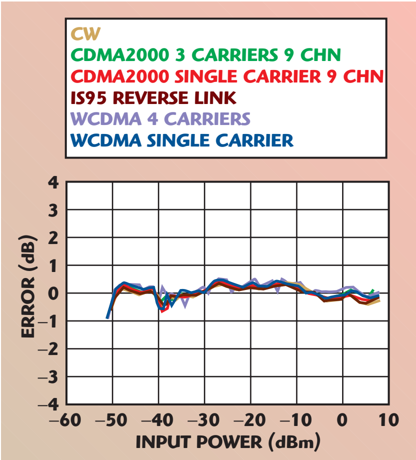
stations in 3G CDMA-based systems transmit downlink signals with crest factors as high as 15 dB for single carrier systems, and 20 dB for base stations with multiple CDMA carriers. ***Figure 1*** shows an example of an implementation of a wireless base station transmitter solution.



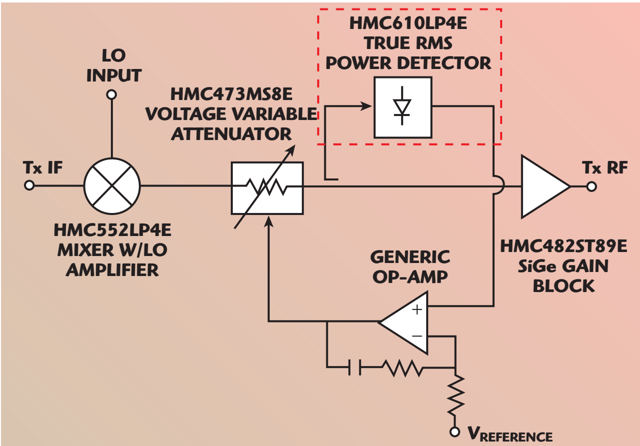
▲ *Fig. 2 HMC610LP4E 70 dB power detector's RMSOUT vs. input power with different modulations at 900 MHz.*



▲ *Fig. 3 HMC610LP4E detector's RMSOUT vs. input power and frequency.*



▲ *Fig. 4 The 70 dB RMS power detector's RMSOUT error vs. P_{in} with different modulations at 3000 MHz.*

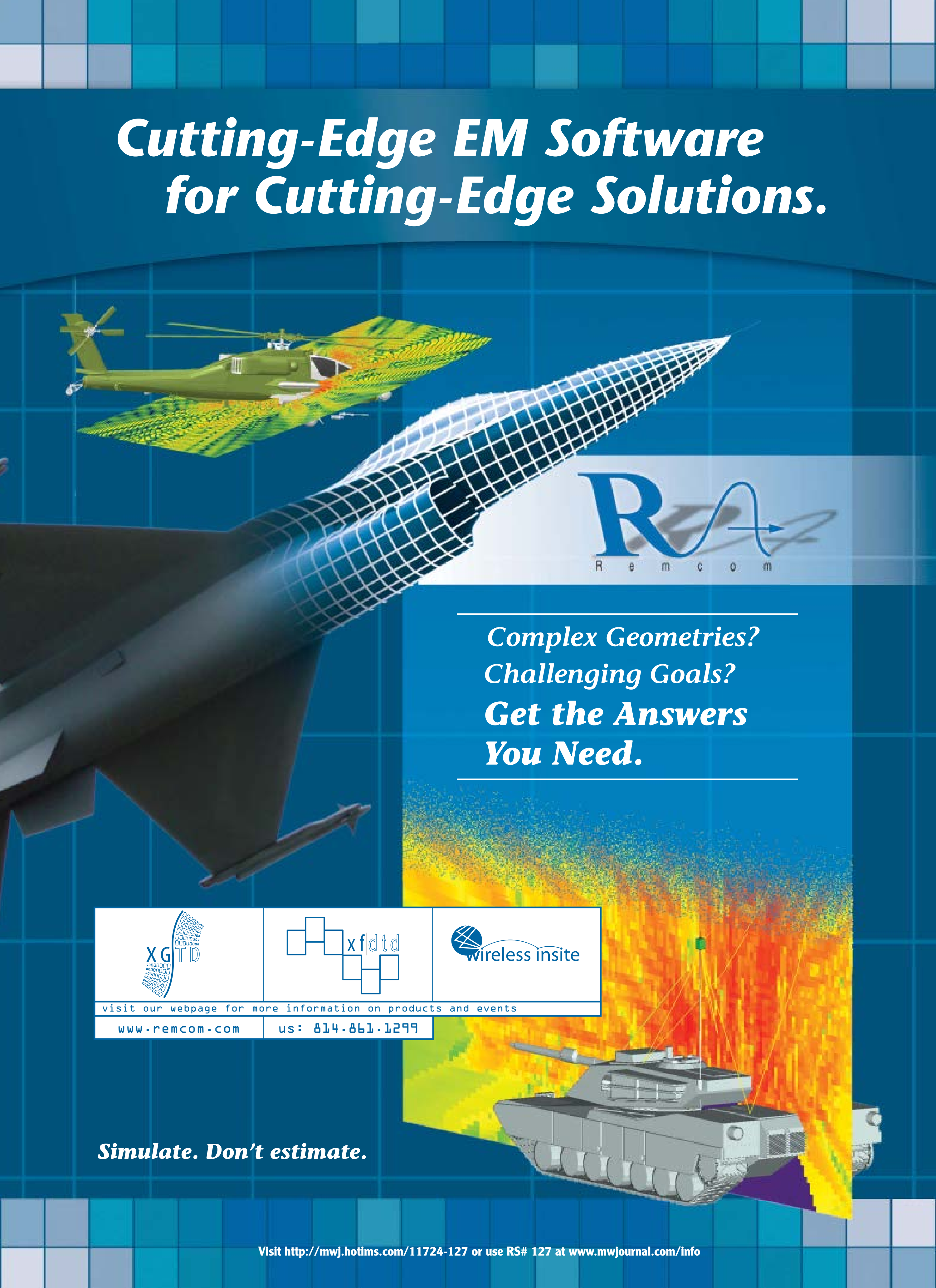


▲ *Fig. 5 Simplified block diagram of the HMC610LP4E in an AGC application at 1.9 GHz.*

It should also be noted that there is a requirement in many types of digital receivers to measure and control the gain of the received signal. This is commonly referred to as the RSSI (Received Signal Strength Indicator). This serves to prevent overdriving the IF amplifier stages and analog-to-digital converters further downstream on the receive channel.

In order to meet the need for power measurement in the challenging environment of high data rate wireless infrastructure applications, Hittite Microwave has released the HMC610LP4E SiGe BiCMOS true RMS power detector. The HMC610LP4E sets a new performance benchmark by providing wide dynamic range RMS signal power measurement in excess of 70 dB. The new detector product converts any RF input signal at its differential input, regardless of modulation or waveform complexity, to an accurately scaled linear-in-dB output response that represents the RMS value of the input waveform (see ***Figure 2***.)

The HMC610LP4E delivers extremely high dynamic range over an input RF frequency range of 50 Hz to 3.9 GHz, covering all of the cellular/


Cutting-Edge EM Software
for Cutting-Edge Solutions.
Remcom
Complex Geometries?
Challenging Goals?
Get the Answers
You Need.
XGTD
xfdtd
wireless insite
visit our webpage for more information on products and events
www.remcom.com
us: 814.861.1299
Simulate. Don't estimate.
Visit http://mwj.hotims.com/11724-127 or use RS# 127 at www.mwjournal.com/info

3G, WiMAX and WiBro bands. The HMC610LP4E delivers a ±1 dB linear in dB dynamic range of 70 dB at 900 MHz. At 2.7 and 3.5 GHz, the new detector extends the current benchmark by providing ±1 dB dynamic ranges of 63 and 56 dB, respectively. At 3.9 GHz, the ±1 dB dynamic range is still very useable at 42 dB.

The HMC610LP4E has been successfully tested with many different input waveforms over a wide range of input frequencies (see ***Figure 3***). It accurately converts a wide range of RF input waveforms with different modulations at 3 GHz over a –50 to +5 dBm input power level range. ***Figure 4*** clearly shows that with single and multiple carrier versions of WCDMA, CDMA2000 and IS95 reverse link, the HMC610LP4E typically exhibits less than 0.3 dB of error versus modulation waveform up to input power levels of +5 dBm.

For normal operation, the RMSOUT pin is shorted to the VSET input, and will provide a nominal logarithmic slope of 37 mV/dB and an intercept of –70 dBm for frequencies up to 2 GHz. Both the nominal logarithmic slope and the intercept are temperature and supply stable. Other logarithmic slopes are achieved with external resistors connected between RMSOUT and VSET pins. Typical output voltage range is from +0.4 to +3.2 V. Temperature stability is excellent with ±0.5 dB error from –40° to +85°C, which is maintained for input frequencies from 100 MHz to 3.9 GHz.

The minimum output rise time (0.2 to 1.9 V) of the HMC610LP4E is 10 ns, and the fall time (1.9 to 0.2 V) is 500 ns, which is ideal to support the proper detection of wireless broadband modulation schemes. The RF input of the HMC610LP4E is externally matched to 50 Ω, and the device operates from a single +5 V supply consuming between 65 and 85 mA, depending on input power level which can vary from –70 to +15 dBm. The ENX pin is connected to ground for normal operation, but when a DC signal of +5 V is applied, the device will power down to 5 mW. The HMC610LP4E powers up within 2 µs to its nominal operating current of 65 mA at 25°C.

Figure 5 shows an example of how the HMC610LP4E may be combined with other Hittite components to construct a circuit suitable for measuring RMS power in the transmit channel of a wireless base station. The simplified block diagram shows how the HMC610LP4E power detector can be used to construct an AGC loop in a transmit RF chain. In this example, the HMC552LP4E, which is a 1.6 to 3.0 GHz double-balanced mixer, is used to upconvert the transmit IF signal. The RF output of the HMC552LP4E is routed through the HMC473MS8 voltage variable attenuator and then coupled into the RF input of the HMC610LP4E. The DC output of the HMC610LP4E, which represents the RMS power in the transmit signal path, is compared with the Vreference value at the other input of the op-amp, and provides feedback control to the HMC473MS8 voltage variable attenuator. The HMC473MS8 accepts a single positive control voltage, and provides an attenuation range of up to 48 dB. This loop ensures that the appropriate signal level is applied to the HMC482ST89 gain block amplifier, and to the subsequent RF amplification stages.

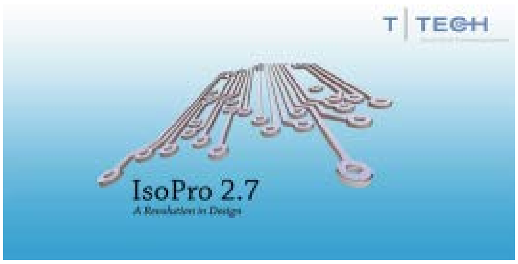
CONCLUSION

A new RMS power detector operating from 50 Hz to 3.9 GHz extends the performance of currently available devices, providing a linear-in-dB transfer function with linearity of ±0.6 dB typical, over an input power range of more than 60 dB. In short, the HMC610LP4E provides wireless infrastructure designers with the means to reduce the design complexity of high data rate systems requiring the measurement of RF signals with high crest factors.

Hittite Microwave also provides a wide range of compatible products to meet the needs of wired and wireless infrastructure applications. These products, together with the HMC-610LP4E RMS power detector, its evaluation PC board and each of the products shown in the block diagrams (Figures 1 and 5) are available from stock and can be ordered via the company's e-commerce site, or via direct purchase order. Released data sheets and S-parameter data are available on-line at www.hittite.com.

Hittite Microwave Corp., Chelmsford, MA (978) 250-3343, www.hittite.com.

RS No. 302



IMPROVEMENTS TO DESKTOP CIRCUIT BOARD PROTOTYPING

Desktop milling machines for prototyping circuit boards have long been particularly helpful to microwave engineering development teams. Often a circuit or a critical part (filter, amplifier, coupler, etc.) needs to be designed quickly to keep the entire project on schedule. In many cases the desktop milling system can create the actual piece so that the part can be tested quicker than software can simulate the performance. This can offer additional help if the physical part is actually needed to make a system work since you then have the part available. What are the challenges that today's microwave development teams face that cause additional difficulties to the users of desktop milling systems and what has one particular vendor done to answer these challenges?

The Quick Circuit system first appeared in 1990. There are thousands of these in use around the world. The use of these systems in microwave applications is particularly popular. It is likely that more than half of the systems in use are primarily or exclusively in microwave applications. The advantage that these systems offer over other prototyping methods is that there is no chemical etching, no need for artwork creation, the edges of the circuit are more perpendicular to the dielectric than in many chemically-etched boards and a wide variety of materials can be used.

In recent years the needs of the microwave development community have evolved to where thinner materials must be used. The need to prototype thinner materials along with smaller feature sizes has pushed the limits of milling prototyping systems. The decreased feature size makes the viewing of the features and the system in operation more difficult. Also, where the median age of engineers and technicians increases, the quality of the eyesight of the user tends to decrease. Another concern is that with thinner and softer materials and smaller sized features the mechanical pressure foot could prove ineffective in certain situations.

In response to these evolving challenges the supplier of the Quick Circuit system has

T-TECH INC.
Norcross, GA

developed new solutions. In order to simultaneously reduce the force of the Z-axis movement and make the force more accurate and dependable, the company has replaced the solenoid movement with a pneumatic one. The limitations of the mechanical pressure foot can be overcome with a pneumatic pressure foot. For thinner materials Quick Circuit offers a vacuum table (see ***Figure 1***). To facilitate operation of the system and to assist viewing of the process an optional camera system called TraceCam™ has been created. To improve control of the system the IsoPro™ software that processes the design file inputs and operates the mechanical prototyping equipment has been bolstered to handle these additional capabilities as well as offer new functionality.

▲ *Fig. 1 Vacuum Table for thin laminate and flexible circuit board materials.*

▲ *Fig. 2 A 0.016 mil thick microwave substrate being milled on a cushion of air as it is held in place by the Pneumatic Pressure Foot.*

The introduction of the pneumatic Z-axis allows the user to set the force with which the Z-axis contacts the circuit material. On thicker and/or harder materials the force can be set relatively high in order to speed up the machining process. For softer and thinner materials this force can be set much lower. The pneumatic control also avoids an occasional problem with the effects of heat on solenoid actuation of the Z-axis. If heat builds up on the solenoid on larger projects the resistance in the solenoid increases thereby decreasing the force applied.

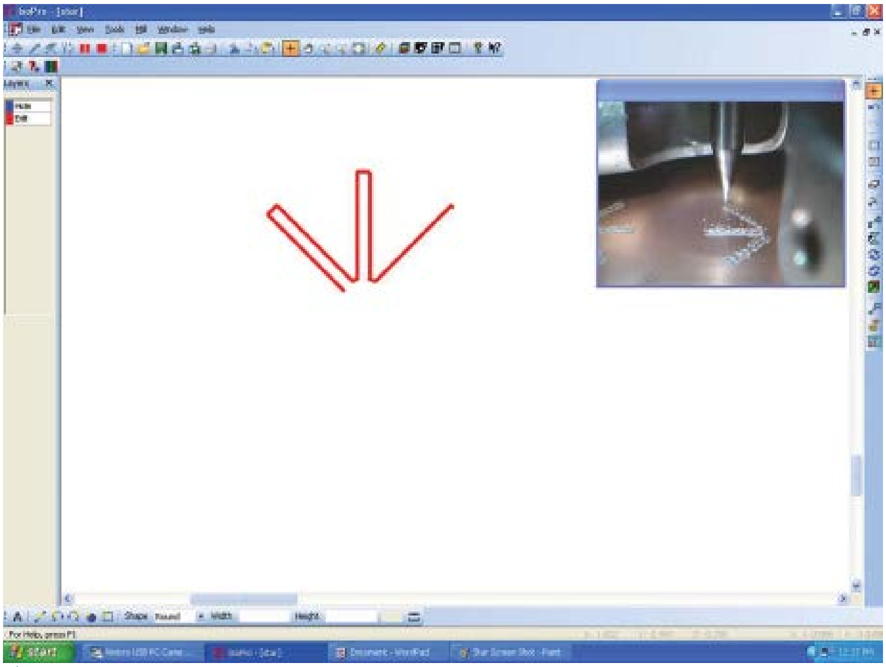
The pneumatic pressure foot replaces the mechanical one. The advantages are twofold. First, the repeatability of the depth of cut is one micron (1 µm). The mechanical setup can be set in increments of 10 micron (10 µm), although there were techniques to set the depth accurately for half-ounce and one-ounce materials. Second, the consistent air pressure allows the system to mill to an accurate depth without physically touching the material being milled. ***Figure 2*** shows the pneumatic pressure foot milling a board on a cushion of air that is being held down on the vacuum table.

For working with thinner materials a vacuum table is now offered. Thinner materials such as flex circuit material are more difficult to handle because the pinning system used on rigid laminate is not very effective. Holding the materials flat with a vacuum table is much easier. The additional challenges that are presented through use of a vacuum table include:

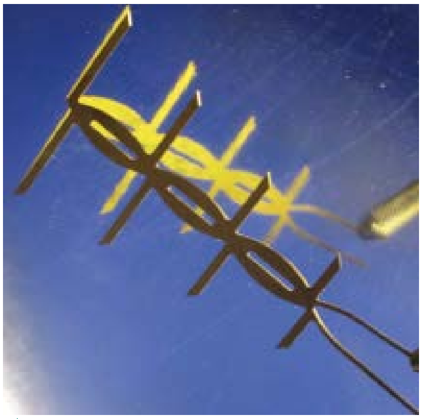
- How one handles the loss of vacuum when holes are drilled or the contour (outline) of the board is cut
- On double-sided circuits the alignment of the bottom side needs to be re-established by the system

T-Tech has devised techniques to handle the loss of vacuum hold caused by drilling holes or routing the board outline. The realignment of the bottom side of the board is done through the latest version of the IsoPro software. IsoPro calculates the skew of the previously drilled holes and modifies the bottom layer files accordingly.

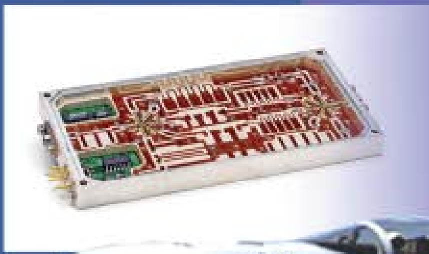
The TraceCam enhancement offers the user the ability to more easily set parameters and view the machine operation. Both the depth of cut, width of cut and the quality of the machining process are all more easily viewed on the screen of the computer driving the system. The software displays on the screen each step of the machining process. The actual cutting is being captured by the TraceCam™ and displayed on the screen. The X,Y coordinates of the next step



▲ *Fig. 3 TraceCam view of the star board being milled.*



▲ *Fig. 4 A 0.010" brass antenna fabricated using Quick Circuit.*




320

in the process are displayed as are the X,Y,Z coordinates of the milling head. The TraceCam also allows the user to send the head over user-designated sections of the work area in order to measure entities.

Tying all of the new functionality together is the latest version of the IsoPro software. In order to take better advantage of the better graphical control offered by TraceCam, the IsoPro offers the user the ability to flip, rotate and mirror images. The user also has the ability to customize the operation of the system through color control, adjustable pixel resolution, lighting control and customizable hot keys. A new function offering the user increased flexibility is the ability to "record motion." ***Figure 3*** shows a TraceCam view of a star board milling in progress. The camera view showing the actual milling and the graphic trace are both displayed on the screen.

In order to make operation of the machining aspects easier there is a lookup table for a wide variety of materials that microwave projects require. Using system-specified speeds and feeds for various materials makes operation more efficient for the user than trial and error. In addition to circuit board laminates the system can help the designer create antennas or shielding out of metals such as brass (see ***Figure 4***). For certain difficult projects such as bi-metallic laminates or entities exceeding the Quick Circuit work area, the latest IsoPro offers a CNC output for use with machining centers.

File handling is easier now that automatic backup is included as is the ability to e-mail files from IsoPro. IsoPro features language support in Spanish, French, German, Japanese, Chinese and Hindi.

The creators of the Quick Circuit have been busy keeping the system up-to-date to today's challenges. If the past is any indication the future will demand that more capabilities continue to be offered, that these capabilities make the system faster and easier to operate, and that the operation will need to include a wider variety of materials and software.

T-Tech Inc.,
Norcross, GA (770) 455-0676,
www.t-tech.com.

RS No. 303

HIGH DENSITY RF INTERCONNECT

With system space ever at a premium and operating frequencies constantly on the rise today's RF/microwave interconnection cables must follow suit and be smaller and higher performance. One of the limiting factors to this progression has always been the cable connector. Its pin/socket-type male and female interconnect system adds much real estate and mechanical complexity.

The HDRFI™ is a Tensolite patented high frequency connection system that transfers high frequency signals through a unique planar interface. This planar interface removes the need for typical pin and socket connections by utilizing a z-axis elastomer to provide the electrical path between the mated connectors. The elastomer is made up of silicone, impregnated with gold-plated stainless steel wires and is arranged on a 0.035 mm pitch. When compressed by the mating halves, the gold-plated wires mechanically connect the two planar surfaces and create an electrical EMI barrier to provide excellent isolation.

The result is a high density, high bandwidth, compact RF interconnect with a center-to-center spacing of 0.130" where the alignment of the connector is independent of the RF path. The new interconnect system eliminates stubbing and can be used differentially or single ended. ***Figure 1*** shows typical RF performance of an HDRFI assembly to 40 GHz.

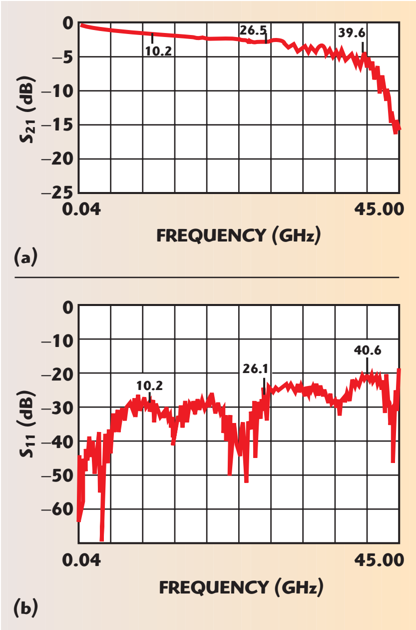
HDRFI is available only as an assembly in three product lines: RF D-Sub, RF Circular, Mixed Signal and in custom applications. The assemblies can be used with a 26AWG coax for internal applications or 24AWG for external requirements.

The RF D-Sub connector family is available in four different shell sizes and can be used in cable-to-cable, cable-to-board or board-to-board applications. The insert arrangements are designed to hold multiple impedance-controlled size 16 type RF press-in style contacts and the connectors can accommodate standard D-Sub backshells and mounting hardware. ***Figure 2*** shows an HDRFI RF D-Sub connector and its mating face.

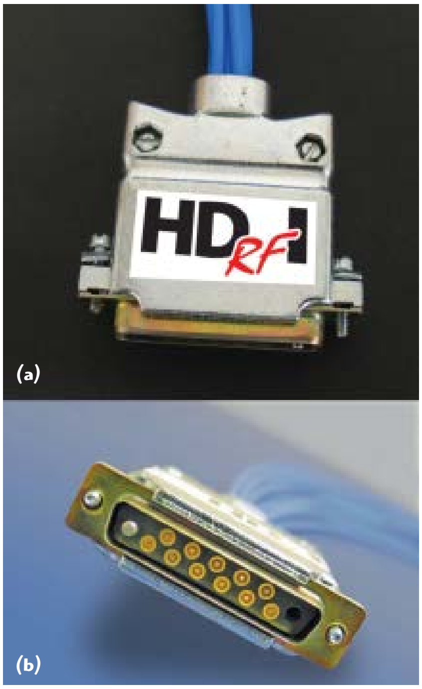
The RF Circular connector family is designed for high performance applications. The insert arrangements have been designed to maximize the number of size 16 RF contacts available in a standard circular connector arrangement. The product line consists of

TENSOLITE, A CARLISLE COMPANY
St. Augustine, FL

Voltronics Corp
Chip Trimmer Capacitors are the Smart Choice!
Our Chip Trimmer Capacitors
■ Stability Better Than ±1%
■ RoHS Compliant
■ Immediate Delivery
Delivery:
Up to 50,000 pieces stock to 4 weeks on most parts!
JZ
JR
JV
Actual Size
JQ
JN
RoHS COMPLIANT
Voltronics CORPORATION
The Trimmer Capacitor Company
A DOVER COMPANY
100 Ford Road, Denville, NJ 07834
973.586.8585 • Fax: 973.586.3404 • e-mail: info@voltronicscorp.com
www.VoltronicsCorp.com
Visit http://mwj.hotims.com/11724-171 or use RS# 171 at www.mwjournal.com/info



▲ *Fig. 1 Transmission loss (a) and forward reflection (b) of an HDRFI mated interface including two feet of 24AWG low loss coax and connector adapters.*



▲ *Fig. 2 An HDRFI D-Sub connector (a) and its mating face (b).*

shell sizes 15 to 25 and is based on the D38999 Series III specification. The HDRFI RF contacts are press-in style and the connectors can accommodate standard D38999 back-shells and hardware. Fully loaded the RF Circular connector system contains up to 34 40 GHz RF contacts. ***Figure 3*** shows an HDRFI RF Circular connector face.

▲ *Fig. 3 An HDRFI RF Circular connector.*

▲ *Fig. 4 An HDRFI RF Circular-Mixed Signal connector.*

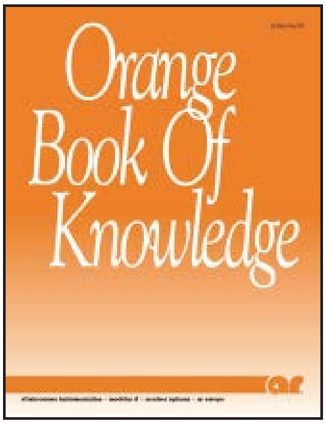
The RF Circular-Mixed Signal connector family combines both power and high frequency RF contacts in the same connector body. The product line consists of shell sizes 15 to 25 and is based on the D38999 specification as well. The power pins are size 20, rated to 7 A, and are combined with HDRFI RF contacts. ***Figure 4*** shows an HDRFI RF Circular-Mixed Signal connector. HDRFI can be customized to fit almost any application, from custom board connectors to insert arrangements that can have a common groundplane, to having each signal path isolated from each other.

The RF Circular products are ideal when upgrading legacy systems that use typical D38999 type connectors for increased performance or to reduce the amount of connections in a box by combining RF and power signals into the same circular connector. Other custom designs may include the direct attachment of the HDRFI contact to the planar array.

Tensolite, a Carlisle company,
St. Augustine, FL
(904) 829-5600,
(800) 458-9960,
www.tensolite.com.

RS No. 301


Catch design flaws before they burn you.
AWR
Half solutions can wreak havoc on product development. Visual System Simulator™ not only does system budget analysis and identifies sources of IM products, including the effects of conversions, harmonics and noise. It also has a powerful simulator for developing and analyzing complex communication systems, including radio and circuit designs, baseband signal processing, algorithmic development and digital fixed-point implementations. It's the complete system tool. Visit appwave.com/vss for more.
Visual System
VSS
Simulator
Advancing the wireless revolution™
Visit http://mwj.hotims.com/11724-18 or use RS# 18 at www.mwjournal.com/info
© 2007 Applied Wave Research, Inc. All rights reserved. Visual System Simulator and AWR are trademarks of Applied Wave Research.



Orange Book of Knowledge

The AR "Orange Book of Knowledge" contains articles and application notes on a wide range of topics and applications—from the importance of mismatch capability to testing beyond specs and everything in between. The book represents the cumulative knowledge of all AR companies, making it perhaps the most comprehensive resource in the industry.

AR RF/Microwave Instrumentation,
Souderton, PA (215) 723-8181, www.ar-worldwide.com.

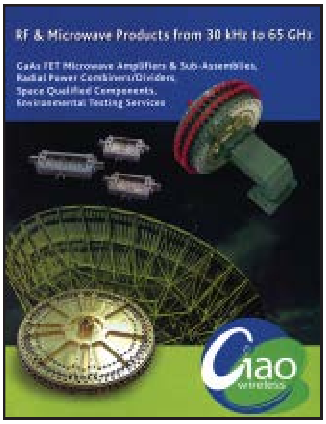
RS No. 310

Product Catalog

The 2007 product catalog features the company's terminations, resistors and attenuators, in various configurations including flanged, leaded or as a chip only. The products are available in BeO, BeO-Free™ and aluminum nitride, including products for WiMAX and Wilkinson applications. To download a free copy, visit the company's web site.

Barry Industries Inc.,
Attleboro, MA (508) 226-3350, www.barryind.com.

RS No. 311

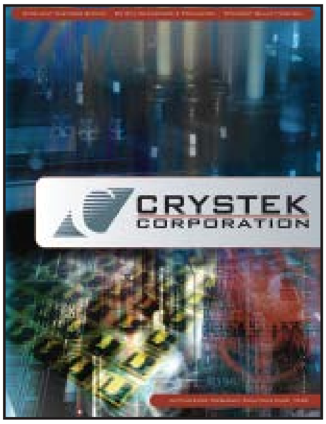


Product Catalog

This catalog features the company's RF and microwave products that operate in a frequency range from 30 kHz to 65 GHz. Products include GaAs FET microwave amplifiers and subassemblies, radial power combiners/dividers, space qualified components and environmental testing services. All of the company's operations are located within a single modern and fully equipped 42,000 square foot facility.

Ciao Wireless Inc.,
Camarillo, CA (805) 389-3224, www.ciaowireless.com.

RS No. 312

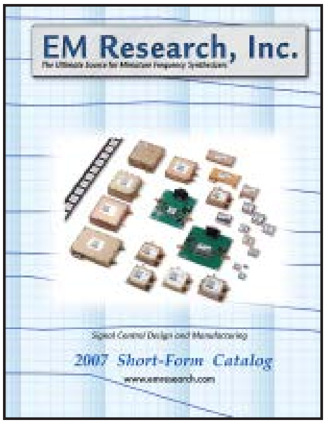


VCOs and PLL Synthesizers

Request Crystek literature for innovative frequency control technology. Crystek Microwave offers VCOs and PLL synthesizers in a wide mix of frequency ranges, standard packaging and custom design options. Product highlights include low phase noise, microstrip and coaxial designs, and octave tuning. Since 1958, Crystek has been an industry leader in engineering, manufacturing, support and service.

Crystek Microwave,
Fort Myers, FL (239) 561-3311, www.crystek.com.

RS No. 313



Short Form Catalog

The 2007 short form catalog highlights the company's latest products and product upgrades offered in 2007. EM Research designs and manufactures high performance frequency sources for hi-rel and military applications. The company specializes in surface-mount and modular phase-locked oscillators and synthesizers from 4 MHz to 18 GHz.

EM Research Inc.,
Reno, NV (775) 345-2411, www.emresearch.com.

RS No. 314

Product Selection Guide

The October 2007 product selection guide summarizes new products, introduced since the release of the June 2007 product selection guide. Hittite's September 2007 Chinese language product selection guide is also available now. To request a copy, visit www.hittite.com or contact your local Hittite sales representative.

Hittite Microwave Corp.,
Chelmsford, MA (978) 250-3343, www.hittite.com.

RS No. 315

Looking for Ultra Low Profile Connection Solutions?

Let **Emerson Network Power Connectivity Solutions** UMC Ultra-miniature coaxial connectors and cable assemblies be your answer for a quality, snap on, surface mount connection built to meet your cost and performance targets.

The UMC cable plugs and jack receptacles offer 2.0mm and 2.5mm maximum mated height options with DC-6 GHz electrical performance.

UMC between series cable assemblies use **Johnson®** SMA connectors (standard and reverse polarity) and MMCX connectors for the quality needed no matter what wireless application you are working in. (LAN, Mini-PCI, GSM, CDMA, GPRS, PDA, Bluetooth and Microwave Radio).

All parts are RoHS compliant and mate with U.FL/U.FL(v) series connectors.

Contact **Emerson Network Power Connectivity Solutions** for our new brochure on UMC Connectors, Cable Assemblies and Adaptors.

ISO 9001:2000

RoHS 2002/95/EC

JOHNSON

Emerson Network Power.
The global leader in enabling business-critical continuity.

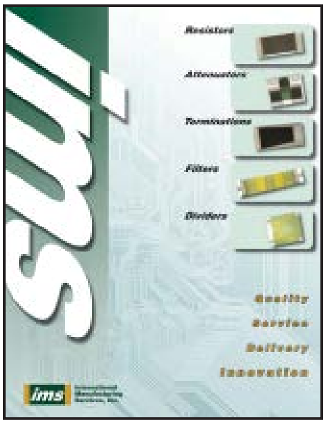
- AC Power Systems
- Connectivity
- DC Power Systems
- Embedded Power
- Inbound Power
- Integrated Cabinet Solutions
- Outside Plant
- Precision Cooling
- Site Monitoring and Services

Connectivity Solutions

For product information:
www.EmersonNetworkPower.com/Connectivity
or call 800-247-8256

EMERSON
Network Power

EMERSON. CONSIDER IT SOLVED.™



Short Form Brochure

This short form brochure features the company's complete product offering including chip resistors, chip terminations, chip attenuators, planar dividers and planar filters. The brochure highlights key product features, specifications and parameters as well as the company's custom capabilities. It includes IMS's new IMA series attenuators with values to 70 dB and IMF series planar filters.

International Manufacturing Services (IMS),
Portsmouth, RI (401) 683-9700, www.ims-resistors.com.

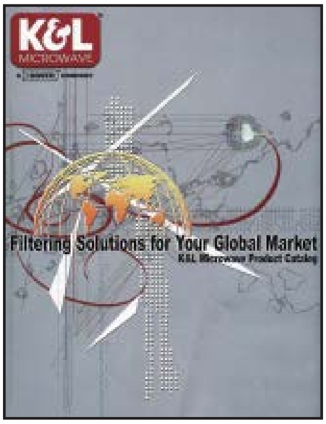
RS No. 316

Microscope Inspection Data Sheet

This data sheet features complete detail on the company's NAT-31 Microscope Inspection System with Universal Serial Bus (USB) 2.0 camera that resolves 1 micron or less features. High clarity zoom optics use a 0.7X-4.5X objective lens for magnification of 42X-270X with the standard 0.5X auxiliary lens and 84X-540X without. This system is ideal for demanding research environments and teaching facilities.

J microTechnology Inc.,
Portland, OR (503) 614-9509, www.jmicrotechnology.com.

RS No. 317



Desktop Reference Guide

This 123-page catalog can be used as a desktop reference guide that offers details and specifications to help designers and engineers choose products quickly. Integrated assemblies and a wide assortment of lumped component, cavity, ceramic and suspended substrate filters are among the many types of products featured in this catalog.

K&L Microwave,
Salisbury, MD (410) 749-2424, www.klmicrowave.com.

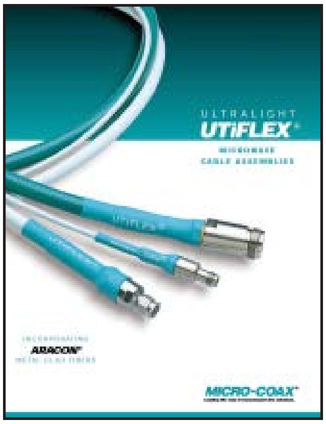
RS No. 318

Commercial and Wireless Catalog

Lorch Commercial & Wireless (LCW) is dedicated to serving the special needs of the commercial/industrial customer. LCW offers quick delivery of prototypes at competitive pricing with high volume manufacturing capability to meet all production requirements. Products include ceramic, lumped element and cavity filters. LCW is a division of Lorch Microwave who for more than 40 years has been a supplier of RF and microwave products.

Lorch Microwave,
Salisbury, MD (410) 860-5100, www.lorch.com.

RS No. 319

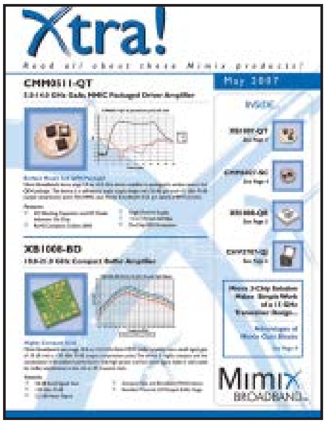


Microwave Cable Assemblies

Micro-Coax's UTiFLEX® Ultralight microwave cable assemblies are outlined in a six-page brochure. Incorporating ARACON® metal clad fibers, UTiFLEX Ultralight cable assemblies provide the lightest weight, lowest insertion loss and best radiation resistance in a flexible cable construction. The cable assemblies are optimized for spaceflight applications.

Micro-Coax,
Pottstown, PA (610) 495-0110, www.micro-coax.com.

RS No. 320



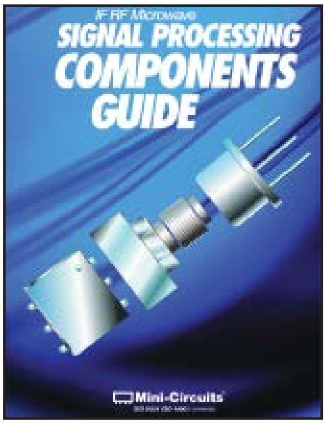
Short Form Catalog

This first edition of Xtra! is a print update to the company's short form catalog. Designed either to be inserted into the short form catalog, or to be used as a stand-alone product newsletter, Xtra! urges designers and Mimix customers to "read all about" the company's latest products, technical updates and application notes. The latest edition features the CMM0511-QT driver amplifier that covers the 5 to 14 GHz frequency range and is offered in a surface-mount 3×3 mm QFN package.

Mimix Broadband Inc.,
Houston, TX (281) 988-4600, www.mimixbroadband.com.

RS No. 321

Catalog Update

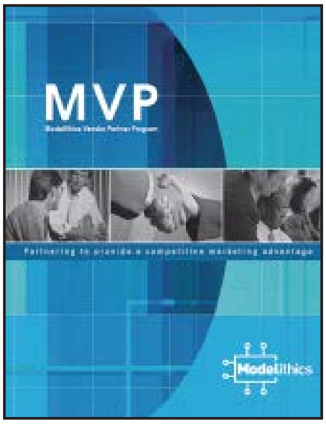


Components Guide

The 2007 IF/RF Microwave Signal Processing Components Guide is available for free from Mini-Circuits. The 144-page catalog offers the RF/microwave industry's most comprehensive listings of RF, IF and microwave components with essential performance specifications for each product. In addition to the extensive component data, the catalog also provides a listing of Mini-Circuits' patents and the product model numbers to which they apply.

Mini-Circuits,
Brooklyn, NY (718) 934-4500, www.minicircuits.com.

RS No. 322

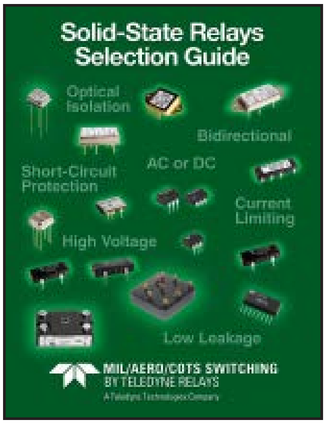


MVP Catalog

This catalog details the company's benefits and opportunities available to component and IC supplier companies through Modelithics Vendor Partner (MVP) Program. The services offered with its MVP Program are explained, as well as how an organization can work together with Modelithics to meet the increasing demand by circuit designers for accurate RF and microwave component and semiconductor device models.

Modelithics Inc.,
Tampa, FL (813) 866-6335, www.modelithics.com.

RS No. 324

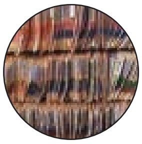


Selection Guide

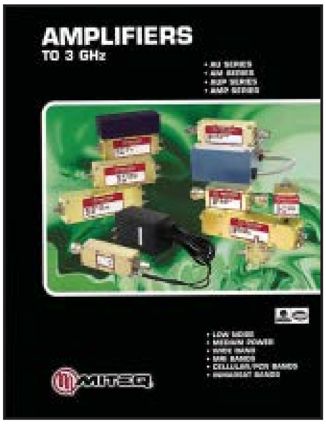
This solid-state relays selection guide features the company's military, aerospace, COTS and HRIP (high reliability industrial parts) applications. The catalog features 76 families in a tabular format designed in an easy to use format to quickly assist engineers in choosing a product. The 20-page digest provides detailed information about the relays, which include AC, DC and bidirectional relays with output ranging from 0.25 to 10 amps.

Teledyne Relays,
Hawthorne, CA (800) 284-7007, www.teledynerelays.com.

RS No. 326



Catalog Update

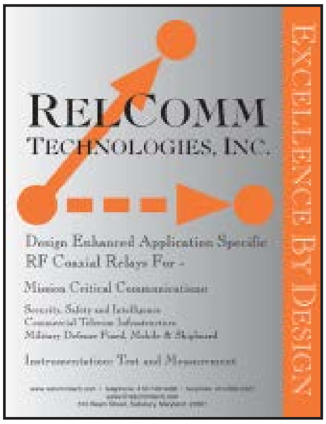


Amplifier Catalog

This new 40-page catalog features the company's complete bipolar amplifier line up to 3 GHz. The catalog features low noise, medium power, wideband, MRI, cellular/PCN and INMARSAT bands. Typical amplifier performance curves are shown, including conversion tables, reflection measurements, outline drawings, and explanation of options and specification definitions.

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

RS No. 323

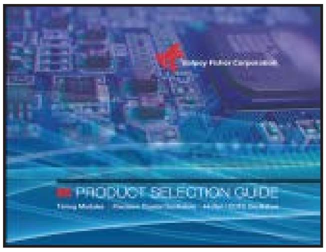


RF Coaxial Relays

This eight-page, full color brochure features the company's standard range of SP1T through SP10T design enhanced application specific RF coaxial relays. The brochure is intended to be used as a building block beginning with low cost, quick delivery standard devices and then introducing modifications to meet more specific needs when appropriate.

RelComm Technologies Inc.,
Salisbury, MD (410) 749-4488, www.relcommtech.com, www.rfrelaystore.com.

RS No. 325



Product Selection Guide

From discrete high precision crystal oscillators to highly integrated low noise timing modules, Valpey Fisher offers a broad array of frequency control products needed in advanced timing applications, including wireless and wireline infrastructure, avionics, test and measurement, and military communications. Valpey Fisher's product catalog is filled with the latest innovative timing and frequency control products, including timing modules, OCXOs, TCXOs, VCXOs, XOs and hi-rel/COTS oscillators.

Valpey Fisher Corp.,
Hopkinton, MA (508) 435-6831, www.valpeyfisher.com.

RS No. 327

Setting the Pace...

...With Innovative Amplifier Solutions!

5 Year Warranty Available!

Model Number	Frequency	Watts
SMX100	10KHz-1.0GHz	100
SMX200	10KHz-1.0GHz	200
SMX500	10KHz-1.0GHz	500
SMXE25-S2	10KHz-2.0GHz	25
SMXE25-S3	10KHz-3.0GHz	25
SMXE50-S2	10KHz-2.0GHz	50
SMXE50-S3	10KHz-3.0GHz	50
SMXE100-S2	10KHz-2.0GHz	100
CMX5005	10KHz-1.0GHz	500
CMX100010	10KHz-1.0GHz	1000
CMX200020	10KHz-1.0GHz	2000
ST81-10	1.0GHz-8.0GHz	10
ST81-25	1.0GHz-8.0GHz	25
ST81-50	1.0GHz-8.0GHz	50
ST81-100	1.0GHz-8.0GHz	100
ST181-10	1.0GHz-18.0GHz	10
ST181-25	1.0GHz-18.0GHz	25
ST181-50	1.0GHz-18.0GHz	50
ST101-100-50	1.0GHz-10.0GHz	100/50
TD122-25	2.0GHz-12.0GHz	25
TD122-50	2.0GHz-12.0GHz	50
TD182-25	2.0GHz-18.0GHz	25
TD182-50	2.0GHz-18.0GHz	50

- Size
- Power
- Customized
- Ruggedized

Have Amplifier Questions?
Ask The Experts @
www.interferencetechnology.com/askexpert
Because We Are The Experts!

INSTRUMENTS FOR INDUSTRY INC.
THE POWER OF CHOICE

903 South Second Street • Ronkonkoma, NY 11779
Tel: 631-467-8400 • Fax: 631-467-8558 • E mail: sales@ifi.com • www.ifi.com

Handheld Cable and Antenna Tester

This handheld, easy-to-use, battery-operated cable and antenna tester is designed for field engineers and technicians. The Agilent N9330A is a cost-effective test instrument that provides optimized usability and basic performance. Covering 25 MHz to 4 GHz, this instrument is an ideal choice for installation and maintenance of wireless service, military communications, broadcasting and radio links. The N9330A tester has distance-to-fault measurement functions and it features longer battery life, modern USB connectivity, multi-language user interface and powerful post-analysis software. Price: starting at $7800.

Agilent Technologies Inc.,
Santa Clara, CA (800) 829-4444,
www.agilent.com.

RS No. 216

Solid-state Power Amplifier

The model BCPA-20-500-100C is a broadband vertical solid-state RF power amplifier (PA) that is suitable for delivering reliable output power over the instantaneous frequency range from 20 to 500 MHz. This PA is ideal for military communications and jamming platforms as well as commercial applications. The PA utilizes the latest in silicon LDMOS push-pull RF devices. This PA uses captive hardware and a narrow mounting footprint, enabling modular, blindmate combining of multiple amplifiers, thereby eliminating interconnecting coaxial cables. This model is ideal for airborne applications.

BC Systems Inc.,
Setauket, NY (631) 751-9370,
www.bcpowersys.com.

RS No. 217

Solid-state Power Amplifier

The model BM2719-125 is a Class AB linear amplifier that operates in a frequency range from 20 to 1000 MHz with output power of 125 W. The amplifier is compact (6.4" × 6.7" × 1.4") and weighs only five pounds. Features include: solid-state design, wideband operation, military environment and 90° quad combiners.

Comtech PST,
Melville, NY (631) 777-8900,
www.comtechpst.com.

RS No. 218

Hybrid Band Reject Filter

The model 4BRX-2975/80-S is a hybrid band reject filter with bi-directional inputs. The filter features a 3 dB typical bandwidth of 80 MHz. The notch depth is 50 dB at 2975 MHz. The VSWR is 2.0 typical from DC to 4500 MHz excluding the notch area. The physical size is 1.5" × 0.800" × 0.50" excluding SMA female connectors.

Lorch Microwave,
Salisbury, MD (410) 860-5100,
www.lorch.com.

RS No. 219

High Reliability Mixer

The ADE-R30W+ is a high reliability mixer that features a proven, time tested, diode quad in a hermetically sealed package. This mixer operates over a wideband of 300 to 4000 MHz with an LO power of 7 dBm. It has a low conversion loss of 7 dB and an L-R isolation of 40 dB typical over the entire band. It has a wide IF bandwidth of DC to 950 MHz, making it suitable for applications such as I&Q modulators/demodulators, phase detectors and up/down converters. Its wide bandwidth makes it usable in several wireless applications such as cellular, PCN, WiMAX, W-CDMA and wideband applications such as instrumentation and military. This mixer is packaged in a low profile (0.112") package and is aqueous washable.

Mini-Circuits,
Brooklyn, NY (718) 934-4500,
www.minicircuits.com.

RS No. 220

X-band Dual Conversion Receiver

This custom X-band dual conversion receiver is designed for a military airborne requirement. The receiver includes an STC attenuator, low noise amplifier, RF bandpass filter, LO filters, ceramic bandpass filters in the first IF and lumped element filters in the second IF. Conversion gain is greater than 70 dB and all spurious signals are suppressed by 90 dB typical.

Rodelco Electronics Corp.,
Ronkonkoma, NY
(631) 981-0900,
www.rodelco-usa.com.

RS No. 221

Flexible Coaxial Cable

This line of low loss phase stable flexible coaxial cable operates in a frequency range up to 40 GHz. TLL40-1111A ("125" type) and TLL40-1130A ("150" type) were designed and engineered to terminate with Tensolite's high performance RF connectors for optimum performance. Furthermore, this new solution was designed to meet the needs of any application where performance and stability at the higher frequency range is critical. The TLL40-1111A and TLL40-1130A product families are ideal for multiple application requirements that include military/aerospace and test & measurement.

Tensolite Co.,
St. Augustine, FL
(800) 458-9960,
www.tensolite.com.

RS No. 222

Dual Directional Coupler

Werlatone's patented design provides continuous 30 to 2500 MHz bandwidth at 200 W CW power handling at 50 dB coupling. Available with N, TNC or SMA connectors, this low loss design provides superior performance throughout the entire bandwidth. The model C7868 offers an insertion loss of 0.25 dB, VSWR (ML) of 1.20, coupling flatness of 50 dB ±1 dB and directivity of 20 dB. Size: 3.5" × 2.6" × 0.7".

Werlatone Inc.,
Brewster, NY
(845) 279-6187,
www.werlatone.com.

RS No. 223

COMPONENTS

Microwave Converters

These universal microwave converters operate in a frequency range from 5 to 18 GHz. A

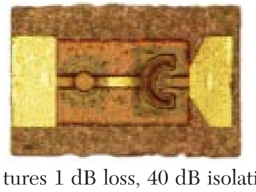
unique feature of these converters is that their modular design allows for easy tailoring to customer specific requirements. These converters come with or without a synthesizer. The converters' thin-film construction allows for a small, rugged and low cost design.

Advanced Microwave Inc., Sunnyvale, CA (408) 739-4214, www.advmic.com.

RS No. 224

Monolithic PIN Diode Switch

The MSSE3792 is a series-shunt silicon PIN diode array designed for high speed multi-



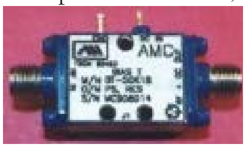
throw switching up to 26 GHz. This new diode represents replacement for Alpha/Skyworks SSE3792. It features 1 dB loss, 40 dB isolation at 18 GHz and Oxide/Nitride/Polyimide triple passivation.

Aeroflex/Metelics Inc., Sunnyvale, CA (408) 737-8181, www.aeroflex-metelics.com.

RS No. 225

Resistive Bias Tee

The model BT-50K18 is a resistive bias tee, with options PS and RES, designed to operate



in a frequency range from 50 kHz to 18 GHz. The VSWR is 1.75 typical and the insertion loss is 0.75 typical while the isolation is 60 dB minimum. Size: 0.80" (L) × 0.62" (W) × 0.40" (H).

American Microwave Corp., Frederick, MD (301) 662-4700, www.americanmicrowavecorp.com.

RS No. 226

Programmable Attenuator

The model 651-025-127 is a 50 Ω programmable attenuator with SMA female connectors

(other impedance values and connector types are available). These solid-state units are TTL controlled via a 10-pin latch connector. The programmable attenuators are ideal for automated testing, research and development as well as programmable matrix assemblies. These devices operate in a frequency range from 500 to 2500 MHz and have a 0 to 127 dB dynamic range with 1 dB binary steps. Attenuation accuracy is ±0.5 dB and typical switching speed is two microseconds.

BroadWave Technologies Inc., Franklin, IN (317) 346-6101, www.broadwavetech.com.

RS No. 227

High Reliability RF Switch

The model G60P-742100 is a SP6T highly reliable latching switch with indicator circuitry and suppression diodes that operates from DC to 26.5 GHz. The switch features an extremely low VSWR of 1.30 maximum and ±0.03 dB maximum repeatability at 18 GHz. The new high-rel series switches are available with all latching configurations. Special materials and design allow for superior RF performance and outstanding switching characteristics across the band. Delivery: stock to two weeks.

Charter Engineering Inc., Pinellas Park, FL (727) 525-1025, www.ceiswitches.com.

RS No. 228

Variable Chip and Coaxial Equalizers

These surface-mount chip and coaxial equalizers are designed to compensate frequency vari-

ations in RF and microwave subsystems. The equalizers are available in a fixed frequency response version and a temperature variable frequency response. In addition, EMC can develop custom variations specific to the frequency band and temperature slope characteristics of a customer's application. All EMC equalizers are available with both negative and positive slope coefficients. The CE chip equalizer (1.30 sq in) offers linear broadband fixed slope frequency compensation from 2 to 18 GHz in 1 to 4 dB values.

EMC Technology, Stuart, FL (772) 286-9300, www.emct.com.

RS No. 230

High Peak Power Terminations

This series of low VSWR, high peak power terminations from 5 to 150 W operates in a frequency range to 4 GHz. The VSWR is 1.05 maximum to 1 GHz and 1.10 maximum to 4 GHz. The peak power handling capabilities are from 5 to 25 kW with a 1 microsecond pulse width, depending upon the model selected. These terminations come with a standard two-year warranty and detachable N-female connectors. There are 26 different quick match connector types for this series including male or female SMA, BNC, LC, TNC, SMA and 7/16. Delivery is typically from stock to two weeks.

Coaxial Dynamics, Middleburg Hts., OH (440) 243-1100, http://coaxial.com.

RS No. 229

RF/RF and RF/DC Crossover

This RF/RF and RF/DC crossover with an integrated 2 W attenuator operates up to 7 GHz

and provides a small package that performs the two functions of an RF jumper and an RF attenuator. The XDBF uses Florida RF Labs' crossover technology along with its proven attenuator expertise to both reduce the footprint size by combining two components in a single package and improve the overall performance. The XDBF is available in 3, 6 and 10 dB values. The device is manufactured RoHS-compliant.

Florida RF Labs, Stuart, FL (800) 544-5594, www.rflabs.com.

RS No. 231

SP4T Absorptive PIN Diode Switch

The model S4N-69-1AB is a medium power low harmonic SP4T absorptive PIN diode

switch that operates from 2 to 18 GHz. Across the entire band, VSWR is less than 2.1, insertion loss is less than 4.5 dB and the isolation is greater than 60 dB. This switch can handle +27 dBm CW with less than 60 dBm harmonic content. It has a two-bit binary TTL compatible logic with a switching speed less than 900 ns. Size: 2.50" × 1.25" × 0.50".

G.T. Microwave Inc., Randolph, NJ (973) 361-5700, www.gtmicrowave.com.

RS No. 232

High Frequency Bandpass Filter

As point-to-point communications, as well as other markets, have shown higher demand for filtering applications at millimeter-wave frequencies, K&L continues to develop products to support this industry. The model CAV-01329 is a seven-pole, extremely high frequency

bandpass filter centered at 44.5 GHz, with a 3 dB bandwidth of 3 GHz. The small size of the filter allows it to be well suited for requirements where space is limited. K&L is also providing filtering products that support applications at frequencies greater than 80 GHz.
K&L Microwave,
Salisbury, MD (410) 749-2424,
www.klmicrowave.com.
RS No. 233

50 W Wireless Band Couplers

These rugged, 50 W couplers are designed for excellent performance across all wireless bands

from 0.8 to 2.2 GHz making them ideal for base station, in-building wireless and repeater systems. A unique design provides low insertion loss (0.3 dB), high directivity (22 dB) and exceptional VSWR (1.15). The couplers are available from stock in 6, 10, 15 and 20 dB coupling values with type-N or SMA-female connectors. These connectors are made in the US and have a 36-month warranty.
MECA Electronics,
Denville, NJ (973) 625-0661,
www.e-meca.com.
RS No. 234

High Speed Phase Shifter

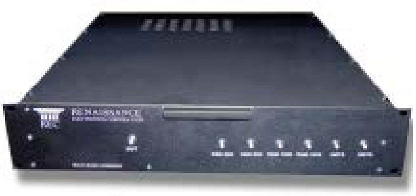
The model PS-90-8018 option 812, HS15NS is a high speed 0 to 180 degree, miniature, bi-

phase modulator/phase shifter with TTL control logic (ECL logic available). This high speed model has 15 ns delay on/off and operates between 8 to 12 GHz. Other frequency ranges are available to meet other requirements (for example, 6012 for 6 to 12 GHz or 2040 for 2 to 4 GHz).
Planar Monolithics Industries,
Frederick, MD (301) 631-1579,
www.planarmonolithics.com.
RS No. 235

AMPS Receive Band Filter

The part number 8C9-836-X25N11 is an AMPS receive band filter. This unit is centered at 836 MHz with a flat passband of 824 to 849 MHz. Passband insertion loss comes in at less than 1 dB, a passband return loss of greater than 16 dB and has 60 dB of attenuation at 869 to 894 MHz. This unit sized at only 2.75" high × 2.75" wide × 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.
RS No. 236

Multi-band Combiner



This multi-band combiner can take between 2 to 16 channels and combine them into a single signal with very low loss and intermodulation performance. This multi-band combiner will allow service providers to combine different frequency bands and modulation schemes into a single output port.
Renaissance Electronics Corp.,
Harvard, MA (978) 772-7774,
www.rec-usa.com.
RS No. 237

Directional Couplers

These miniature air dielectric directional couplers are rugged lightweight devices that offer

lower insertion loss than comparable stripline units. The simplified construction allows for greater flexibility in creating customized configurations. Any port can be used as the input with these symmetrical devices. The standard units are available with a choice of coupling values and frequency ranges and an optional termination.
RLC Electronics Inc.,
Mount Kisco, NY (914) 241-1334,
www.rlcelectronics.com.
RS No. 238

AMPLIFIERS

RF Power Amplifier

This RF power amplifier module covers the VHF/UHF military communications band,

from 30 to 512 MHz with a power output of 100 W P1dB CW. Model KMW-2025M11 is ideal for OEM or embedded communications applications that require high reliability from a proven design, good intermodulation distortion, and the ability to be gated on or off via a remote control line. The module operates efficiently from 28 VDC with an average current of only 8 amps.
AR Modular RF,
Bothell, WA (425) 485-9000,
www.ar-worldwide.com.
RS No. 239

Millimeter-wave Amplifiers

The LA series of millimeter-wave amplifiers include 10 models that cover 33 to 75 GHz in up

to 20 GHz bandwidths. They feature P1dB input powers as high as +11 dBm, noise figures as low as 7 dB and gain options from 10 to 40 dB. Additional performance characteristics include input/output VSWR of 2.2 and gain flatness of ±3 dB. Innovative PHEMT device technology and thin-film hybrid construction are used to achieve these characteristics across these broad bands. They are ideal for EW, ECM and instrumentation applications.
Endwave Corp.,
San Jose, CA (408) 522-3100,
www.endwave.com.
RS No. 240

Low Noise Amplifiers

The HMC605LP3(E) and the HMC593LP3(E) are GaAs PHEMT MMIC bypass LNAs that are rated from 2.3 to 2.7 GHz and 3.3 to 3.8

Bipolar Amplifiers

AM-Series

FEATURES:

- .01 – 2500 MHz
- Low Cost
- Available From Stock
- Operating Temp.: -30 to +75°C

Model Number	Frequency (MHz)	Gain (dB) Min.	Gain (dB) Typ.	Gain Flatness (±dB, Max.)	Noise Figure (dB, Max.)	Output Power (dBm, Min.)	VSWR In/Out (Max.)	DC Power @ 15 to 30 VDC (mA, Nom.)
AM-1607-1000	.01 – 1000	40	41	0.75	3	12	2:1	110
AM-1607-2000	.01 – 2000	40	41	1	3	9	2:1	110
AM-1607-2500	.01 – 2500	40	41	1.5	3.2	7	2:1	110
AM-1616-1000	.01 – 1000	20	21	.5	3.2	12	2:1	60
AM-1616-2000	.01 – 2000	20	21	.75	3.2	9	2:1	60
AM-1616-2500	.01 – 2500	20	21	1	3.2	7	2:1	60

3 YEAR WARRANTY

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

ISO 9001 Registered ANAB

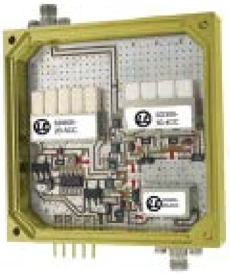
MITEQ®

100 Davids Drive, Hauppauge, NY 11788
TEL: (631) 436-7400 • FAX: (631) 436-7430
www.miteq.com

GHz, respectively. These wide dynamic range LNAs deliver noise figure as low as 1 dB, output IP3 as high as +29 dBm and up to 20 dB gain. Both LNAs feature an integrated bypass path that exhibits only 2 dB loss, making them ideal for infrastructure and subscriber applications in telematics, broadband, WiBro, WiMAX and fixed wireless systems.
Hittite Microwave Corp.,
Chelmsford, MA (978) 250-3343,
www.hittite.com.

RS No. 241

Switch Filter Amplifier



This switch filter amplifier (SFA) series is available in both ceramic and lumped element configurations. The SFA series offers a wide frequency range of 100 to 3000 MHz and bandwidth range from 1 to 40 percent, with a typical return loss of 18 dB/14 dB. The noise figure of 1.5 to 5 dB combined with 300 ns switching speed, 10 to 40 dB gain and bias of +10, +5 VDC) make the SFA series ideal for receiver applications and improvement of overall system performance.
Lark Engineering Co.,
San Juan Capistrano, CA (949) 240-1233,
www.larkengineering.com.

RS No. 242

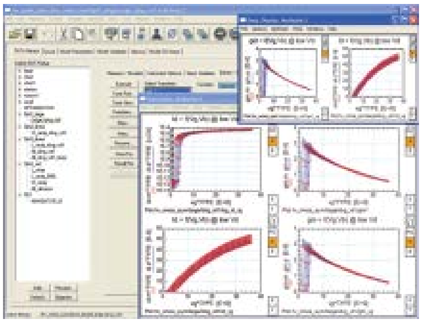
1 W Power Amplifier

The model AMF-4D-01000800-85-30P is a connectorized small outline high dynamic range amplifier that covers multi-octave bandwidth from 1 to 8 GHz. The housing is 23 (H) × 18 (L) × 8 mm (W) without the connectors and heat sink. The amplifier is environmentally sealed, EMI shielded and includes reverse voltage protection, in addition to full internal regulation. Nominal small-signal gain is a minimum of 28 dB while noise figure is less than 8 dB across the full band. Maximum gain variation is less than ±1.5 dB typically over the full frequency band and temperature range.
MITEQ Inc.,
Hauppauge, NY (631) 436-7400,
www.miteq.com.

RS No. 243

SOFTWARE

HVMOS Software Package



This new parameter extraction solution is designed for high voltage (HV) complementary metal oxide semiconductor (CMOS) devices used in a range of automotive and consumer products, as well as LCD and display driver applications. The HVMOS extraction package, for use with Agilent's Integrated Circuit Characterization and Analysis Program (IC-CAP) software platform, enables engineers to model HV CMOS devices using Synopsys' HSPICE simulator, HVMOS Level 66 compact model. The HVMOS model includes all relevant physical effects unique to high voltage operation, including symmetric and asymmetric source and drain resistances, quasi-saturation, transconductance fall off at high gate voltage and self-heating effects. As a result, it allows HV CMOS devices to be modeled with unparalleled DC and capacitance modeling accuracy and simulation speed.
Agilent Technologies Inc.,
Santa Clara, CA (800) 829-4444,
www.agilent.com.

RS No. 245

ANTENNA

High Frequency Antenna

The model 6000 is a high frequency antenna that operates in a frequency range from 2 to 8 GHz. This high frequency antenna features an extension mast mounting standard. Magnetic mount is available.
Interad Ltd.,
Melfa, VA (757) 787-7610,
www.interadlimited.com.

RS No. 244

SOURCES

Voltage-controlled Oscillator

The model CVCO55CC-2970-3230 is a voltage-controlled oscillator (VCO) that operates from 2970 to 3230 MHz with a control voltage range of 0.5 to 4.5 V. This VCO features a typical phase noise of –104 dBc/Hz at 10 kHz offset and has excellent linearity. The model CVCO55CC-2970-3230 is packaged in the industry standard 0.5" × 0.5" SMD package. Input voltage is 5 V, with a maximum current consumption of 35 mA. Pulling and pushing are minimized to 1.5 MHz and 3 MHz/V, respectively. Second-harmonic suppression is –20 dBc typical. The CVCO55CC-2970-3230 is ideal for use in applications such as digital radio equipment, fixed wireless access, satellite communications systems and base stations.
Crystek Corp.,
Fort Myers, FL (239) 561-3311,
www.crystek.com.

RS No. 246

Multi-purpose Frequency Synthesizers

The SLFS/SLS series frequency synthesizers are available as fixed-frequency (SLFS) or serially-programmable (SLS) devices in frequencies from 50 MHz to over 12 GHz. The SLS features step sizes ranging from 10 kHz to 10 MHz and is available with RS-232/USB serial programming computer interfaces. Options include internal buffer amplifiers for up to +13 dBm output and use with supplies at +5, +8 and +12 VDC. These units are housed in a 1.5" × 1.5" × 0.6" package and weigh less than 2 ounces, and are supplied with SMA connectors for the reference and output frequencies.

EM Research Inc.,
Reno, NV (775) 345-2411, www.emresearch.com.

RS No. 247

Frequency Synthesizer

The PTS 1600 X-142 is an enhanced version of the basic PTS 1600 model featuring certain external narrowband modulation capabilities. AM/FM/PM is injected via an external modulated signal generally in the 900 MHz range to modulate the output signal within the range of 10 to 1600 MHz. The PTS 1600 X-142 covers its range with direct architecture using both analog and digital technologies. It has excellent close-in phase noise as well as the ability to switch rapidly from one frequency to another. High speed remote control is provided through the standard TTL-level parallel interface port, but for easy integration into testing environments a GPIB interface is also available.

Programmed Test Sources Inc.,
Littleton, MA (978) 486-3400,
www.programmedtest.com.

RS No. 248

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 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.synergymwave.com.

RS No. 249

Coaxial Resonator Oscillator

The model CRO3744A-LF is a lead free, RoHS-compliant, coaxial resonator oscillator in C-band (3731 to 3757 MHz) featuring extraordinary low phase noise performance of –112 dBc/Hz at 10 kHz offset. This unique design offers superior harmonic suppression of –20 dBc with a typical tuning sensitivity of 15 MHz/V and covers the entire band between 0.5 to 4.5 V. It is designed to operate at 5 VDC supply while drawing 25 mA (typical) over the extended operating temperature range of –40° to 85°C. The CRO3744A-LF is ideally suited for applications that require signal stability and low phase noise performance. Size: 0.50" × 0.50" × 0.22". Price: $29.95/VCO (5 pcs min). Delivery: stock to four weeks.

Z-Communications Inc.,
San Diego, CA (858) 621-2700,
www.zcomm.com.

RS No. 250

TEST EQUIPMENT

Configurable RF Test Platform

This modular RF test platform is designed for wireless applications up to 6 GHz. The scaleable platform has the flexibility to easily perform at any stage of wireless development from research to manufacturing, and can integrate seamlessly into any wireless market including cellular, wireless data, RFIC test and military/aerospace. The configurable RF measurement system encompasses three powerful new additions: New PXI 3000 Series hardware modules, PXI Studio software with new measurement plug-ins, and a new PXI instrument chassis to tie it all together.

Aeroflex Inc.,
Plainview, NY (516) 694-6700,
www.aeroflex.com.

RS No. 252

Upgrade for Field Monitor

AR RF/Microwave Instrumentation has released a new version of the firmware for its field monitor model FM7004. The new update adds the ability to internally apply correction factors for field probe readings. Up to four tables of correction factors containing up to 30 different frequency points can be stored in the field monitor at one time. In addition to this new feature, the FM7004 automatically configures itself to work with any of the AR laser powered or battery powered probes and can be controlled from either the front panel of remotely through four digital interfaces. For customers who already own an FM7004, their firmware can be updated to obtain this new feature by downloading a utility program from the company's web site: www.ar-worldwide.com/html/50000.asp?S=3.

AR RF/Microwave Instrumentation, Souderton, PA (215) 723-8181, www.ar-worldwide.com.

RS No. 251

MICRO-ADS

Visit http://mwj.hotims.com/11724-(RS#)

Radio Wireless Week 2008

http://www.radiowirelessweek.org/

20-25 January, 2008 Orlando, FL USA

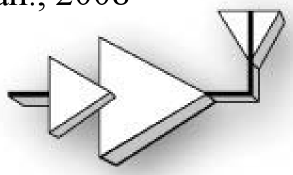
~ Come and See the Big Picture In Wireless ~

Three Conferences, Exhibits, Workshops and more!

Radio & Wireless Symposium incorporating WAMICON
22 - 24 Jan., 2008

RWS incorporating WAMICON is a leading interdisciplinary forum for the latest results in wireless technology, providing unique comprehensive view of wireless field from system level design to implementation, particularly for commercial wireless communication systems such as 3G/4G, WLAN, SDR, 802.xx, and UWB, etc, and RF up to mm-wave frequencies, and optical technology applied to wireless communications.

Power Amplifier Symposium
21 - 22 Jan., 2008



Power amplifiers are a vital enabling technology for emerging wireless communications systems, and are evolving rapidly under the dual pressures of providing improved efficiency and improved linearity. This meeting seeks to provide a forum for innovative work in the area of power amplifiers, including requirements for and accomplishments in amplifiers for both handsets and base stations.

8th Topical Meeting on Silicon Monolithic Integrated Circuits in RF Systems
23 - 25 Jan., 2008

SiRF is the only conference devoted to Si-based devices, passives, integrated circuits, and applications for high-frequency systems. Over three days, papers and sessions will highlight the significant technological advances of this dynamic field, as well as provide a unique forum for the presentation of new ideas and candid exchange on the emerging challenges and opportunities.

For more information, visit us at

http://www.radiowirelessweek.org/

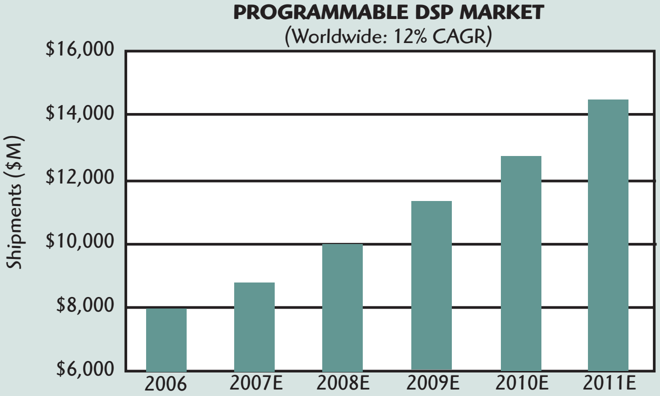
Platinum Sponsorship by RFMD

IEEE · MTT-S · APS · IEEE COMMUNICATIONS SOCIETY

Microwave Metrics

The Embedded Chip Trend Continues

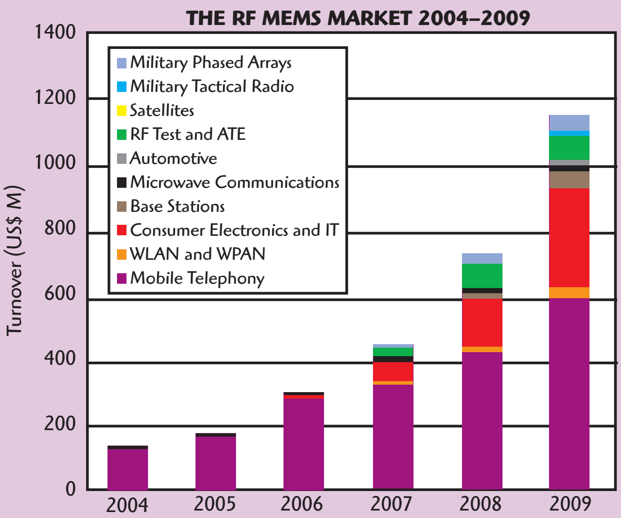
The market for general-purpose digital signal processor (DSP) chips is forecast to grow 8% in 2007 to the $9 B level according to this new market study. The study predicts a more typical growth of 15% in 2008 driven by communications and multimedia applications. But the study also emphasizes the even bigger embedded DSP market that will grow to $17.6 B in 2007, to almost twice the size of the general-purpose DSP chip market. This new in-depth study is believed to be the most comprehensive study available of markets driven by DSP technology, and includes the results of a new survey of DSP professionals in over 30 countries.



Source: Forward Concepts, 1575 W. University Dr., Suite III, Tempe, AZ 85281-3283 (www.fwdconcepts.com)

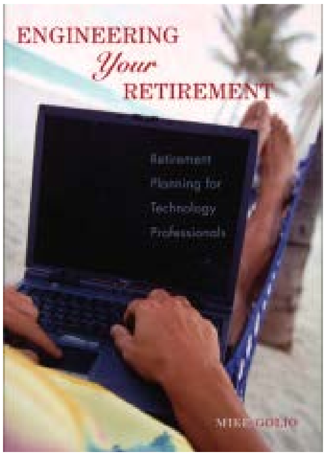
RF MEMS Components Break Through Hype

RF MEMS components are rapidly living up to their promise, according to a new market study from WTC covering the 2005 to 2009 period. According to the new updated report, the market for RF MEMS components was $126 M in 2004, confirming WTC's forecast from 2002. It is forecasted to grow rapidly in the next few years to over $1.1 B in 2009. In addition, the market will accelerate quickly in the period 2007 through 2009 as full-scale production starts for the majority of RF MEMS components. The major part of the market in 2004 was for bulk acoustic wave (BAW) devices, which include duplexers and filters for mobile phones. This product will continue to dominate and constitute around 40% of the total market in 2009.



Source: Wicht Technologie Consulting, Frauenplatz 5, D-80331 Munich, Germany (www.wtc-consult.de)

Engineering Your Retirement

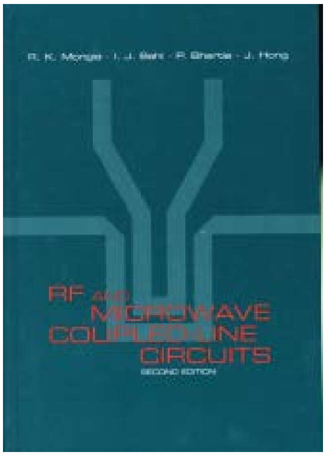


Mike Golio
IEEE Press • 223 pages; $34.95
ISBN: 978-0-471-77616-1

This book should be of interest to anyone looking forward to retiring comfortably on one's own schedule. It is the result of the author's research as well as countless discussions with technical professional retirees. It addresses topics of concern and high priority to anyone considering careful planning of retirement. The first chapter describes the retirement options: how much is needed to retire and how long will it take to save enough money as well as learning one's own life values. Chapter 2 offers analysis tools and calculations. Chapter 3 considers spending and living below one's means. Chapter 4 investigates emergency funds and insurance, such as medical insurance and healthcare budgets, personal financial concerns and the necessary documents. Chapter 5 reviews diverse investment possibilities, such as bonds, stocks, real estate, annuities, pension plans, cash and certificates of deposit, Social Security, mutual funds and commodities, while Chapter 6 develops an investment plan which includes eliminating bad debt, investment issues, tax-advantaged accounts and free money, taxable investments and taxes. The last two chapters consider more personal issues, such as "What will I do when I retire?" and some final issues: where to live, sources of income and taxes. The text examines the primary issues of each topic and then points to more detailed references. A complementary web site, www.golio.net, provides supplemental data, tools, spread sheets and analysis organized according to the table of contents. Three appendices list: Web site URLs: Information, Online Calculators and Software, Fundamental Financial Equations, and a Longevity Table.

To order this book, contact:
John Wiley & Sons Inc.
One Wiley Drive
Somerset, NJ 08875
(800) 225-5945

RF and Microwave Coupled-line Circuits: Second Edition



R.K. Mongia, I.J. Bahl, P. Bhartia and J. Hong
Artech House • 567 pages; $139, £77
ISBN: 978-1-59693-156-5

The first edition of this book was published in 1999. While the fundamentals of coupled-line circuits have not changed, many novel configurations of coupled-line components, such as directional couplers, filters and baluns have since been reported. With the deletion of some chapters in their entirety and the addition of new chapters and new material in others, this second edition remains the same size as the first one. The first few chapters reflect only minor changes. Most of the major changes occur in the "Applications" part of the text, that is Chapter 8 onward. Thus, Chapter 9, on filters, includes the design of bandstop filters using coupled lines and a discussion of software packages used for filter design, together with their limitations and strengths. Chapters 10 and 11 are new. They discuss advanced filter technology and the design of filters using new materials and technologies. Chapter 10 concentrates on coupled-line filters with many specialized characteristics that are often encountered in practice. Chapter 11 takes a different direction, tackling filters using advanced materials. Chapter 12 discusses the design of common microwave components requiring coupled-line technology, such as DC blocks, transformers, interdigital capacitors and spiral inductors. Chapter 13 covers baluns of different configurations, such as microstrip-to-balanced stripline, planar transmission line and Marchand types, which are discussed in detail.

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

Advertising Index

RS No.	Advertiser	Page No.	Phone	Fax	Web Address
76	Jersey Microwave	40	908-684-2390 ext. 23	908-684-2391	http://mwj.hotims.com/11724-76
77	K&L Microwave, Inc.	7,222	410-749-2424	443-260-2268	http://mwj.hotims.com/11724-77
78	KOR Electronics	101	714-898-8200	714-895-7526	http://mwj.hotims.com/11724-78
79	KR Electronics, Inc.	227	732-636-1900	732-636-1982	http://mwj.hotims.com/11724-79
80	Lark Engineering Company	32	949-240-1233	949-240-7910	http://mwj.hotims.com/11724-80
81	Locus Microwave, Inc.	230	814-466-6275	814-466-1104	http://mwj.hotims.com/11724-81
82	Lorch Microwave	45	800-780-2169	410-860-1949	http://mwj.hotims.com/11724-82
83	M/A-COM, Inc.	11	800-366-2266	978-442-5350	http://mwj.hotims.com/11724-83
84	M2 Global Technology, Ltd.	108	210-561-4800	210-561-4852	http://mwj.hotims.com/11724-84
85	Marki Microwave, Inc.	105	408-778-4200	408-778-4300	http://mwj.hotims.com/11724-85
86	Maruwa America Corp.	102	516-477-0783	718-728-2493	http://mwj.hotims.com/11724-86
87	MECA Electronics, Inc.	142	973-625-0661	973-625-9277	http://mwj.hotims.com/11724-87
24	Microlab/FXR, (a Wireless Telecom Group Company)	23	973-386-9696	973-992-0513	http://mwj.hotims.com/11724-24
88	Micronetics	17	603-579-0900	603-882-8987	http://mwj.hotims.com/11724-88
89	Microsemi	96	408-986-8031	408-986-8120	http://mwj.hotims.com/11724-89
90	Microwave Development Laboratories	113	781-292-6680/6684	781-453-8629	http://mwj.hotims.com/11724-90
91	Microwave Filter Company, Inc.	178	800-448-1666	315-463-1467	http://mwj.hotims.com/11724-91
	Microwave Journal	12,152,166,214, 226,231,237	800-225-9977	781-769-5037	www.mwjournal.com
92	Milmega Limited	201	+44 (0) 1983 618004	+44 (0) 1983 811521	http://mwj.hotims.com/11724-92
93	Mimix Broadband, Inc.	COV 3	281-988-4600	281-988-4615	http://mwj.hotims.com/11724-93
94,95,96, 97,98,99, 100,101,102, 103,104,105, 106,107	Mini-Circuits	4–5,20,35, 41,49,50, 59,87,139, 147,153,164–165, 219,235	718-934-4500	718-332-4661	http://mwj.hotims.com/11724-94
108,109	MITEQ Inc.	24–25,223	631-436-7400	631-436-7430	http://mwj.hotims.com/11724-108
110	Modular Components National, Inc.	197	410-879-6553	410-638-7356	http://mwj.hotims.com/11724-110
111	MTI Wireless Edge	60	+972-3-9025050	+972-3-9025051	http://mwj.hotims.com/11724-111
112	Narda Microwave-East, an L3 Communications Co.	8	631-231-1700	631-231-1711	http://mwj.hotims.com/11724-112
113	National Association of Tower Erectors	207	605-882-5865	605-886-5184	http://mwj.hotims.com/11724-113
114	Networks International Corporation	36	913-685-3400	913-685-3732	http://mwj.hotims.com/11724-114
115	Nexyn Corporation	68	408-982-9339	408-982-9275	http://mwj.hotims.com/11724-115
116	OML Inc.	181	408-779-2698	408-778-0491	http://mwj.hotims.com/11724-116
117	Pascall Electronics Limited	134	+44(0) 1983 817300	+44(0) 1983 564708	http://mwj.hotims.com/11724-117
118	Planar Electronics Technology, Inc.	175	301-662-5019	301-662-1731	http://mwj.hotims.com/11724-118
119	Planar Monolithic Industries, Inc.	145	301-631-1579	301-662-2029	http://mwj.hotims.com/11724-119
120,121	Radiall	98,140	33-1-49-353535	33-1-48-546363	http://mwj.hotims.com/11724-120
122	Radiall-AEP	125	203-776-2813	203-776-8294	http://mwj.hotims.com/11724-122
123	Radio Research Instrument Co., Inc.	230	203-753-5840	203-754-2567	http://mwj.hotims.com/11724-123
124	Reactel, Incorporated	15	301-519-3660	301-519-2447	http://mwj.hotims.com/11724-124
125,126	RelComm Technologies, Inc.	115,173	410-749-4488	410-860-2327	http://mwj.hotims.com/11724-125
127	Remcom	189	814-861-1299	814-353-1420	http://mwj.hotims.com/11724-127
128	REMEC Defense & Space	30	858-560-1301		http://mwj.hotims.com/11724-128
129	RF Micro Devices	171	336-678-5570	336-931-7454	http://mwj.hotims.com/11724-129
130	RF TEC Mfg., Inc.	227	770-487-2187	770-486-9499	http://mwj.hotims.com/11724-130
131,132,133	RFHIC	70,72,74	82-31-250-5011	82-31-250-5088	http://mwj.hotims.com/11724-131
134	Richardson Electronics, Ltd.	187	800-737-6937	630-208-2550	http://mwj.hotims.com/11724-134
135	RLC Electronics, Inc.	27	914-241-1334	914-241-1753	http://mwj.hotims.com/11724-135
136	Rodelco Electronics Corp.	33	631-981-0900	631-981-1792	http://mwj.hotims.com/11724-136
137	Rogers Corporation	81	480-961-1382	480-961-4533	http://mwj.hotims.com/11724-137
138	Rohde & Schwarz GmbH	57	+49-1805-124242	+49-89-412913777	http://mwj.hotims.com/11724-138
139	Rosenberger	88	+49-8684-18-0	+49-8684-18-499	http://mwj.hotims.com/11724-139
140	Roswin Inc.	190	+82-41-621-4450	+82-41-621-4451	http://mwj.hotims.com/11724-140
141	Santron Inc.	COV 2	978-356-1585	978-356-1573	http://mwj.hotims.com/11724-141
142	Satellink, Inc.	227	972-487-1434	972-487-1204	http://mwj.hotims.com/11724-142
143	Sector Microwave Industries, Inc.	227	631-242-2300	631-242-8158	http://mwj.hotims.com/11724-143
144	Sirenza Microdevices	85	303-327-3030		http://mwj.hotims.com/11724-144
145	Special Hermetic Products, Inc.	52	603-654-2002	603-654-2533	http://mwj.hotims.com/11724-145
146	Spectrum Elektrotechnik GmbH	109	+49-89-3548-040	+49-89-3548-0490	http://mwj.hotims.com/11724-146
147	Spectrum Microwave, Inc.	132–133	888-553-7531	302-727-3729	http://mwj.hotims.com/11724-147
148	Spinnaker Microwave, Inc.	66	408-732-9828	408-732-9793	http://mwj.hotims.com/11724-148
149	State of the Art, Inc.	144	800-458-3401	814-355-2714	http://mwj.hotims.com/11724-149
150	Stealth Microwave, Inc.	77	888-772-7791	609-538-8587	http://mwj.hotims.com/11724-150
151	Storm Products Company	167	630-754-3300	630-754-3500	http://mwj.hotims.com/11724-151
152	SV Microwave, Inc.	169	561-840-1800	561-842-6277	http://mwj.hotims.com/11724-152
153,154,155	Synergy Microwave Corporation	55,159,225	973-881-8800	973-881-8361	http://mwj.hotims.com/11724-153
156	Talley Communications	104	800-949-7079		http://mwj.hotims.com/11724-156
157	Tampa Microwave	123	813-855-2251		http://mwj.hotims.com/11724-157
158	Tecom Industries, Inc.	100	866-840-8550		http://mwj.hotims.com/11724-158
159	Tektronix, Inc.	130			http://mwj.hotims.com/11724-159
160	Teledyne Cougar	149	408-522-3838	408-522-3839	http://mwj.hotims.com/11724-160
161	Telogy LLC	99	800-835-6494		http://mwj.hotims.com/11724-161
162	Times Microwave Systems	119	203-949-8400	203-949-8423	http://mwj.hotims.com/11724-162

ADVERTISING INDEX

Visit **Microwave Journal** *on the Web at* **www.mwjournal.com**

Visit mwjournal.com/info and enter RS# to request information from our advertisers

SALES REPRESENTATIVES

microwave journal

CARL SHEFFRES, PUBLISHER | **ED JOHNSON, ASSOCIATE PUBLISHER** | **KEN HERNANDEZ, TRAFFIC ADMINISTRATOR**

Eastern and Central Time Zones
Chuck Boyd
Northeast Reg. Sales Mgr.
(New England, Upstate NY, Eastern Canada)
685 Canton Street
Norwood, MA 02062
Tel: (781) 769-9750
FAX: (781) 769-5037
cboyd@mwjournal.com

Michael Hallman
Eastern Reg. Sales Mgr.
(Mid-Atlantic, Southeast, Midwest)
4 Valley View Court
Middletown, MD 21769
Tel: (301) 371-8830
FAX: (301) 371-8832
mhallman@mwjournal.com

Brian Green
Inside Sales Manager
685 Canton Street
Norwood, MA 02062
Tel: (781) 769-9750
FAX: (781) 769-5037
bgreen@mwjournal.com

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

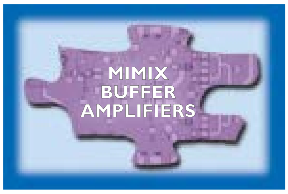
Germany, Austria, and Switzerland (German-speaking)
Juergen Wissling
Wissling Marketing Services
Riedstrasse 5
72813 St. Johann-Wuertingen
Germany
Tel: +49 7122 828140
FAX: +49 7122 828145
jwissling@horizonhouse.com

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

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

p r o v i d i n g   o p t i m a l   s e m i c o n d u c t o r   s o l u t i o n s   w o r l d w i d e



Our "Perfect Fit" Buffer Amplifiers are highly compact, offer a dynamic combination of broadband performance with high power and low noise, are available in bare die and industry-standard QFN packages, and provide a cost-effective solution for a variety of frequency and functional applications. And many of our amplifiers are highly integrated with no external components required! Visit www.mimixbroadband.com to learn more about these devices:

CMM4000-BD
Self-Bias Architecture and On-Chip Drain Bias Coil/DC Blocking

CMM0511-QT
RoHS Compliant 3x3mm QFN and Single Positive Supply

Device	Frequency (GHz)	Gain (dB)	Noise Figure (dB)	Output P1dB (dBm)	OIP3 (dBm)	Bias (mA @V)
CMM2000-QT	1.5-6	13	6.0	+14	+24	35 @ 8.0
CMM9000-QT	1.5-6	15	5.5	+15	+25	60 @ 6.0
CMM4000-BD	2-18	8	4.5	+19	+29	115 @ 5.0
XB1007-QT	4-11	23	4.5	+20	+30	100 @ 4.0
CMM0511-QT	5-14	20	-	+11	+22	90 @ 6.0
XB1008-QT	10-21	18	5.5	+20	+30	100 @ 4.0
CMM1118-QT	11-20	20	-	+14	+22	90 @ 5.0
XB1004-BD (Low Noise/Power)	16-30	20 / 21	2.2 / 3.2	+14 / +19	+24 / +29	90 @ 4.0 / 180 @ 6.0
XB1005-BD (Low Noise/Power)	35-45	19 / 23	2.7 / 3.7	+13 / +16	+23 / +26	50 @ 3.5 / 154 @ 4.5

Mimix
BROADBAND™

Mimix Broadband, Inc., 10795 Rockley Rd., Houston, TX 77099 U.S. 281.988.4600 mimixbroadband.com

Visit http://mwj.hotims.com/11724-93 or use RS# 93 at www.mwjournal.com/info

WIRELESS DESIGN GUIDE

Data Sheets • Application Notes • Free Samples

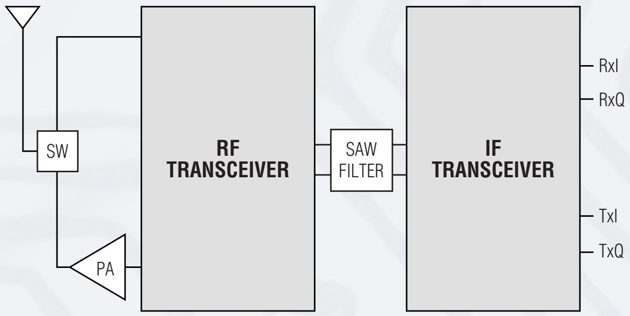
23rd EDITION

NEW

Single-Chip RF Transceivers Enable Mobile WiMAX Worldwide

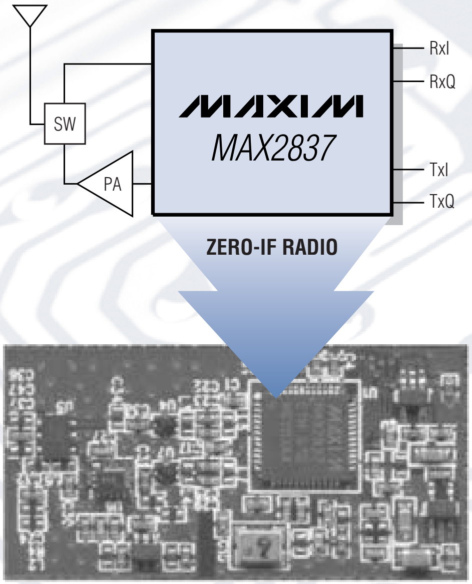
Small Solution Size and Low Power Consumption for Notebooks, PMPs, Cell Phones, CPEs, and Pico/Femto Base Stations

OLD WiMAX™ SOLUTION
(2 RFICs, 1 SAW Filter)



SUPER-HET RADIO

Maxim's NEW WiMAX SOLUTION
(ONLY 1 RFIC)



Complete Radio in 30mm x 12mm

Unsurpassed RF Performance

Receiver

- 2.3dB Rx Noise Figure
- -8dBm Input IP3
- -35dB Rx EVM
- Supports 1.75MHz to 28MHz Channel Bandwidth

Transmitter

- 0dBm Tx Output (64-QAM)
- -37dB Tx EVM
- > 45dB SSB Suppression

VCO/Synthesizer

- -39dBc Integrated VCO Phase Noise
- Frac-N Phase-Locked Loop (PLL) with 20Hz Step Size

RF Transceiver Family for 802.16e Mobile WiMAX

WiMAX Profile Frequency Bands (GHz)	Radio Configuration	No. of Tx	No. of Rx	Part
2.3 to 2.7	SISO	1	1	MAX2837
	MIMO	1	2	MAX2839*
3.3 to 3.8	SISO/MIMO	1	1	MAX2838*

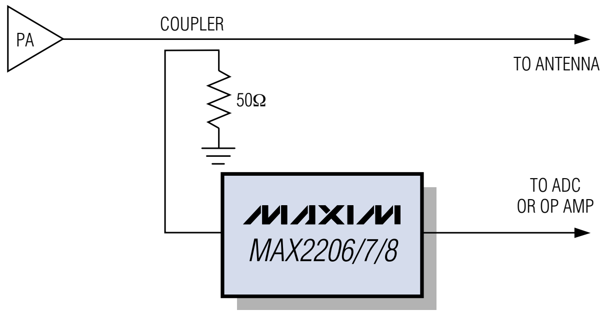
Coming soon: 2 Tx/2 Rx MIMO solution for 3.3GHz to 3.8GHz.

For RF or RF/Baseband Reference Designs, Contact:
wimax-RD@maximhq.com

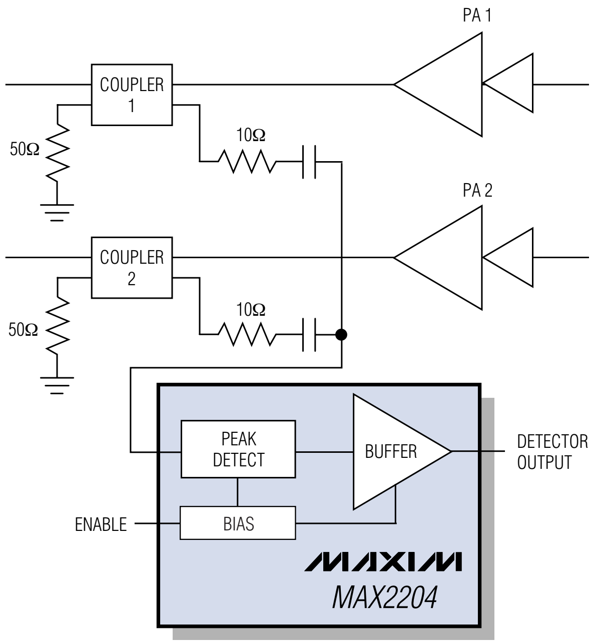
WiMAX is a trademark of the WiMAX Forum.
*Future product—contact factory for availability.

MAXIM

Industry's Smallest Power Detectors Replace Discrete Solutions



PEAK DETECTOR



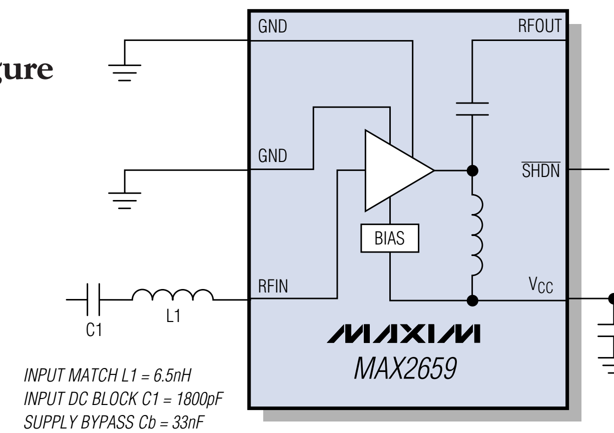
APPLICATION DIAGRAM FOR TWO PAs

- Power-Detection Range
  - 21dB (MAX2204)
  - 25dB (MAX2205/7/8)
  - 40dB (MAX2206)
- 1mm x 1mm, 2 x 2 UCSP (Available with Backside Coating for Easier Nozzle Pickup)
  - MAX2205: CDMA
  - MAX2206: CDMA, GSM
  - MAX2208: CDMA, WCDMA
- 5-Pin SC70
  - MAX2204: WCDMA, UMTS, HSPA
- No External Filter or Op Amp Required
- Internal Temperature Compensation Gives ±0.3dB Accuracy

NEW 0.8dB Noise Figure, 20dB Gain, GPS LNA Improves Your Existing Solution

Ultra-Small Leadless Package Saves Size and Cost

- High 20.5dB Gain
- Ultra-Low 0.8dB Noise Figure
- Integrated 50Ω Output-Matching Circuit
- 4.1mA Supply Current
- 1.6V to 3.3V Supply Voltage
- Ultra-Small, RoHS-Compliant, Leadless 6-Pin μDFN Package



IMPROVES YOUR CURRENT GPS RECEIVER'S SENSITIVITY

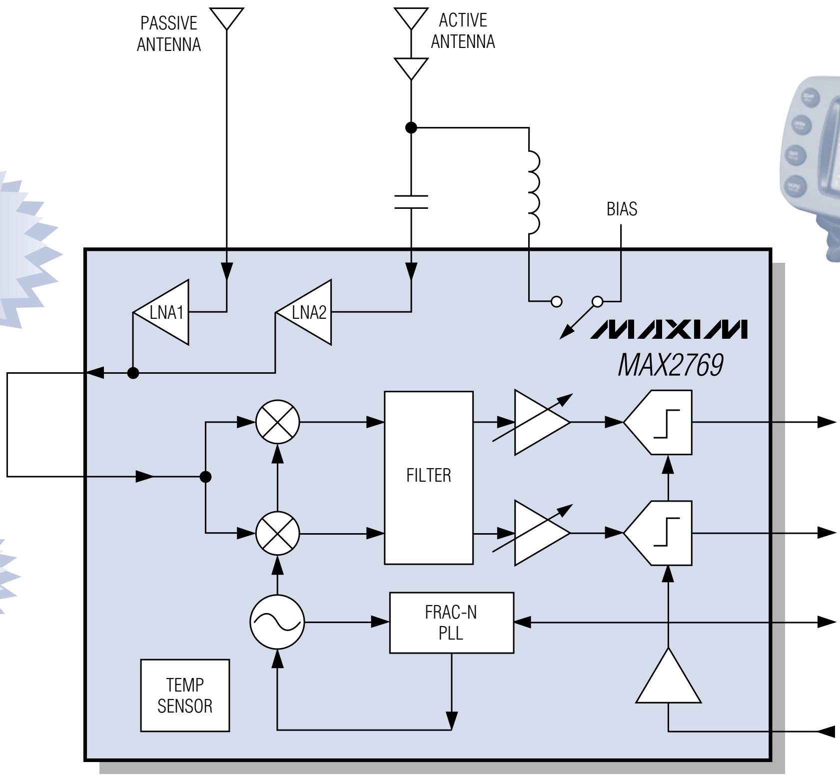
NEW Is Your GPS System Performance Limited by Your RF Front-End?

Improve Your GPS and Galileo Performance and Reduce Cost with the First Fully Programmable, Universal GNSS RF Receiver

The MAX2769 is a single-conversion, low-IF GPS receiver that provides a low NF of 1.4dB. The integrated ADC output is quantized in 1 or 2 bits for both I and Q channels, or up to 3 bits for the I channel. The fully integrated fractional-N synthesizer and VCO enable programming of the IF frequency between 0 and 8MHz, while operating with any reference frequencies ranging from 8MHz to 44MHz. The MAX2769 includes an integrated active-antenna sensor and a dual-input uncommitted LNA for separate passive- and active-antenna inputs. With its programmable power-savings mode, the MAX2769 consumes as low as 10mA.

ONLY 1.4dB NF; ELIMINATES EXTRA LNA

ONLY 10mA I_{SUPPLY}



Packages Available

- Leadless 28-Pin TQFN
- Wafer-Level Packaging (WLP) Available by Request

NOW AVAILABLE IN TESTED DIE

Ideal for

- Cellular E911/E112
- Location-Based Services
- Asset Tracking/Telematics
- Portable Navigation
- Automotive Navigation
- Digital Cameras

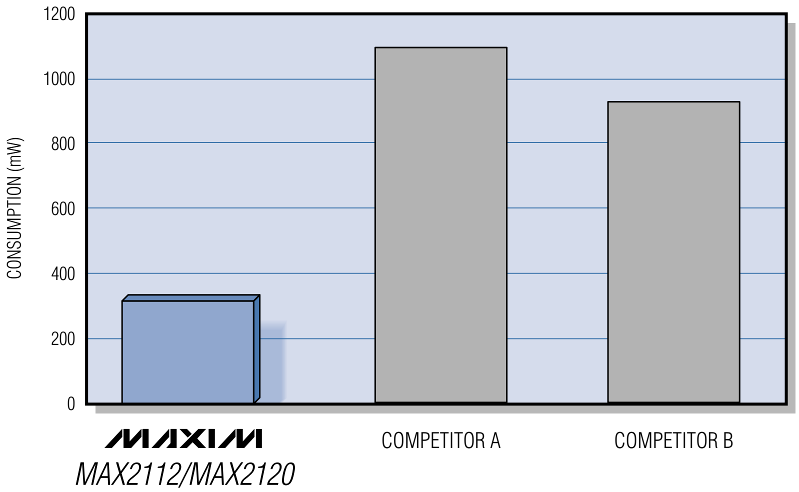
For More Information on Maxim's GPS Solutions, Go to: www.maxim-ic.com/GPS

NEW 3.3V Satellite Tuners Boast 8PSK Performance at Only 330mW of Power Consumption

Small Package Is Ideal for Multituner Set-Top Box Applications

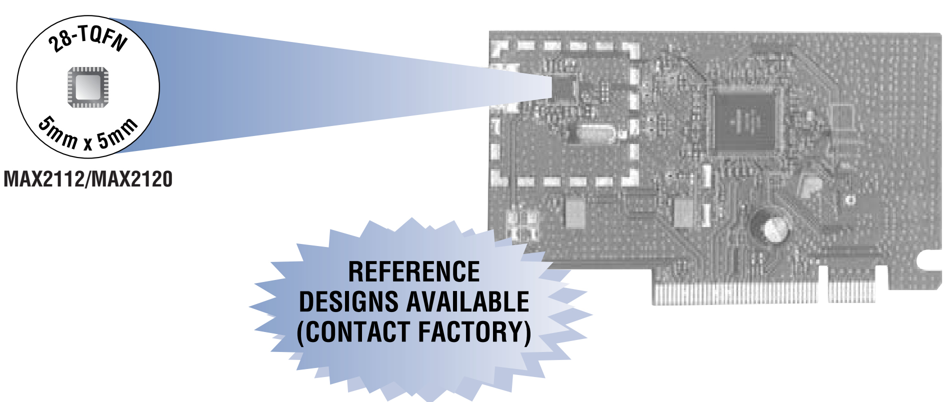
The MAX2112/MAX2120, Maxim's newest satellite tuners, offer the highest performance at the lowest power of any competitive solution. The MAX2112 meets DVB-S2 requirements, while the MAX2120 is targeted for the highly competitive DVB-S market.

MAX2112/MAX2120 USE 64% LESS POWER THAN COMPETITORS



- 3.3V Supply
- 8dB NF Enables Reception of Weak Free-to-Air Signals
- IIP3 of +15dBm Provides Immunity from Adjacent-Channel Interference
- Automatic Configuration of PLL and VCO Simplifies Firmware
- Operation at -40°C Enables Outdoor Applications
- Small 5mm x 5mm, 28-Pin TQFN Package

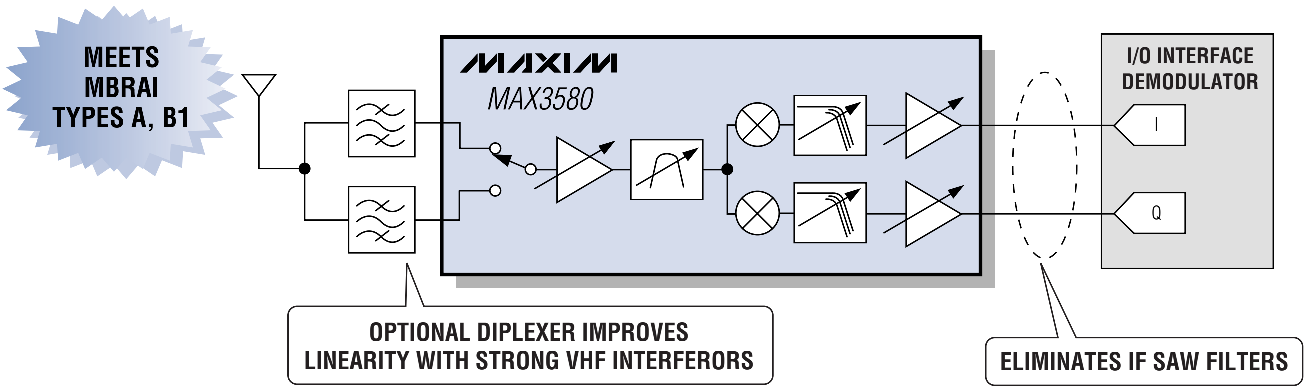
VERY SMALL SOLUTION FOOTPRINT REQUIRES LESS THAN 9cm² OF PCB AREA



Single-Chip Digital Terrestrial-TV Tuners for Mobile, Portable, and Set-Top Box Devices

MAX3580 VHF/UHF DVB-T Tuner

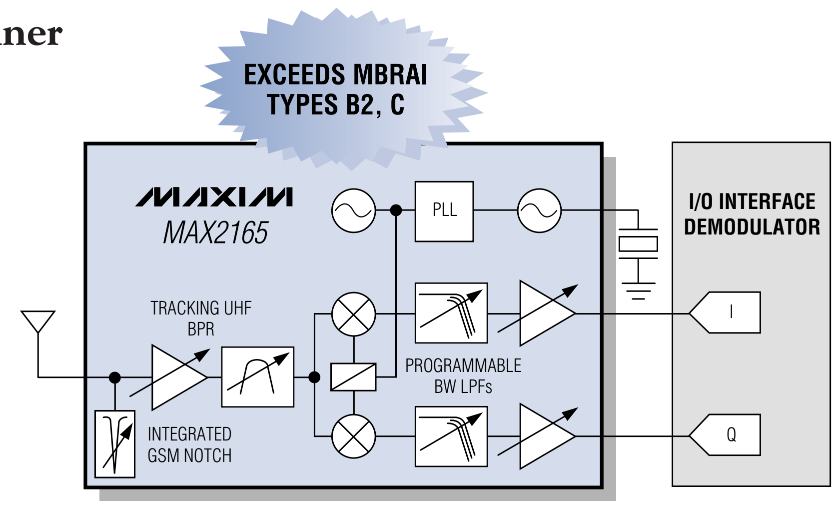
The MAX3580 3.3V digital TV tuner is compatible with DVB-T, ISDB-T, and DMB-T/H standards for both portable and set-top box applications, while meeting MBRAI and NorDig industry standards.



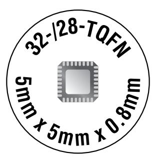
- 6/7/8MHz Channels (Variable BW-LPF)
- Integrated RF-Tracking Filters
- Integrated DC-Offset Correction
- MBRAI and NorDig Unified 1.0.2 Compliant

MAX2165 UHF DVB-H Tuner

- 6/7/8MHz Channels (Variable BW-LPF)
- Integrated RF-Tracking Filter
- Integrated DC-Offset Correction
- MBRAI and NorDig Unified 1.0.2 Compliant
- 2.85V Supply Voltage



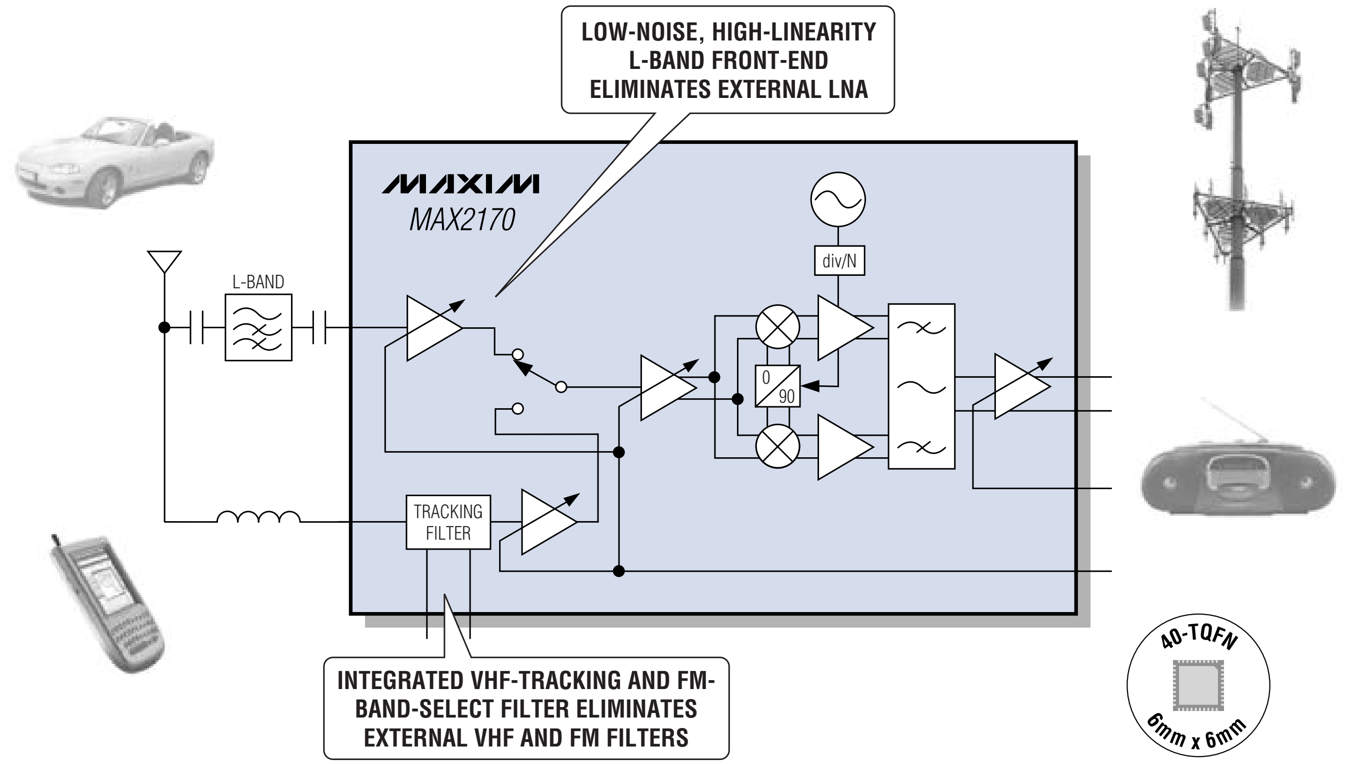
Feature	MAX3580	MAX2165
Bands	VHF/UHF	UHF
Standards	DVB-T, ISDB-T 13 segment, DMB-T/H	DVB-H, DVB-T (UHF)
Cellular notch		✓
Typical NF (dB)	5	3.5
MBRAI compliance	Types A, B1	Types B2, C
Package (5mm x 5mm)	32-TQFN	28-TQFN
Power consumption (mW)	680	24 at 8% duty cycle



Highest Integration Triple-Band Tuner for DAB, DMB-T, and FM Applications

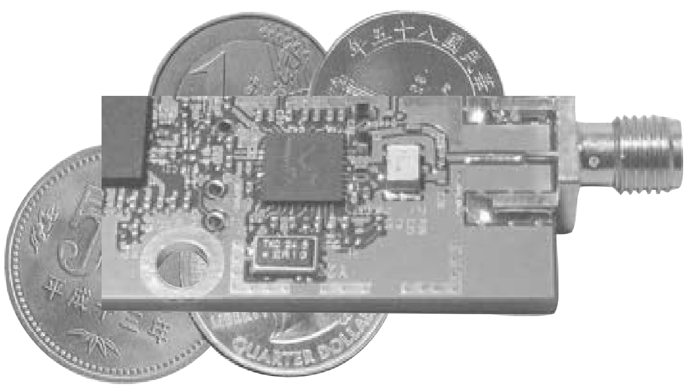
Eliminates the Need for External LNAs and VHF/FM Filters

The MAX2170 is a fully integrated, RF-broadcast tuner for DAB, DMB-T, and FM applications. The integrated low-noise LNA achieves an L-band sensitivity of -99dBm, thereby eliminating the need for external amplifiers. At VHF frequencies, the integrated channel-selection filter achieves an adjacent-channel protection ratio of better than 35dBc; in high-interference environments, it also increases performance while doubling as an FM-band-select filter.



- **First Adjacent-Channel Handling of +40dBc in VHF Band**
- **-100dBm VHF Band-III Sensitivity**
- **-99dBm L-Band Sensitivity**
- **Industry-Standard 2.048MHz Low-IF Interface**
- **2.7V to 3.5V Power Supply**
- **Integrated Closed-Loop RF AGC**
- **Sigma-Delta Fractional-N Synthesizer**
- **Low Power Consumption (170mW in L-Band Mode, Continuous Operation)**

REFERENCE DESIGNS AVAILABLE (CONTACT FACTORY)



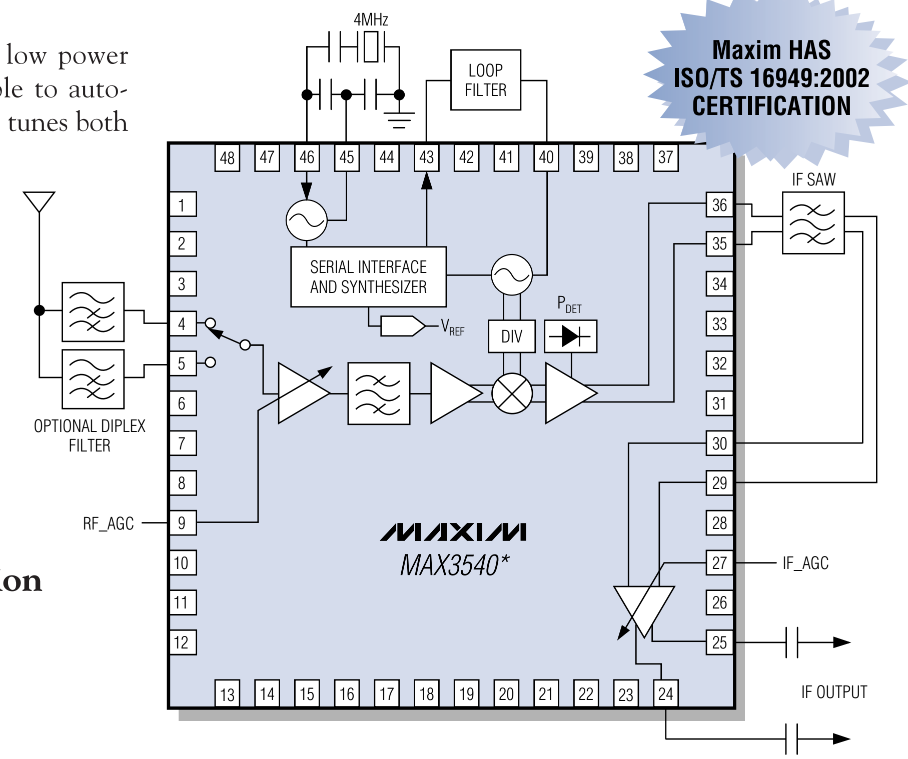
Analog/Digital Tuners Run Cool and Save Space in Automotive TVs

Ultra-Compact MAX3540* Tunes Analog and Digital TV

The MAX3540's small size and low power consumption make it uniquely suitable for automotive TV. Its traditional architecture tunes both analog and digital TV signals.

- **50MHz to 860MHz Frequency Range**
- **36MHz/44MHz IF Frequency**
- **On-Chip Triple-Band Tracking Filter**
- **ATSC, NTSC, and PAL Compliant**
- **800mW Power Consumption**
- **3.3V Supply**

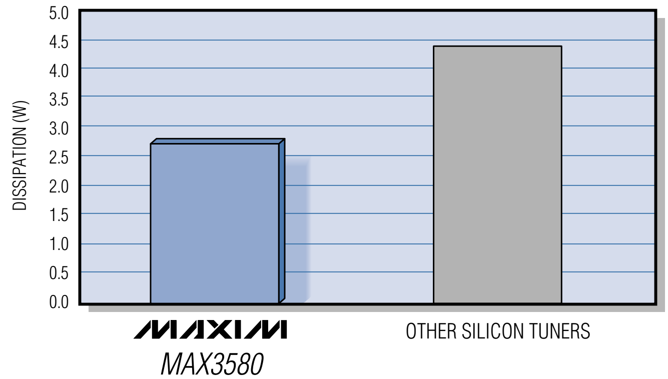
Maxim HAS ISO/TS 16949:2002 CERTIFICATION



MAX3580's Novel Architecture Drastically Shrinks Automotive Diversity Tuner Designs, Meets MBRAI and NorDig Requirements

The MAX3580 is a multistandard digital TV tuner covering DVB-T (Europe), DMB-T/H (China), and ISDB-T 13 segment (Japan). Its direct-conversion architecture eliminates SAW filters. On-chip RF filtering reduces the need for external RF filtering, typically required by traditional CAN-type tuners. This integration results in a greatly reduced overall solution size. The MAX3580 is specified to operate over the -40°C to +85°C temperature range.

POWER DISSIPATION IN A FOUR-TUNER AUTOMOTIVE DIGITAL TV



Maxim's Full Range of Mobile TV Tuners

Broadcast standards dedicated to mobile TV are becoming established or are on the way in many countries around the world. Maxim offers a full range of solutions for mobile TV tuners.

Part	Standard	Region
MAX2160	ISDB-T 1 segment	Japan/Brazil
MAX2165	DVB-H, DVB-T	Europe
MAX2170	DMB-T	Europe/China
MAX3540*	ATSC, NTSC, PAL	All
MAX3580	DVB-T, DMB-T/H, ISDB-T 13 segment	Europe/China/Japan

*Future product—contact factory for availability.

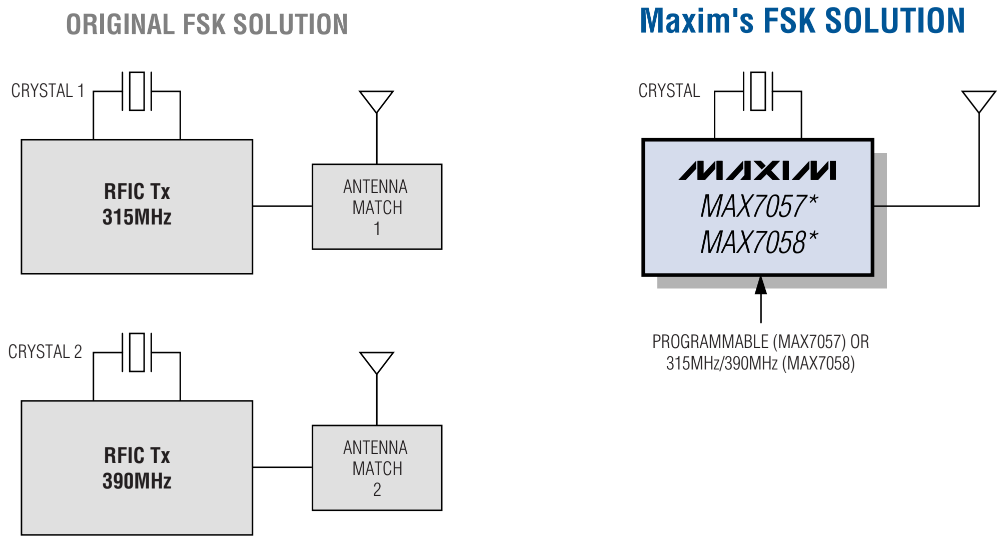
Choose More than One Transmit Frequency and Keep Your Antenna Matched with Just One Crystal

FUTURE PRODUCTS

Programmable Transmitters Open Up the 300MHz to 450MHz ISM Band

The MAX7057*/MAX7058* are programmable multifrequency transmitters that can transmit multiple frequencies using the same crystal. The built-in, 16-bit fractional-N synthesizer operates at any frequency over a 1.475:1 tuning range. The internal tuning capacitor has 16 selectable values for matching the antenna. FSK modulation is spectrally cleaner than ever because you just change the divider ratio without removing the crystal.

The MAX7057 fully programmable, ASK/FSK transmitter is controlled through the SPI™ port and is offered in a 16-pin SO package. The MAX7058 dual-frequency, ASK-only transmitter is available in a 16-pin TQFN package.



- **Tuning Range of 1.475:1**
  - **300MHz to 442.5MHz with a 15.7895MHz Crystal**
  - **305MHz to 450MHz with a 16.0714MHz Crystal**
- **Internal Variable Capacitor for Optimum Antenna Tuning**
- **+10dBm Output Power**
- **ASK/OOK/FSK Modulation**
- **2.1V to 3.6V Single-Supply Operation**
- **< 7.5mA DC Current Drain (50% Duty Cycle OOK)**
- **< 12mA DC Current Drain (FSK)**
- **< 1mA Standby Current**
- **Frequency and Tuning Control Through an SPI Port**
- **Small, 16-Pin TQFN or SO Package**

Part	Temperature Range (°C)	Modulation	Frequency (MHz)	Package	Price† ($)
MAX7057ASE*	-40 to +125	ASK/FSK	SPI programmable	16-SO	1.08
MAX7058ATG*	-40 to +125	ASK	315/390	16-TQFN	1.13

SPI is a trademark of Motorola, Inc.
*Future product—contact factory for availability.
†10k-up recommended resale. Prices provided are for design guidance and are FOB USA. International prices will differ due to local duties, taxes, and exchange rates. Not all packages are offered in 1k increments, and some may require minimum order quantities.

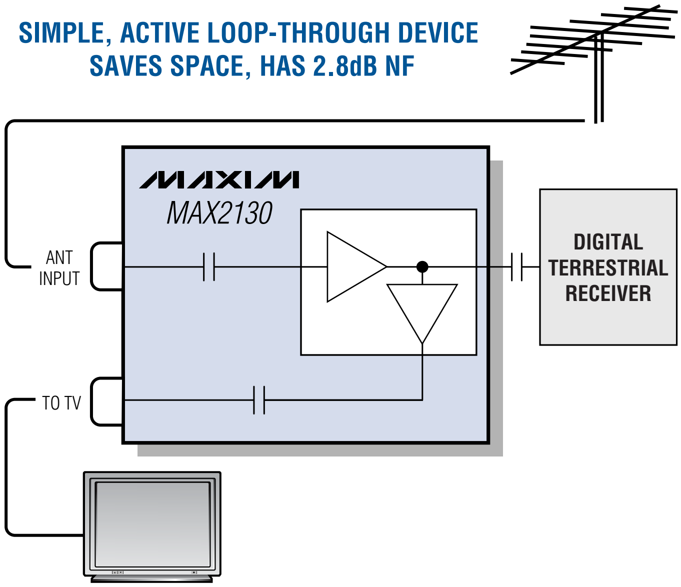
Low-Noise Amp for TV Tuners and Set-Top Boxes

Eliminates Broadband Splitter and Improves SNR

The MAX2130 is ideal for digital terrestrial receivers (DVB-T or VSB). The amplifier has a low 2.8dB noise figure and an IIP3 of 17.5dBm. The MAX2130 also has a second integrated loop-through output. The unbalanced input and outputs allow use with existing canned-tuner architectures.

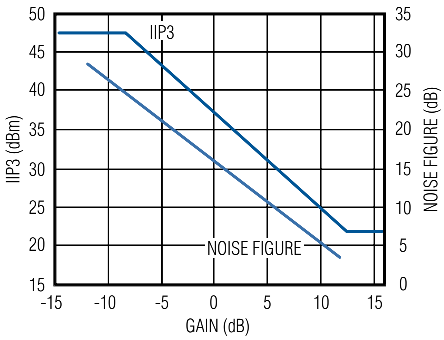
When used with a pin-diode attenuator, the low-noise MAX2130 provides enough gain (15dB) at low input levels to deliver an acceptable signal-to-noise ratio (SNR) to the receiver. Also, it simultaneously provides low distortion during high signal-level conditions. The loop-through output eliminates the need for a splitter or directional coupler to provide a TO TV output. The part requires a 5V supply and draws 93mA.

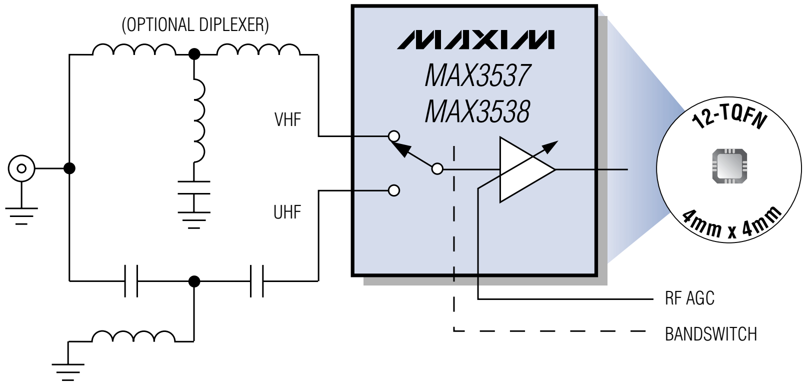
SIMPLE, ACTIVE LOOP-THROUGH DEVICE SAVES SPACE, HAS 2.8dB NF



Broadband Variable-Gain Amps Meet Tough Linearity Requirements, Improve TV-Tuner NF and AGC Range

IIP3 AND NOISE FIGURE vs. GAIN





- **50MHz to 878MHz Operating Frequency Range**
- **Improve Sensitivity for Low-Input-Power Applications**
- **Very High IIP3: +33dBm at 12dB Backoff**
- **On-Chip Bandswitch Works with External Diplex Filter to Significantly Reduce 2nd-Order Distortion**
- **Single-Ended Inputs and Outputs Eliminate Expensive Baluns**

FUTURE PRODUCT

Industry's Only +125°C-Rated 300MHz to 450MHz ASK Receiver

Maintains Excellent Sensitivity, Even at +125°C, Making It Ideal for Remote-Start/Automotive Applications

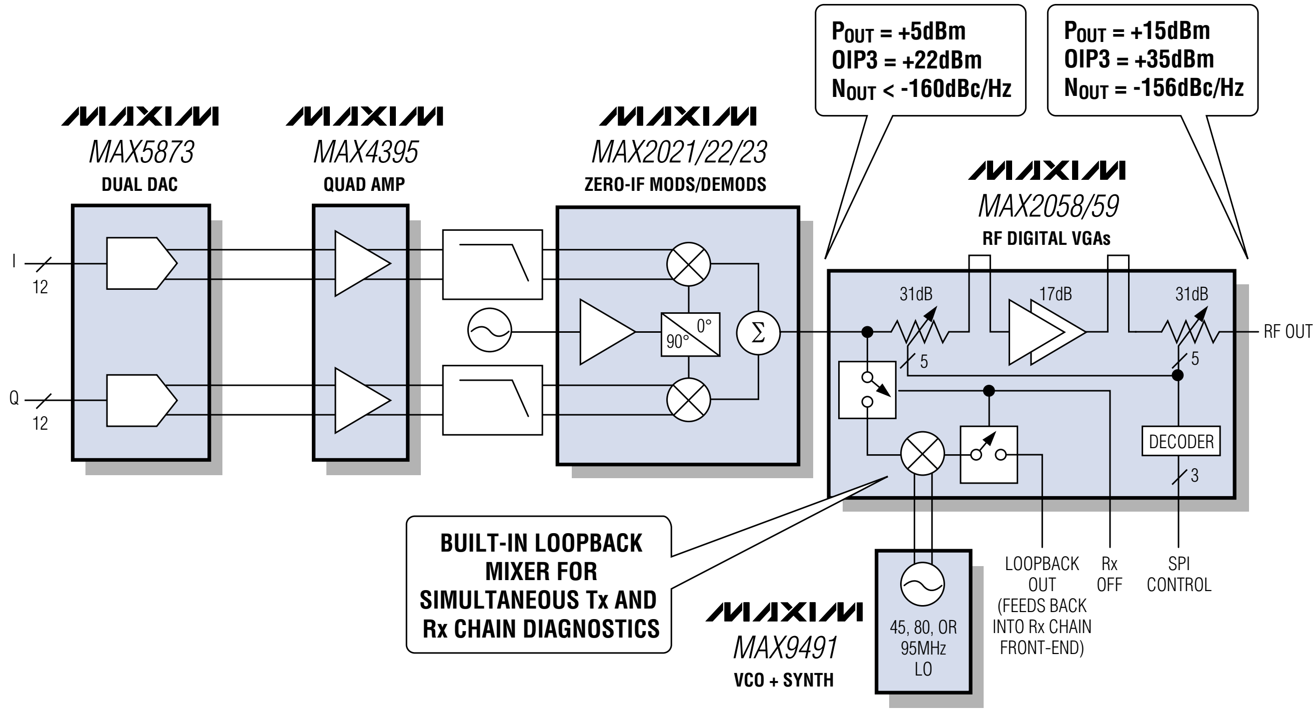
The MAX7034* is a +125°C-rated ASK receiver ideally suited for remote-start/automotive applications where the receiver is exposed to extreme high temperatures. The MAX7034 is based on the highly successful MAX1473/MAX7033. Like these devices, this receiver includes an LNA, a fully differential image-rejection mixer, an on-chip PLL with an integrated VCO, a 10.7MHz IF limiting amplifier stage with received-signal-strength indicator (RSSI), and analog baseband data-recovery circuitry. The MAX7034 is available in a 32-pin TQFN package that is pin-compatible with the MAX1473/MAX7033.

- **Excellent Receive Sensitivity over Temperature**
  - **-114dBm (at Peak Power, 315MHz, +25°C)**
  - **-105dBm (at Peak Power, 315MHz, +125°C)**
  - **-113dBm (at Peak Power, 434MHz, +25°C)**
  - **-103dBm (at Peak Power, 434MHz, +125°C)**
- **Operates from a Single 5.0V Supply**
- **Selectable Image-Rejection Center Frequency**
- **< 6.5mA Low Operating Supply Current**
- **< 3µA Low-Current Power-Down Mode for Efficient Power Cycling**
- **250µs Startup Time**

Part	Temperature Range (°C)	Modulation	Frequency (MHz)	Package	Price† ($)
MAX7034ATJ*	-40 to +125	ASK	300 to 450	TQFN	1.39

*Future product—contact factory for availability.
†10k-up recommended resale. Prices provided are for design guidance and are FOB USA. International prices will differ due to local duties, taxes, and exchange rates. Not all packages are offered in 1k increments, and some may require minimum order quantities.

Highest Linearity, Lowest Noise, Direct-Conversion Transmitter for GSM/EDGE Base Stations

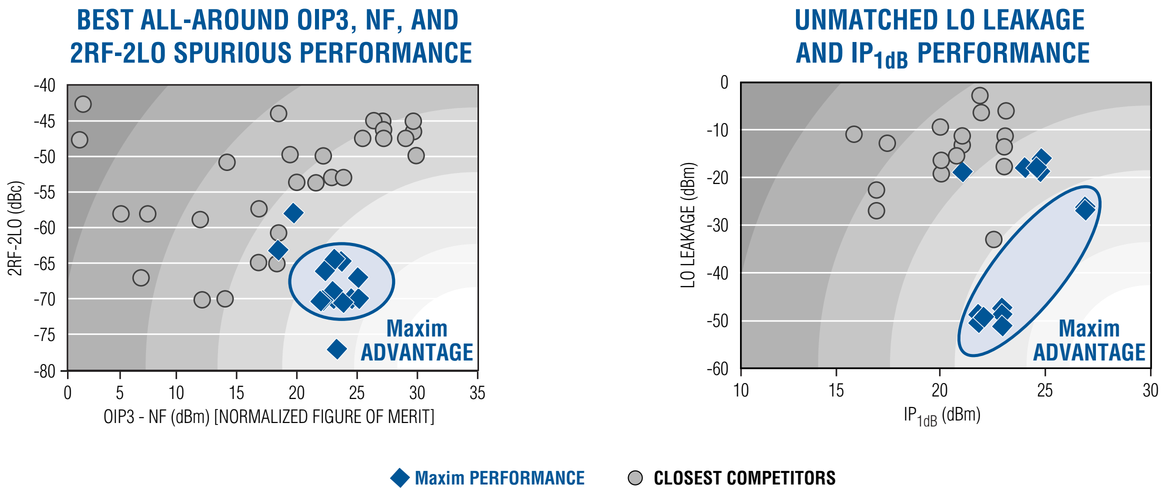


- **Complete Conformance to GSM/EDGE Specifications**
  - Meets All Spectral-Mask and Noise-Floor Requirements
  - < -156dBc/Hz Noise at 6MHz Offset
  - LO Leakage < -40dBc Over Temp and Frequency (After Nulling)
  - +15dBm/+12dBm Output Power (GSM/EDGE)
- **Highly Efficient, Low-Cost Solution**
  - Four-Chip Solution (Five Chips with Tx Diagnostic Loopback Feature)
  - No Ancillary RF Filters Required
- **Up to 62dB of Lineup Gain Control**
  - 12dB Static Control
  - 30dB Dynamic Control
  - > 10dB Lineup Compensation
- **Built-In Loopback Test Mixer (MAX2058/MAX2059)**
  - Ideal for Performing Simultaneous Diagnostics of Tx and Rx Chains in Real Time
  - Preprogram the MAX9491 with 45/80/95MHz LO Settings
- **Pin-Compatible Lowband and Highband Versions**

For More Information, Go to:
www.maxim-ic.com/gsmzif

Industry's Highest Performin

Complete Line of Up-/Downconvert



- **Lowest NF Equates to Less Gain Needed Ahead of Mixer, Allowing**
  - Relaxation of ADC Dynamic-Range Requirements
  - Relaxation (or Complete Elimination) of AGC
  - Greater Receiver Resiliency to Blockers

- **Unparalleled 2RF-2LO Performance**
  - Eases Filtering Requirements
  - Allows Design to Employ Lower IF Frequencies, Leading to
    - Easier Frequency Planning
    - Use of More Cost-Effective, Low-IF ADCs

- **Highest Levels of Integration**
  - Low LO Drive Needed Due to On-Chip LO Buffers
  - On-Chip LO Switches Support Frequency Hopping
  - On-Chip IF Amplifiers
  - Integrated RF and LO Baluns

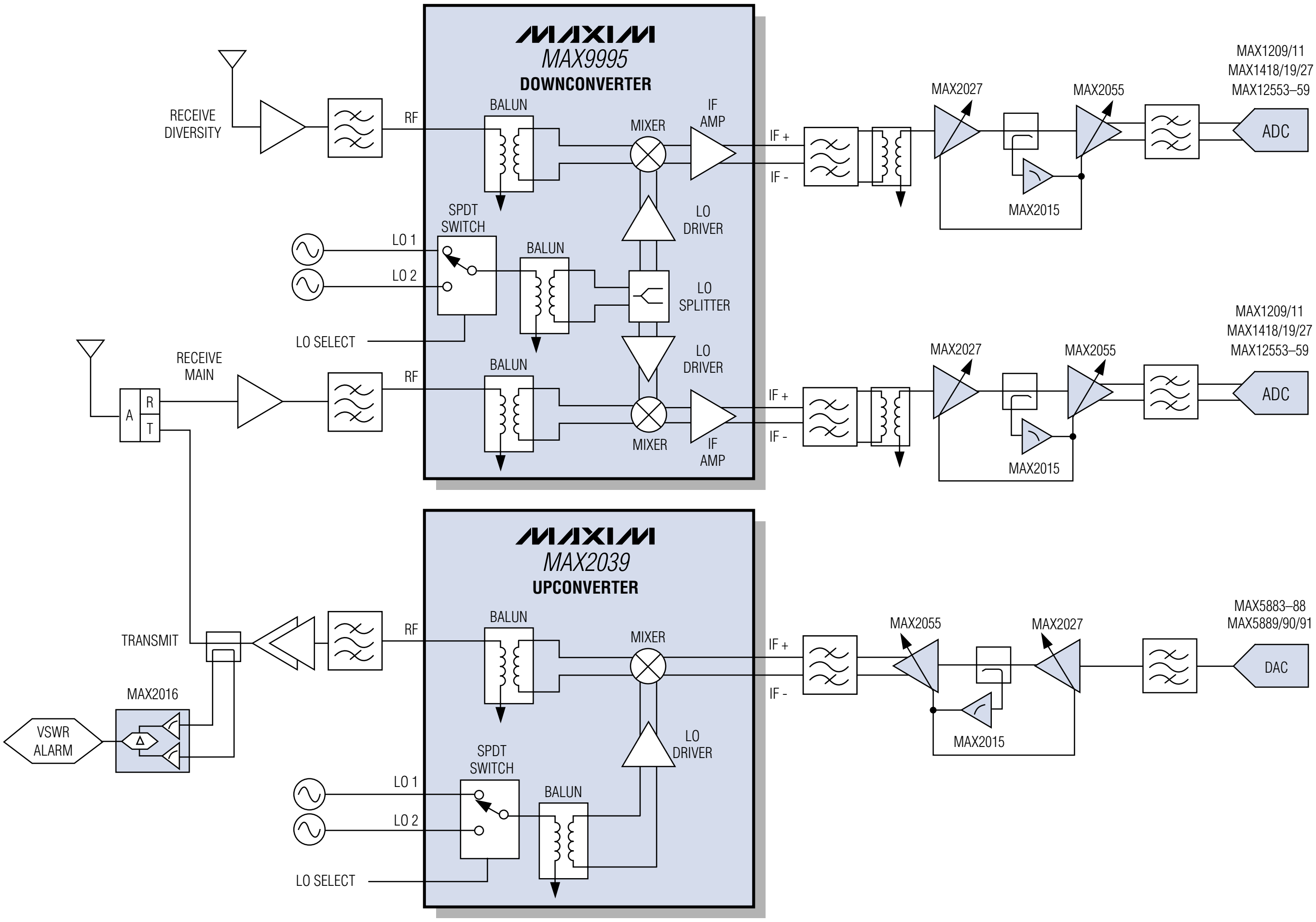
- **Compact, 5mm x 5mm, 20-Pin and 6mm x 6mm, 36-Pin TQFN**

- **Pin-Compatible Parts for the 400MHz, 850MHz/900MHz, 2GHz, 2.5GHz, and 3.5GHz Bands**

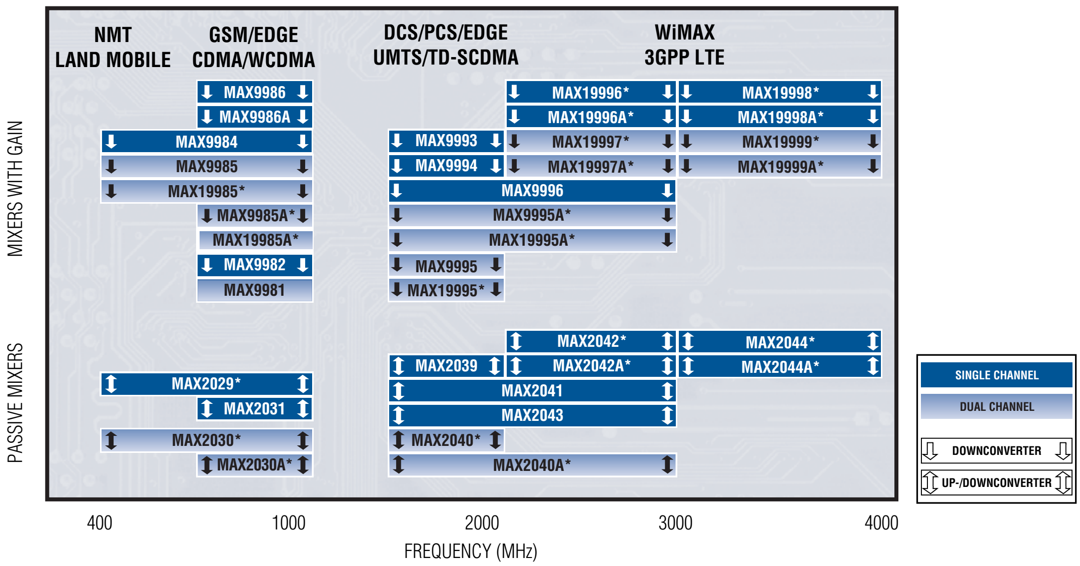
Continued on Next Pa

Monolithic Mixer Portfolio

Wireless Infrastructure

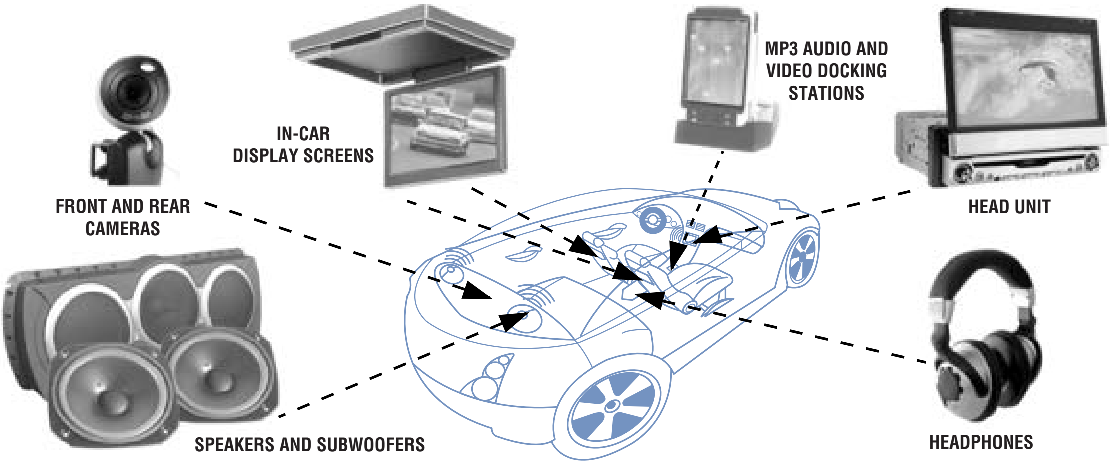


COMPLETE PORTFOLIO OF SINGLE-/DUAL-CHANNEL PIN-COMPATIBLE SOLUTIONS FOR ALL 400MHz TO 4000MHz WIRELESS STANDARDS

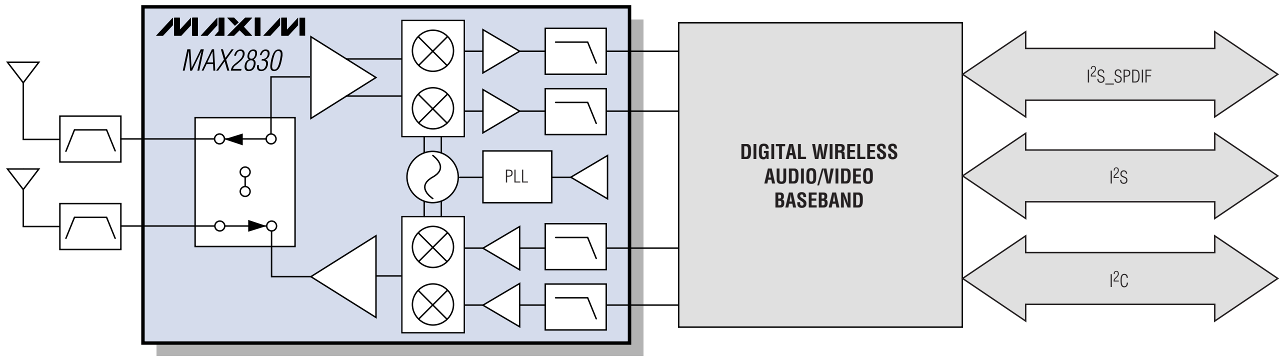


*Future product—contact factory for availability.

NEW Digital Wireless Audio/Video Solution Provides Robust, Interference Resistant, CD-Quality Audio



DIGITAL WIRELESS AUDIO/VIDEO SOLUTION



Digital Wireless Audio/Video Solution

- Encrypted, Wideband, Worldwide 2.4GHz Link
- Real-Time RF Sniffer for Clear Channel Detection
- Automatic and Seamless RF Channel Switching
- Robust Coexistence and Interference Resistance
- Automatic Antenna Diversity for Improved Range
- Uncompressed CD-Quality Audio (16 bit/48ksps)
- Supports 6Mbps to 8Mbps SD Video
- Configurable, Low-Latency Performance
- Up to Eight Uncompressed Audio Channels
- Point-to-Point and Point-to-Multipoint Operation
- 20kbps Bidirectional Data Channel

MAX2830 2.4GHz, 802.11g Transceiver

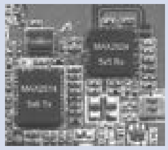
- +17dBm, 11g PA
- Tx/Rx and Rx Antenna Diversity Switches
- 62mA Receive Current
- Low-Power Shutdown Mode
- 3.3dB Noise Figure
- -75dBm, 11g, 54Mbps Sensitivity
- Programmable 14MHz to 40MHz Channel Bandwidth
- Integrated Crystal Oscillator Allows Use of Small, Low-Cost Crystals

For More Details Regarding the Wireless Digital Audio Solution, Contact: WLAN@maximhq.com

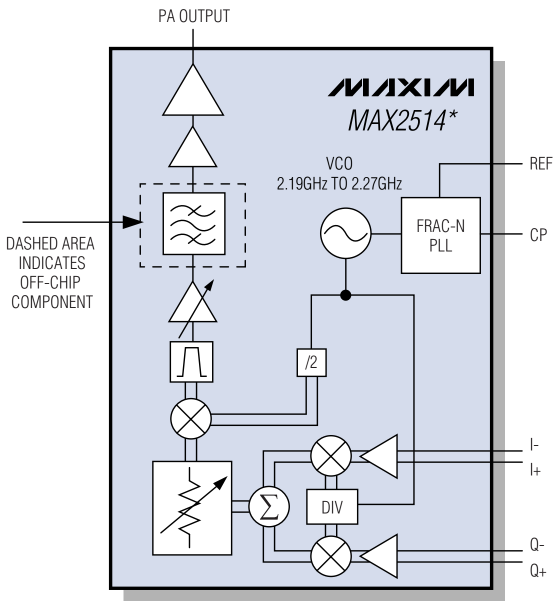
Ultra-Compact CDMA Radio Enables ULC Thin Phones for Emerging Markets

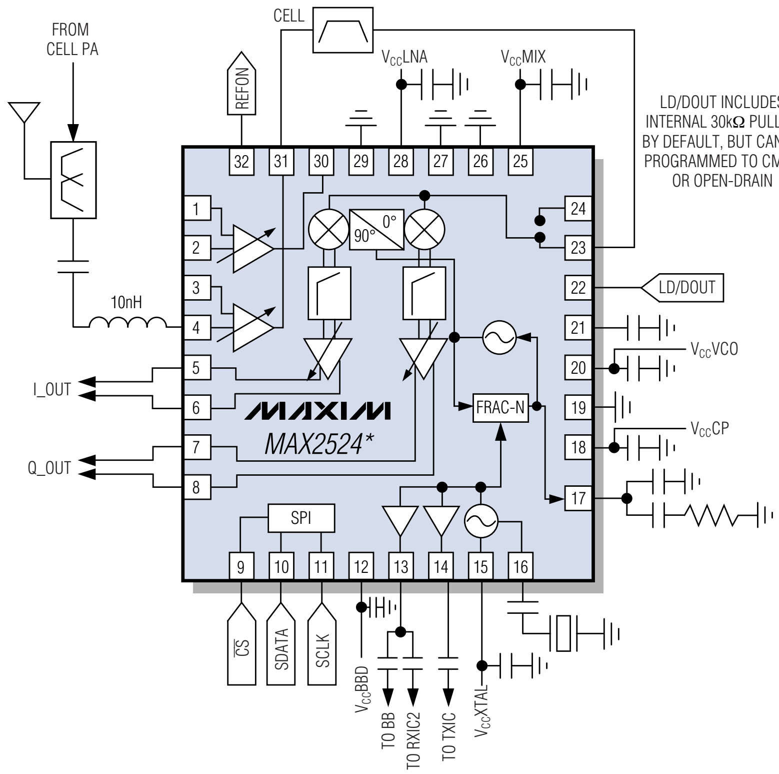
Maxim's ultra-compact CDMA radio, designed using the MAX2514* transmitter and MAX2524* receiver chipset, integrates an Rx VCO, PA, Rx LNA, and digital crystal control (DCXO). The full radio BOM for this design is: 2 small ICs (MAX2514 and MAX2524), 2 tiny SAW filters, 1 small duplexer, 1 crystal, 6 resistors, 31 capacitors, and 5 inductors. Due to innovative design and high levels of integration, the solution size is only 18mm x 16mm and the overall cost is very low, thus enabling the next generation of thin cell phones in emerging markets such as India.

Maxim's CDMA RADIO



18mm x 16mm





MAX2514* Transmitter with Integrated PA

- Excellent PAE
- ~50mA I_{CC} (Tx Only)
- No Need for Couplers/Detectors
- 90dB Dynamic Range
- I_{CQ} Registers Optimize Talk Time
- Low Rx Noise
- 5mm x 6mm FCLGA

MAX2524* Receiver with Integrated DCXO

- 2.0dB System NF
- Four Programmable Gain States
- -26dBm Single Tone
- Low I_{CC}
- Excellent DC Offset
- 5mm x 5mm, 32-Pin TQFN

For More Information About the Ultra-Compact CDMA Radio Design, Contact: cellular@maximhq.com

*Future product—contact factory for availability.