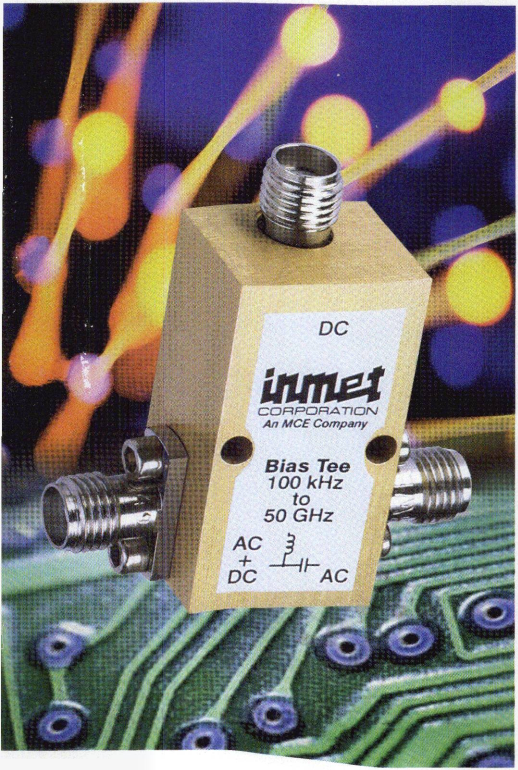
microwave JOURNAL®
EURO-GLOBAL EDITION

OCTOBER 2000
VOL. 43, NO. 10



COMMUNICATIONS AND PCNs

CD RADIOS FOR AUTOMOBILE USE

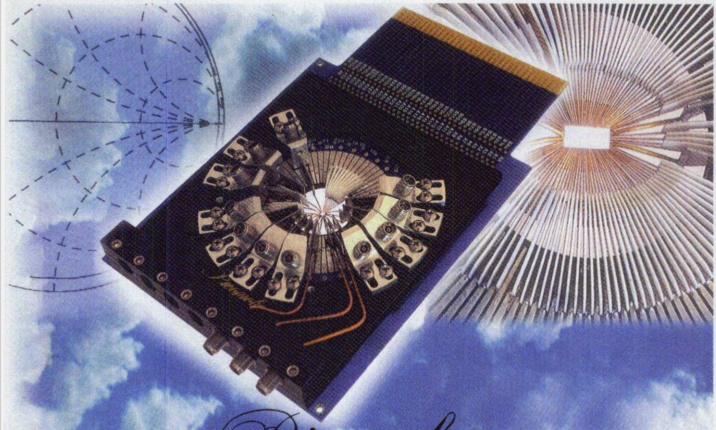
A HIGH ORDER FREQUENCY MULTIPLIER

ISM VS. SPREAD SPECTRUM — AVOIDING THE FCC

CONTENTS, P. 10

Founded in 1958

horizon house®

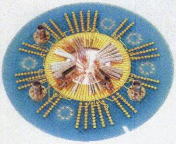


Picoprobe®

Picoprobe elevates probe cards to a higher level...

(...110 GHz to be exact.)

For 17 years GGB Industries, Inc., has blazed the on-chip measurement trail with innovative designs, quality craftsmanship, and highly reliable products. Our line of custom microwave probe cards continues our tradition of manufacturing exceptional testing instruments.



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

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

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

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

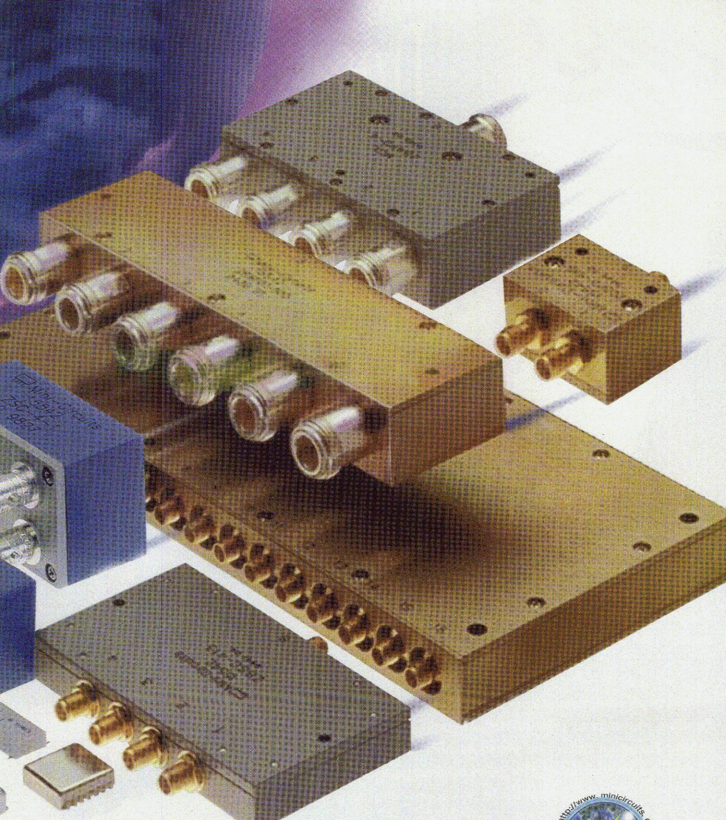
Typical Specs	10GHz	20GHz	40GHz
Insertion Loss	0.6 dB	0.8 dB	1.3 dB
Return Loss	22 dB	18 dB	15 dB

For technical assistance, custom product designs, or off-the-shelf delivery, call GGB Industries, Inc., at (941) 643-4400.

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

Telephone (941) 643-4400 • Fax (941) 643-4403 • E-mail email@ggb.com • www.picoprobe.com

CIRCLE 57 ON READER SERVICE CARD



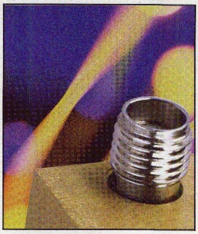

3G
Design In
Build Out
Wireless Products
PROBLEM: Reduce size of 3G feedforward power amplifiers by 50%
SOLUTION: Specify K&L Delay filters in primary and secondary loops
Primary loop delay filter assemblies integrate high power cavity delay filters, couplers and isolators into a single compact module for performance improvement, space savings and cost reduction.
Secondary loop miniature delay filters utilize a Patent Pending topology to provide delay equalization. The filters exhibit excellent delay and phase flatness in a miniature surface mount package. The 3G model measures a mere 1.5"L x 0.60"W x 0.4"H and can be mounted directly onto your PWB with pick and place machinery.
K&L MICROWAVE
KC40-2150-100/D15.0-A
Order On-Line
New! Buy K&L Filters over the web
www.klmicrowave.com
USA
Phone: 410-749-2424
FAX: 410-749-2788
www.klmicrowave.com • E-mail: wireless@klmicrowave.com
EUROPE
Phone: 44-(0)-1262 605500
FAX: 44-(0)-1262 605504
K&L
MICROWAVE INCORPORATED
A DOVER TECHNOLOGIES COMPANY

microwave JOURNAL®

OCTOBER 2000 • VOL. 43, NO. 10

FEATURES

[Continued on page 12]



ON THE COVER

A broadband bias tee for optical networking applications is featured on this month's cover

Cover art courtesy of Inmet Corp.

148

43 Years of Publishing Excellence

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

POSTMASTER: Send address corrections to *Microwave Journal*, PO Box 3256, Northbrook, IL 60065-3256. 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 deals with VHF through light frequencies. Other subscriptions are: domestic, $110.00 per year, two-year subscriptions, $165.00; foreign, $180.00 per year, two-year subscriptions, $340.00; back issues (if available) and single copies, $10.00 domestic and $20.00 foreign.

BPA INTERNATIONAL

Horizon House also publishes *Telecommunications®* and *Journal of Electronic Defense*

Posted under Canadian international publications mail agreement #0738654

microwave JOURNAL®

FEATURES

DEPARTMENTS

Press run for this issue is 58,605 copies

Printed in the USA

STAFF

Publisher/Editor: Harlan Howe, Jr.
Associate Publisher: Edward Johnson
Managing Editor: Amy E. Norcross
Technical Editor: Frank M. Bashore
Staff Editor: James T. Walsh
Editorial Secretaries: Allison Greco, Gayl Sanzi
Consulting Editor: Howard I. Ellowitz
Consulting Editor: Theodore S. Saad
Consulting Editor: Peter Staecker
Int'l Correspondent: Martin Streetly
Int'l Staff Editor: Steve McClelland
Assistant to the Publisher: Kristen Dednah
Traffic Manager: Edward Kiessling
Traffic Administrator: Michelle Carletti
Production Manager: Robert Bass
Production Assistant: Jennifer Johnson
Design Director: R.A. Pike
Art Director: Bill Haff
DTP Coordinator: Janet A. MacDonald
Graphic Designer: Sachiko Stiglitz
Graphic Design Group:
Sandra Deneault • Andrew Ross
Amanda Ruppert

EUROPE

Deputy Publisher: Sam Baird
Office Manager: Eugenie Hardy
Sales Manager: Gareth Watson

CORPORATE STAFF

Chairman & Executive Officer: William Bazzy
President: William M. Bazzy
VP Finance & Operations: Charles A. Ayotte
VP Group Publishing: William Waller
Corporate Vice President: Joan B. Egan

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

www.mwjournal.com

European Editorial Office:
46 Gillingham Street, London SW1V 1HH, England
Tel: Editorial: +44 171 596 8730 Sales: +44 171 596 8740
Fax: +44 171 596 8749

Eighth IEEE International Symposium on Electron Devices for Microwave and Optoelectronic Applications (EDMO 2000)
November 13–14, 2000
Glasgow, Scotland

Sponsors: The University of Glasgow, IEEE UK&RI MTT-S, Electron Device Society, Antennas & Propagation Society, Lasers and Electro-Optic Society joint chapter and the Scottish chapter of the IEEE Lasers and Electro-Optics Society. Topics: Advances in III-V transistors for mm-wave applications; high speed laser diodes, optical modulators and photodetectors; Si- and SiGe-based devices for RF and optoelectronics applications; modeling of microwave and optoelectronic devices; wide bandgap devices for microwave and optoelectronic applications; novel material optoelectronic and microwave devices; low distortion microwave devices for efficient mixer and power amplifier applications; optical control of microwave and mm-wave devices; microwave and optoelectronic photonic crystal devices; and components for fiber radio applications. Contact: Iain Thayne or Karen McIlvaney, University of Glasgow, Department of Electronics and Electrical Engineering, Glasgow G12 8LT, Scotland, UK +44 (0)141 330 3859/6674, fax +44 (0)141 330 6010 or e-mail: edmo@elec.gla.ac.uk. Additional information is available at www.elec.gla.ac.uk/edmo2000.

56th ARFTG Microwave Measurements Conference: Metrology and Test for RF Telecommunications
November 30 - December 1, 2000
Boulder, CO

Topics: Fundamental microwave measurements and microwave metrology, with a focus on wireless RF telecommunications. Contact: Kate Remley, National Institute of Standards and Technology (NIST) (303) 497-3652 or e-mail: remley@boulder.nist.gov. Additional information is available at www.arftg.org.

2000 Asia-Pacific Microwave Conference (APMC 2000)
December 3–6, 2000
Sydney, Australia

Sponsors: CSIRO Telecommunications and Industrial Physics, IEEE South Wales and South Australia sections and IEEE MTT-S. Topics: Computational electromagnetics, CAD, electromagnetic field theory, guided waves, EMC/EMI, ferrite and solid-state devices, MMIC technology, medical/biological applications of microwaves, microwave superconductivity, high speed digital circuits, microstrip and planar antennas, microwave acoustics and measurements, optical devices and systems, optoelectronic techniques, microwave-optical interactions, phased- and active-array techniques, mobile communications systems and remote sensing. Contact: ICMS Pty Ltd. +61 2 9290 3366, fax +61 2 9290 2444 or e-mail: apmc@icms.com.au. Additional information is available at www.icms.au/apmc.

2000 IEEE International Electron Devices Meeting (IEDM)
December 11–13, 2000
San Francisco, CA

Topics: Research breakthroughs in semiconductors and other electron devices. Contact: Phyllis Mahoney, IEDM 2000, 101 Lakeforest Blvd., Suite 400B, Gaithersburg, MD 20877 (301) 527-0900, ext. 103, fax (301) 527-0994 or e-mail: phyllism@widerkehr.com. Additional information is available at www.ieee.org/conference/iedm.

22nd Army Science Conference
December 12–13, 2000
Baltimore, MD

Sponsor: Assistant Secretary of the Army (Acquisition, Logistics and Technology). Topics: Advanced materials and manufacturing, microelectronics and photonics, advanced propulsion technologies, engineering sciences, environmental and geosciences, biomedical and behavioral sciences, force protection, high performance computing and simulation, soldier sys-

tems, and sensors and information processing. Contact: Army Science Conference Registration Desk (757) 357-4011, fax (757) 357-5108 or e-mail: asc2000info@aol.com. Additional conference information is available at www.asc-2000.com.

International Symposium on Advanced Packaging Materials: Processing, Properties and Interfaces
March 11–14, 2001
Braselton, GA

Sponsors: IMAPS; IEEE Components, Packaging and Manufacturing Technology Society; and the Packaging Research Center, Georgia Institute of Technology. Topics: adhesives, bumping materials and processing, consumer electronic material issues (cellular phones), integral passive materials, interfacial adhesion, manufacturing process control, mechanics of materials, microwave materials, on-chip interconnect materials, optoelectronics substrates, HEI and dielectrics, thermal management materials, and underfills and encapsulant materials. Contact: IMAPS, 1850 Centennial Park Dr., Suite 105, Reston, VA 20191 (888) 464-6277 or (703) 758-1060, fax (703) 758-1066. Additional information is available at www.imaps.org.

IEEE Sarnoff Symposium
March 21, 2001
Trenton, NJ

Call for papers. Sponsors: IEEE MTT-S, IEEE Princeton section, The College of New Jersey (TCNJ) student branch and TCNJ engineering department. Advances in wired and wireless communications. Send abstracts as hard copy, electronically or via fax. **Deadline: October 31, 2000.** Contact: Bernard D. Geller, Sarnoff Corp., 201 Washington Rd., Princeton, NJ 08540 (609) 734-2629, fax (609) 734-2050 or e-mail: b.geller@ieee.org.

MIOP (The German Wireless Week)
May 8–10, 2001
Messe Stuttgart, Germany

Topics: Active/passive microwave components; antennas/feeding networks/filters; MMICs; new semiconductor technologies and materials; modern CAD tools; simulation/linear and nonlinear modeling; field theory; integration/assembly and interconnect; microwave measurements; reliability; electromagnetic compatibility; commercial/industrial subsystems/sensors; MEMS; biological/medical applications; quasi-optics; microwave, millimeter-wave and terahertz photonics; optically controlled phased-array antennas; optical communications; optical sensors; optical measurements; and microwave/optics. Contact: Christine Vesche, NETWORK-OSE GmbH +49 (0) 50 33 70 57, fax +49 (0) 50 33 79 44 or e-mail: vesche@networkgmbh.de.

2001 IEEE MTT-S International Microwave Symposium and Exhibition
May 20–25, 2001
Phoenix, AZ

Call for papers. Research, development and application of RF and microwave theory and techniques. Technical papers for this symposium must be submitted via the IMS2001 Web site (www.ims2001.org). Complete information on how to submit a paper and register for the conference, as well as other important information, can be found at the site. **Deadline: November 27, 2000.** A microwave exhibition and historical exhibit, the RFIC Symposium and the ARFTG Conference will also be held during Microwave Week 2001. For symposium information, contact: Vijay Nair, technical program chair, Motorola Inc. (408) 413-5922, fax (408) 413-5934 or e-mail:vnair@ieee.org. For exhibition information, contact: Kristen Dednah, Horizon House Publications, 685 Canton St., Norwood, MA 02062 (781) 769-9750 or e-mail: kdednah@mwjournal.com.

WORKSHOPS & COURSES

RF AND WIRELESS MADE SIMPLE

■ **Topics:** RF waves and their characteristics, converting numbers to decibels, RF devices and how they work, the block diagram of a complete wireless system, how voice and video signals are digitized and multiple access technology in lay terms. Fee: $895.
■ **Site:** Mountain View, CA
■ **Dates:** November 14–15, 2000
■ **Contact:** Besser Associates, 201 San Antonio Circle, Bldg. E, Suite 280, Mountain View, CA 94040 (650) 949-3300, fax (650) 949-4400 or e-mail: info@bessercourse.com.

PHASED-ARRAY RADAR

■ **Topics:** Principles and technology of the phased-array antenna as well as overall system significance, design and performance. Fee: $1470.
■ **Site:** Stockholm, Sweden
■ **Dates:** November 14–16, 2000
■ **Contact:** Research Associates of Syracuse (RAS), 6780 Northern Blvd., Suite 100, East Syracuse, NY 13057 (315) 463-2266, fax (315) 463-8261 or e-mail: seminars@ras.com.

GUIDANCE, NAVIGATION AND CONTROL: THEORY AND APPLICATION

■ **Topics:** Principles of Inertial Navigation Systems (INS), how INS errors arise and grow with time, and how other navigation systems are integrated with an INS. Fee: $1195.
■ **Site:** Atlanta, GA
■ **Dates:** November 14–17, 2000
■ **Contact:** Continuing Education, Georgia Institute of Technology, Atlanta, GA 30332 (404) 385-3502 or e-mail: conted@gatech.edu.

DIGITAL CELLULAR COMMUNICATION SYSTEMS: GSM, CDMA, TDMA

■ **Topics:** Digital systems, with emphasis on GSM and related systems based on TDMA, such as IS-54, and the evolving personal communications systems, such as DCS1800. Fee: $1195.
■ **Site:** Tempe, AZ
■ **Dates:** December 4–7, 2000
■ **Contact:** Arizona State University, College of Engineering and Applied Sciences, Center for Professional Development, PO Box 877506, Tempe, AZ 85287 (480) 965-1740, fax (480) 965-8653 or e-mail: asu.cpd@asu.edu.

HIGH SPEED INTERCONNECT MODELING USING TDR

■ **Topics:** Operation and accuracy issues for Agilent and Tektronix TDR instruments, interconnect probing and fixing, and interconnect modeling and model validation. Fee: $395.
■ **Site:** Portland, OR
■ **Date:** December 11, 2000
■ **Contact:** TDA Systems Inc., 11140 SW Barbur Blvd., Portland, OR 97219 (503) 246-2272, fax (503) 246-2282. A registration form is available at www.tdasystems.com/training.htm.

FREQUENCY SYNTHESIS TECHNOLOGY AND APPLICATIONS IN WIRELESS SYSTEMS

■ **Topics:** PLL circuits and their components and phase noise profiles; basic phase noise theory; integer-N and fractional-N circuits; direct digital, direct analog and DSP principles; and test procedures and updated parts.
■ **Site:** Mountain View, CA
■ **Dates:** December 11–13, 2000
■ **Contact:** Besser Associates, 201 San Antonio Circle, Bldg. E, Suite 280, Mountain View, CA 94040 (650) 949-3300, fax (650) 949-4400 or e-mail: info@bessercourse.com.

PRACTICAL DESIGN OF INTEGRATED AND DISCRETE WIRELESS CIRCUITS

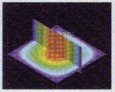
■ **Topics:** Finding the best circuit approach and technology for transceiver applications; comparing very compact passive inductor, transformer, autotransformer and balun designs with their active counterparts; and the effectiveness of MOS and bipolar devices.
■ **Site:** Copenhagen, Denmark
■ **Dates:** December 11–15, 2000
■ **Contact:** CEI-Europe, PO Box 910, S-612 25 Finspong, Sweden +46 122 175 70, fax +46 122 143 47 or e-mail: cei@cei.se.

CERAMIC TECHNOLOGIES FOR MICROWAVE

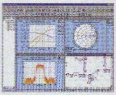
Topics: The most recent advances in ceramic interconnect technology, materials and processes for wireless and other microwave applications.
Site: Denver, CO
Dates: March 26–27, 2001
Contact: Samuel J. Horowitz, DuPont Microcircuit Materials (919) 248-5752 or samuel.j.horowitz@usa.dupont.com.

287 specs. 23 designers. 4 departments. 1 goal.

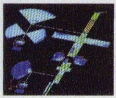
...is everybody on the same page?



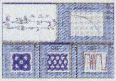
Ansoft HFSS
3D electromagnetic
structure simulation



Harmonica
linear & nonlinear
circuit simulation



Ensemble
planar electromagnetic
field simulator



Symphony
wireless & wired
system simulation

Interoperate

OPENING A NEW WORLD
IN ANALOG, DIGITAL, SIGNAL INTEGRITY, RF
AND MICROWAVE DESIGN.
CHECK OUT
www.ansoft.com\No-Boundaries.html

Ansoft's Serenade Design Environment

...delivering system, circuit, electromagnetic simulation, synthesis, and physical design in a single software suite. Streamline your product development process using integrated schematic capture, simulation, layout, IC package modeling, and links to third-party tools from companies such as Cadence®, Mentor Graphics and EEsof.

Handshaking between modules allows engineers to focus on critical components at any stage of development. Each simulator can be used as a powerful, stand-alone tool, or in concert with others for end-to-end high-frequency design. The Serenade Design Environment is built on Ansoft's core electromagnetics technology; and offers accuracy, an easy-to-use Windows® interface, advanced design utilities, and superior value.

For a free evaluation copy of any of the tools in Ansoft's Serenade Design Environment call 412-261-3200 or send e-mail to info@ansoft.com.

ANSOFT
high performance EDA

www.ansoft.com

CIRCLE 18 ON READER SERVICE CARD

CIRCUIT DESIGNER'S NOTEBOOK

Effective Capacitance vs Frequency

It is generally assumed that the capacitance value selected from a vendor's catalog is constant over frequency. This is essentially true for applications with applied frequencies that are well below the capacitors self-resonant frequency. However as the operating frequency approaches the capacitors self-resonant frequency, the capacitance value will appear to increase resulting in an effective capacitance (C_E) that is larger than the nominal capacitance. This article will address the details of effective capacitance as a function of the application operating frequency. In order to illustrate this phenomenon, a simplified lumped element model of a capacitor connected to a frequency source operating in a network will be considered, as depicted in Figure 1.

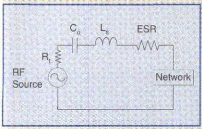


Figure 1
Lumped Element Equivalent Model

This model has been selected because the effective capacitance is largely a function of the net reactance developed between the capacitor and its parasitic series inductance (L_S). The equivalent series resistance 'ESR' shown in this illustration does not have a significant effect on the effective capacitance.

Effective Capacitance:

The nominal capacitance value (C_0) is established by a measurement performed at 1MHz. In typical RF applications the applied frequency is generally much higher than the 1MHz measurement frequency, hence at these frequencies the inductive reactance (X_L) associated with the parasitic series inductance (L_S) becomes significantly large as compared to the capacitive reactance (X_C). Figure 2 illustrates that there is a disproportionate increase in X_L as compared to X_C with increasing frequencies. This results in an effective capacitance that is greater than the nominal capacitance. Finally at the capacitors series resonant frequency the two reactance's are equal and opposite yielding a net reactance of zero. The expression for C_E becomes undefined at this frequency.

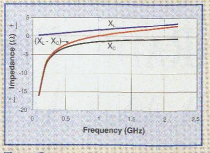


Figure 2
Net Impedance vs. Frequency

As illustrated in Figure1, the physical capacitor can be represented as C_0 in series with L_S. The impedance of the series combination of C_0 and L_S can then be set equal to C_E, which may be referred to as an "ideal equivalent" capacitor. This will yield the following equation:

This will yield the following equation:

$$j(\omega L_s - 1/\omega C_0) = -j\,1/\omega C_E$$
$$\omega^2 L_s - 1/C_0 = -1/C_E$$

The relationship between the operating frequency F_0 and the effective capacitance C_E can then be stated as:

$$C_E = C_0/(1 - \omega^2 L_s C_0)$$
$$C_E = C_0/1 - (2\pi F_0)^2 L_s C_0$$

Where:

C_E = Effective Capacitance at the application frequency, (F_0)
C_0 = Nominal Capacitance at 1 MHz
L_s = Parasitic Inductance, (Ω)
F_0 = Operating Frequency, (Hz)

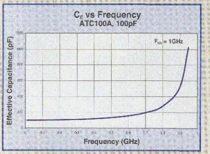


Figure 3
Effective capacitance (C_E) vs. frequency vs F_0

From this relationship it can be seen that as the applied frequency increases the denominator becomes smaller thereby yielding a larger effective capacitance. At the capacitors series resonant frequency the denominator goes to zero and the expression becomes undefined. The relationship of C_E vs frequency is a hyperbolic function as illustrated in Figure 3.

Example:

Consider an ATC 100A series 100pF capacitor.

Calculate the effective capacitance (C_E) at 10MHz, 100MHz, 500MHz, 900MHz, 950MHz.

Solution: Calculate by using the relationship $C_E = C_0/1-(2\pi F_0)^2 L_S C_0$. Refer to Table 1.

Operating Frequency (MHz)	Effective Capacitance (C_E), pF	Impedance, (Ω)
10	100.01	0.013 – j 159.13
100	101.01	0.023 – j 15.76
500	133.34	0.051 – j 2.38
900	526.29	0.069 – j 0.337
950	1025.53	0.070 – j 0.168

Table 1
Relationship between F_0, C_E and Z

Application Considerations:

Impedance matching and minimum drift applications such as filters and oscillators require special attention regarding C_E. For applications below the capacitors self-resonant frequency the net impedance will be capacitive (-j) whereas for applied frequencies above resonance the net impedance will be inductive (+j). Operating above series resonance will correspondingly place the impedance of the capacitor on the inductive side of the Smith chart (+j). When designing for these applications both C_E and the sign of the net impedance at the operating frequency must be carefully considered.

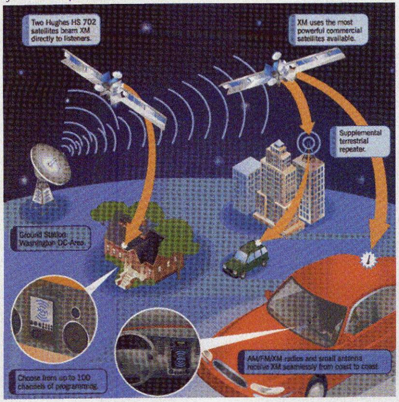
In contrast, the majority of coupling, bypass and DC blocking applications are usually not sensitive to the sign of the impedance and can be capacitive or inductive, as long as the magnitude of the impedance is low at the applied frequency. The effective capacitance will be very large and the net impedance will be very low when operating close to resonance. At resonance the net impedance will be equal the magnitude of ESR and the capacitance will be undefined.

Richard Fiore
Sr. RF Applications Engineer
American Technical Ceramics Corp.

CD Radio Promises Data and Audio Listening Relief

If while driving on the interstate you cannot elude Hank Williams' laments about cheatin' love and his long-dead hound, or are trapped in New York, Chicago or San Francisco, irritated by bad reception when trying to listen to your favorite radio station, relief is on the way. It is coming in the form of digital audio broadcasting (DAB), popularly called CD radio, which, in its two incarnations — terrestrial and satellite — will not only provide some 100 channels of high quality fade- and static-free audio, but data as well. (***Figure 1*** shows the satellite version of CD radio; its terrestrial counterparts will use established commercial broadcasting facilities.)

Fig. 1 The satellite version of CD radio.



There are several major players in the CD radio arena. Some, like Lucent and Delphi Delco, are well known; others, like XM, Sirius and DRE, are not, but will be. The parts needed to begin nationwide service are either in place or quickly coming together, and the point of entry will not be the home but the automobile.

According to Ben Benjamin, senior vice president of product management at Lucent Digital Radio (LDR), Warren, NJ, ever since the merger of LDR and USA Digital Radio (USADR) into iBiquity Digital, everything has been going very well. "The merger is good for us and the consumer, who we envision will benefit from this type of radio," he said, adding that the technology can now be brought to market faster and more cost-effectively: "Faster, because now a standard will be adopted in the US much earlier than it would have if we were competing. Cost-effectively, because we'll get to higher run rates and bring economies of scale to bear faster than if we were competing."

XM Satellite Radio, Washington, DC, is building a prototype digital satellite radio receiver. According to Richard Wormington, senior vice president of engineering and opera-

[Continued on page 24]

Ernest Rejman
Contributing Editor

tion for XM, "We'll provide all this technology license-free to our partners to build AM/FM/XM radios so that when you want to listen to us in your car you just punch the XM button, and if you want to listen to an FM radio station you punch the FM button."

Ken Erickson, product director of North America Audio Business for Delphi Delco, Kokomo, IN, is confident receiver development and broadcast schedules will converge as expected. "Sirius already has one of its satellites up, and XM will get at least one up this fourth quarter, and the rest of their launch schedule is set up," he said. "We're at the point of getting first physical hardware on the receiver side in two months. Everything's reasonably on schedule, close to the timing stated by both XM and Sirius."

DISPLAYS AND RECEIVERS

Delphi Delco is working with General Motors and "others" it is not yet prepared to name on a remote box that will feed the audio signals into the radio head. "From the user interface viewpoint it's transparent — just another band on the dial," explained Erickson. Although this new technology's first application will be focused on music, there are a number of data applications. "Newer radios today typically have larger displays with more text capability, so messages will be shown there. If you had a station panel such as '80s Oldies, that could be on the first line, the song or artist on the second." In fact, depending on the service provider, there is a string of messages that could be shown on the display, including where to buy the CD that is playing.

Over the last few years the trend has been to increase display content, particularly in the case of cellular phones. In the navigation world, some displays are comparable to cathode ray tubes in their capabilities. This improvement has spilled into personal digital assistants (PDA) and, now, to radios. Ten years ago, a typical display had a 3.5-figure capability, showing time and frequency, and perhaps four icons at best. "Now you're seeing 8, 12, 2 × 12 with icons, dot matrix displays to enable increasingly more graphics and text capability," said Erickson.

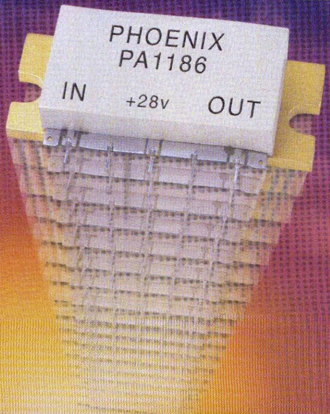
This graphic capability is not cheap. "You pay a price," admitted Erickson. "The new base radios have more graphics than the old ones, and high end radios have significantly more graphics capabilities still, with sometimes a color LCD display, depending on the OEM." Although the new radios will be rolled into the base price of the car, disguising the cost, the fact remains that, depending on the content display capability, the cost of the radios can have as much as a 20-to-1 price spread.

Bringing 2.5 GHz into the automotive environment is a new field. Indications are that both Sirius and XM have done a fine job working out compression techniques and fitting considerable data into the bandwidth the FCC has regulated for them. The hardware is being built and tested as you read this. Obviously, beyond all the computer simulation, design re-

[Continued on page 28]

Introducing High Power Linear Power Amplifier Modules

NEW!
+28volt single supply
GaAs FET
rugged modules



6 Watt Wireless Linear Power Amplifiers

Typical performance @ +25° C

Parameter	PA1186	PA1166	PA1182
Frequency (MHz.)	800-960	1930-1990	2300-2400
Gain (dB.)	29.0	26.0	23.0
Pout @ 1 dB. comp. (dBm.)	38.0	38.0	37.5
Noise Figure (dB.)	2.4	2.7	3.0
ACPR (30kHz BW)*	-50.0	-54.0	-47.0
VSWR (Input/Output)	1.5:1/2:1	1.5:1/2:1	1.5:1/2:1
IP3 (two tone)**	+56.0	+54.0	+53.0
Supply Required	+28/1000	+28/1000	+28/1000

* ±850kHz from fc at power level of 30 dBm. (IS-95)
** IP3 measured with 2 tones @ +25dBm. per tone

In today's competitive wireless environment "Time to Market" is a very crucial factor for the success of a new product.

For Cellular, PCS, and WLL cell sites, Stellex Phoenix Microwave *offers the largest selection of linear amplifier modules* to accelerate your multi-carrier power amplifier designs.

With our *unmatched performance and delivery* you not only reduce your design time but also enhance your system's capability.

In addition, our application's staff is ready to develop new cost effective linear amplifier modules customized to your requirements.

So from your initial design concept to high volume production, make Stellex Phoenix Microwave your linear amplifier module partner.

Call today: 215-723-6011 or e-mail us at info@phnixmw.com

Stellex PHOENIX MICROWAVE

ISO 9001 Registered Company

Stellex Phoenix Microwave 100 Emlen Way Telford, PA 18969 Website: www.stellexms.com

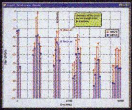
RIDE THE

POWER CURVE

OF NONLINEAR SIMULATION PERFORMANCE

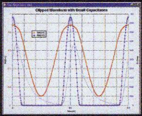
Power, Accuracy and Speed.

That's what you get with Eagleware's new harmonic balance simulator, HARBEC™. From real-time tuning, to application of artificial intelligence techniques, to co-simulation with electromagnetics, HARBEC does it all ... with a powerful set of features that includes:



Robust Simulation

- unlimited, arbitrary circuit topology
- wide range of nonlinear device models (diodes, JFET, BJT, MOSFETS, MESFETS)
- wide range of sources (voltage, power, current, waveform)
- DC analysis and optimization
- unlimited tone harmonic balance analysis and optimization



High Performance Design

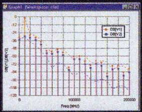
- AI performance optimization
- fast tuning

EM Co-simulation

Spice Model Import

Extensive Parts Library

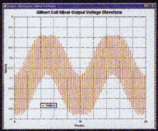
Equations and Post Processing



And it's fully integrated into the GENESYS suite of synthesis, S-parameter, electromagnetic and physical design tools.

So Grab a Seat and Hold On!

With nonlinear modules priced at $4990, they're going fast. And so will your design.



EAGLEWARE
RF and Microwave Design Software

Phone: +1 678-291-0995 | www.eagleware.com
sales@eagleware.com | Fax: +1 678-291-0971

views, peers reviews and progress made, the proof of the pudding should come out during the next quarter, when real-life testing begins. As Erickson put it, "Then the satellites get turned on and we start driving cars to see whether we have a saleable product, then do further development." There is still a list of minor action items being followed, such as getting the right type of decoding through software adjustment. However, as Erickson views it, "The proof is when I turn that switch and hear the music and get the data."

THE STANDARDS QUESTION

There were three proponents for in-band on-channel (IBOC): Digital Radio Express (DRE), Milpitas, CA; USADR (a consortium of broadcasters); and Lucent Digital Radio. The Lucent/USADR merger into iBiquity Digital has as investors 15 of the nation's top 20 radio broadcasters, including Infinity Broadcasting Corp. of Viacom Inc. and Clear Channel Communications Inc.

iBiquity will develop and commercialize digital broadcasting technology solutions, including Lucent's perceptual audio coder (PAC) audio compression technology, to enable radio broadcasters to send audio and data content via digital signals. These signals will allow existing radio stations to transmit CD-quality audio with crystal-clear reception plus wireless data for a variety of consumer applications, such as station and program content, stock and news information, local traffic and weather, and much more, over existing radio frequencies without degrading the transmission of current analog programming.

For a time, it appeared there would be a drawn-out systems battle. It was recognized that if IBOC was to become a reality in a reasonable timeframe, there had to be some form of a grand alliance.

According to Norm Miller, DRE's president, no one knows what the launch date is for IBOC. "This is the $64 question," he said, "when a system will be finalized, deployed and be production-ready. Particularly with the merging of Lucent and USADR, it means that there must be a melding of both technologies to a certain extent. With a consortium they can move forward quickly; at least there will be no opposition from the marketplace — it'll be just like digital TV, which only became reality when a heavyweight consortium was formed. The USADR alliance with Lucent brings in the 600-pound gorilla that creates the de facto standard which then everyone follows."

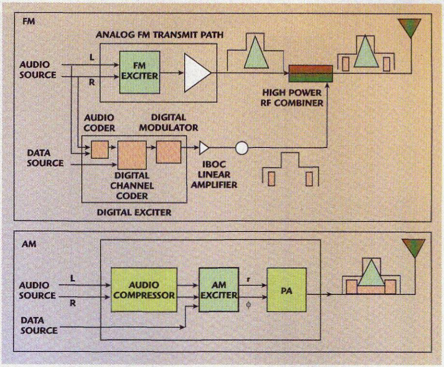
Automobiles will be first in fielding the technology, at least at the receiver end. IBOC proponents do not propose subscription fees as part of their model, and conventional broadcasting will keep its current business model, which is commercial revenues driven. Once digital radio is established and there is a low cost receiver, the expectation is that the public will slip into digital radio almost without noticing it. The newer cars will have it, as will new stereos and portables.

IBOC allows digital to co-exist with analog. The listener still receives the standard analog AM/FM signal, so if he buys a new receiver and installs it in his car, there will be no difference as far as the analog stations are concerned — he will get them as he always has. When he switches to the digital station format, audio quality will be improved but, more importantly, he will acquire the capability to receive a powerful data channel that can provide all sorts of customized information — from real-time traffic to stock quotes and news. As it is defined now, the business model shows that the standard audio and news and conventional broadcasting will continue being free. Not so with the valuable, nationwide data channel that provides a wireless data link into your car as well as to hand-held devices.

TWO-WAY DATA

Although the downlink is one way, it would be easy to couple it with an uplink using cellular technology. From a business model perspective this works well because users download data in a 10:1 ratio compared with what they upload; therefore, using the more expensive cellular infrastructure as an uplink would not be prohibitive. The view is that downloading more data than needed is expensive. For instance, the service supplier would pump out a flood of stock or traffic information, and the

[Continued on page 30]



▲ *Fig. 2 LDR's approach to hybrid IBOC transmitter implementation.*

user would program his receiver, whether radio or PDA, to pick up the stocks of interest or the traffic zones he wants. Such a low cost, real-time data download like this is ideal and, if something more specific is required, the user can always reach for his cellular phone. The radio link for low cost downloading could be networked to work side-by-side with a cellular link for uplinking.

SATELLITE REPEATERS AND IBOC

Satellite digital radio has two proponents: XM and Sirius. The FCC has granted them licenses to use the 2.5 GHz frequency. However, satellites still need to be orbited and earth stations set up for the system to work.

On the other hand, IBOC uses the current broadcast infrastructure — approximately 14,000 radio stations in the US divided 50/50 between AM and FM. These stations already have towers and transmitters and are broadcasting signals. Converting over to IBOC is not an expensive proposition and, practically overnight, it enables these broadcasters to acquire a digital terrestrial network across the country. (Lucent Technology's approach to CD radio, shown in ***Figure 2***, lies in adding an IBOC module to existing AM or FM transmitters in operating commercial radio broadcast facilities, providing them with digital capabilities for audio as well as a data channel.)

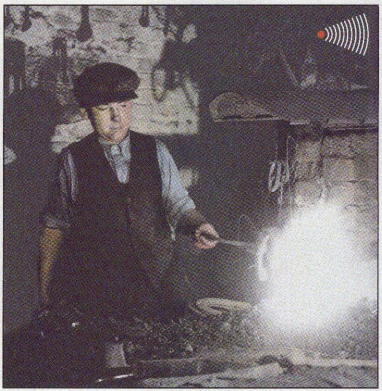
It is interesting to review the development of digital radio. At first, broadcasters fought satellite radio, fearing that it would ruin them. When the FCC finally ruled that it would grant licenses to XM and Sirius, things began looking less bleak, especially when it was realized that a shortcoming of satellite digital radio is its line-of-sight problem. In a metropolitan area, there is what is known as the "canyon effect." If you park under a shelter or drive through a skyscraper-lined street, you may not receive digital satellite radio.

A year after receiving their initial license, XM and Sirius realized that to enable themselves to offer a viable service, they needed terrestrial repeaters for the major cities and applied to the FCC for an additional license. Again, broadcasters did not like this, claiming that with repeaters they were no longer a satellite broadcaster but a terrestrial one. The FCC, however, granted XM and Sirius a license to operate low power terrestrial repeaters in metropolitan areas.

Thus, for satellite radio to work in metropolitan areas, the signal must be put through a repeater, providing the listener with a terrestrial signal. However, it should keep subscribers

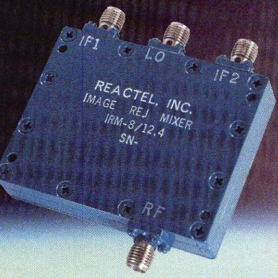
[Continued on page 35]

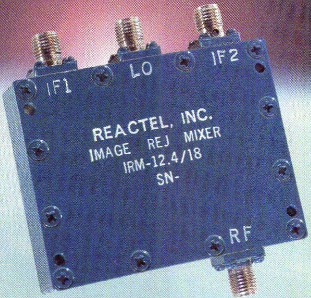
FABRICATION



GALLIUM ARSENIDE

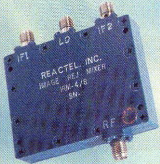
New Product Announcement





You have known REACTEL, INC. for the past 20 years for their high performance RF & Microwave filters, multiplexers, and switch filter banks for both military and commercial applications...

...NOW, try our NEW broad band image rejection and quadrature IF mixers, covering frequency range of 2 to 18 Ghz. in the bands of 2-4, 4-8, 8-12, & 12.4-18 Ghz.



REACTEL, INC.

Or our subsidiary E.S. Microwave, LLC

Address > 8031 Cessna Ave. Gaithersburg, MD 20879

Phone > 301.519.3660 Fax > 301.519.2447

Email > reactel@reactel.com Web Site > www.reactel.com

E.S. MICROWAVE, LLC. Phone > 301.279.9601 Email > esmllc@aol.com

ISO 9001 Certified certification #960161 paying $9.95 a month for CD-quality music from being annoyed by a signal that keeps fading in and out while they are driving, as is sometimes the case with some FM stations. This addition increases cost but makes the system viable, assuming you are within range of a repeater. It also brings up the issue of how many repeaters are needed for cities like Los Angeles, New York, San Francisco, Detroit or Chicago.

IBOC's overwhelming advantage is its low implementation cost, and that makes possible a digital data network covering the US, capable of providing valuable wireless data links into PDAs and car radios. Here is the real advantage of true terrestrial digital radio.

For AM stations especially, the IBOC conversion cost is relatively low — in the $10,000 range — because most broadcasters have relatively modern transmitters. It just requires an IBOC generator that is plugged into the transmitter. The digital signal is fed through the box into the main transmitter as with subcarriers, where a subcarrier box is put into the transmitter, which already has a subcarrier feed. FM's case is somewhat more complicated because IBOC requires a linear amplifier, and many of the older FM amplifiers are extremely nonlinear

Approximately 40 million other radios are consumed in the US, ratcheting this number up to a 50 to 60 million yearly consumption. Clearly, some are cheap, giveaway radios, but with a market like car radios, boomboxes and stereo tuners, a US 40-million-radios-per-year market is reasonable. Obviously there is no question of volume — it exists.

In addition, there will be low cost receiver chip sets implemented for PDAs, laptops and others as add-on modules. Those numbers are also significant. Consider the case of the PalmPilot, for instance, already a fairly powerful computational device with memory and processing power. Getting a small plug-in unit with an FM decoder that — whether it is used for audio or not is immaterial — provides a low cost data link capable of feeding information into it becomes very attractive. It would be possible to go a step further and add a Global Positioning System (GPS) chip to the module to prove location information as well, permitting the incoming datastream to be customized for the user's location, enabling him, for example, to find out when the next bus will arrive at the street corner where he is standing.

DRE has an alliance with Cue Networks, Los Angeles, CA, and this fall will bring in a digital carrier system based on its IBOC technology using the subcarrier spectrum, which can be taken to market now without any further FCC approvals. The focus will be on digital subcarriers, and DRE is designing with them a plug-in for the Handspring PDA, which is expected to be available before Christmas. The basic Handspring unit costs about $150 and the user can buy plug-in modules from independent suppliers that convert it into a GPS unit or a cellular phone. Some seven modules are available for it already. The module that Cue will deliver is a small FM radio with an IBOC-based digital subcarrier unit, and Cue will provide a host of datastreams for the unit.

Digital radio — whether satellite or terrestrial — will bring a robust wireless datalink to the mobile envi-

IBOC's overwhelming advantage is its low implementation cost, and that makes possible a digital data network covering the US, capable of providing valuable wireless data links into PDAs and car radios. Here is the real advantage of true terrestrial digital radio.

For AM stations especially, the IBOC conversion cost is relatively low — in the $10,000 range — because most broadcasters have relatively modern transmitters. It just requires an IBOC generator that is plugged into the transmitter. The digital signal is fed through the box into the main transmitter as with subcarriers, where a subcarrier box is put into the transmitter, which already has a subcarrier feed. FM's case is somewhat more complicated because IBOC requires a linear amplifier, and many of the older FM amplifiers are extremely nonlinear

PDAs, laptops and others as add-on modules. Those numbers are also significant. Consider the case of the PalmPilot, for instance, already a fairly powerful computational device with memory and processing power. Getting a small plug-in unit with an FM decoder that — whether it is used for audio or not is immaterial — provides a low cost data link capable of feeding information into it becomes very attractive. It would be possible to go a step further and add a Global Positioning System (GPS) chip to the module to prove location information as well, permitting the incoming datastream to be cus-

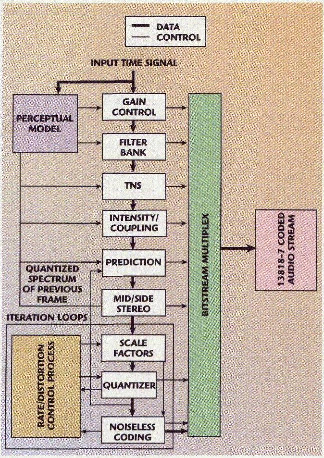
DRE is designing with them a plug-in for the Handspring PDA, which is expected to be available before Christmas. The basic Handspring unit costs about $150 and the user can buy plug-in modules from independent suppliers that convert it into a GPS unit or a cellular phone. Some seven modules are available for it already. The module that Cue will deliver is a small FM radio with an IBOC-based digital subcarrier unit, and Cue will provide a host of datastreams for the unit.

Digital radio — whether satellite or terrestrial — will bring a robust wireless datalink to the mobile envi-

IBOC's overwhelming advantage is its low implementation cost, and that makes possible a digital data network covering the US, capable of providing valuable wireless data links into PDAs and car radios. Here is the real advantage of true terrestrial digital radio.

PDAs, laptops and others as add-on modules. Those numbers are also significant. Consider the case of the PalmPilot, for instance, already a fairly powerful computational device with memory and processing power. Getting a small plug-in unit with an

DRE is designing with them a plug-in for the Handspring PDA, which is expected to be available before Christmas. The basic Handspring unit costs about $150 and the user can buy plug-in modules from independent suppliers that convert it into



▲ *Fig. 3 Audio stream block diagram for DAB, data tracking and control modes.*

ronment, as shown in ***Figure 3***. Many of the problems with wireless are related to the mobile environment-particularly in the case of a vehicle traveling at 60 or 70 mph. Present systems work well if the user is stationary or moves slowly, but that is not a true mobile environment. A moving automobile is a very demanding environment, and few wireless datalinks are capable of feeding reasonable amounts of information into it. With digital radio using the broadcast infrastructure across the US, the technology with which to provide a robust datalink in the mobile environment will be available.

The wireless data link will also drastically reduce repetition. A problem with harsh environments is that if the bit error rate (BER) is too high, this must be met with redundancy, consuming bandwidth. If a data system has 128 kb available but redundancy becomes necessary, this is reduced to 64 kb — half the bandwidth capability is lost.

LOOKING FOR COMMITMENT

The LDR/USADR merger came up with a unified design — a system developed at Bell Labs that uses a high quality audio coder called perceptual audio coder (PAC). According to Lucent's Benjamin, PAC will be used because it allows efficient bandwidth use, always a challenge when attempting to communicate through digital means. PAC allows transparent CD quality at 120 kb. The channel consists of both the analog and digital signal in the sideband, which Lucent refers to as a hybrid IBOC implementation because it contains both the analog and digital signals. In that configuration, the digital signal is 25 dB down from the analog signal at the center of the channel. This provides an interesting challenge to receive the signal in the same coverage area as the analog signal requiring a modicum of processing, which must be accomplished while maintaining CD quality.

Although everyone involved in digital broadcasting is quick to point at partnerships with radio receiver manufacturers, the fact is that beyond those involved in supplying car radios, there does not appear to be much gearing up. All major manufacturers are looking at designing receivers for this technology, but not much seems to be happening. Sony is often mentioned; however, a call to the company revealed that although it is "closely following developments," it has no plans to go into production.

It appears no one is willing to commit or allocate resources until there is a standard in place and some sort of service has begun — production lines are expensive things to keep idle. Receiver manufacturers will not get involved until after having identified the production time and the number of units that will be manufactured. All of this action will be triggered by the FCC implementing a standard. "Our expectation was that the standard would be adopted by year's end," said Benjamin. This may not happen due to purely political and bureaucratic reasons. One way or another, there is going to be a change of administration in Washington and, as an industry insider confided, "We're seeing a number of people from the FCC commission already beginning to look for, and finding, other jobs." A realistic appraisal indicates it would be surprising if a standard is in place before well into the first quarter of 2001.

Once the FCC adopts a standard, three major requirements must be fulfilled before service can begin on a commercial scale. Obviously, the first one is getting a number of digital stations up. Because of the relatively small costs involved, it is likely they will appear in sufficient numbers, at least in major markets, with large, readily available listening audiences. According to Lucent, this change should take place around the third or fourth quarter of 2001.

"We expect to have the major building blocks for receiver manufacturers to begin delivering product to the marketplace around the first quarter of 2002," said Benjamin. "A major element that must be provided is the IC that will allow them to build their radios in the compact form necessary for integration into a car's dashboard." This would meet the second requirement. The third most important requirement is exciting the prospective consumer about the technology through demonstrations at a number of shows and in markets in conjunction with broadcasts. Everyone involved has fresh in his mind what happened to stereo AM and there is no desire to repeat that debacle.

Lucent is working with "three of the major consumer IC manufacturers," which it declined to identify until that arrangement can be disclosed. "They will determine costs," said Benjamin. "Our assessment of the incremental cost for such a system is that it will fit within the construct of a $100 increment at the retail price level." (This means that, whatever its price is now, you will have to pay an additional C-note for the boombox or tuner of your choice.)

It is expected that eventually satellite and terrestrial broadcasting will merge. Because dashboard real estate is

[*Continued on page 38*]

When it comes to RF Wideband Transistors, make the right choice...

www.FutureElectronics.ca/rf/Philips

1-888-306-5347

for your free copy of our

Philips Wideband Transistor Sample Kit.

This sample kit contains 24 of the best from Philips' range of RF Wideband transistors, and a CD ROM with data sheets, application notes, S-parameters and SPICE models. These 24 parts have been carefully selected from more than 100 different types for the best in performance, size, cost, and for the widest range of application requirements.

...or get left behind!

PHILIPS

PHILIPS

FUTURE ELECTRONICS

THE LARGEST "AVAILABLE-TO-SELL" INVENTORY

FUTURE ELECTRONICS

CIRCLE 54 ON READER SERVICE CARD

unlikely to increase, there will not be a second radio receiver there. Lucent is already providing some of the subsystems for the satellite broadcasters, who are using PAC in both the Sirius and XM satellites.

OFFSHORE DIGITAL

There are some countries, notably Great Britain and Germany, where digital broadcasting is already taking place. The European standard, Eureka 147, has been operational for three years. However, digital radio has not exactly set Europe on fire. One of the principal reasons is that receivers run about $1000.

Future service providers in the US are betting on IBOC for a different outcome. "First, US receivers will cost $100 or less in terms of incremental cost," said Benjamin. "Second, we know that broadcasters have spent considerable money and effort developing a brand following associated with their call signs. People know their favorite stations' call signs and with IBOC that won't change. They'll find the signal where it's always been. With Eureka 147, the European listener must migrate to an entirely different band and familiarize himself all over again with where to find the stations he wants."

While volume will certainly bring costs down in IBOC's case, the European receiver's design elements are different because it operates in S band. As one climbs up in frequency, equipment tends to be more expensive. "This is an advantage that has made the proposed US system's incremental cost smaller — we're operating in the same frequency band," pointed out Benjamin.

It now appears that the European and American systems will be incompatible, but Lucent expects that once its system begins service in the US, there will be offshore applications. Lucent is presently dealing with European authorities, who, according to the company, are actively considering IBOC's adoption.

THE DATASTREAM

As mentioned previously, if a broadcaster has upgraded its equipment over the years, or the equipment is five years old or less, only a small modification is required. For an FM station, the upgrade cost would mostly be a high power combiner. The signal leaves the power amplifier and is delivered into the antenna to transmit; with today's analog power amplifier, the combiner is used to essentially sum the analog and digital paths, the latter being the second path that would be coming into the combiner. For an AM station, there are relatively inexpensive digital-ready exciter boxes for the transmitter. Because of linearity requirements, modern AM equipment is already designed to accept a digital system.

"Crucial data applications are linked to the more efficient use of time," said Benjamin. "There are situations related to traffic and downloadable maps. We see the system working as an adjunct to what is out there already, in terms of GPS-type guidance systems. We see in GPS

[Continued on page 40]

▲ *Fig. 4 An example state-of-the-art CD radio facility.*

that people need maps of very wide areas and often local municipalities need to redirect traffic due to construction or other factors such as traffic flow situations where a two-way road becomes a one-way road." This information would be automatically updated in the system as the driver enters the vicinity.

Today, as commuters crawl to work, traffic reports come in maybe every 15 minutes and emphasize heavily traveled roads that may not be of interest. A driver who might want to know about traffic that is beyond his or her area could program the receiver to profile his or her interests, and it would only pick up information specific to the route of interest, avoiding having to listen to all the other broadcasts. These functions would not necessarily be available as part of a subscription service, but rather be made available free by present broadcast service providers. However, other data such as sports scores and stock quotes that people want instantaneously wherever they may be, might be provided on a subscription basis.

These data could reach the user in audio or visual format. However, there are concerns linked to providing too much visual input. Work is under way with the Consumer Electronics Association to set boundaries on what to put on a dashboard without dangerously distracting the driver. A usage etiquette is being developed around how data can be displayed without encumbering the driver.

SATELLITE RADIO GEARS UP

XM's development plan is typical of digital satellite broadcasting. "First you have to get a signal source programming center," said Wormington. "That is already under construction at our new facility in Washington, DC. Eighty-two studios, all modular, all digital, all tied together by fiber optics — everything will be operational by year's end." (***Figure 4*** shows an example of a state-of-the-art facility under construction by XM.)

Next comes satellite transmission capability. In XM's case, this means 15 kW Hughes 702 satellites, the biggest, most powerful commercial communications satellites ever made. The first was orbited in the first quarter of this year, and the next one launches the first quarter of next year.

Then come the repeaters to cover urban canyons. "We have 1500, and their test deployment has begun," said Wormington. "There's a network set up in Pittsburgh that we're running tests on, and full deployment will begin by the first quarter of 2001. These will go in 70 cities to cover the top 70 Arbitron markets. The number of repeaters ranges from 200 in New York, down to four or five for a place like Albuquerque. It is directly dependent upon the urbanization level, and the amount of acreage that we need to cover."

All of this preparation is useless without fielded radio receivers. "We don't produce radios," said Wormington, "but have a number of partners — people like Pioneer, Sony, Alpine, Delco, Sharp, Mitsubishi and others. We have a group in Florida whose sole purpose is building the hardware reference platform: antenna, tuner, an ASIC for channel decode and a DSP housing the software for the service layer decode, decompression and encryption."

XM is doing the engineering for a prototype radio capable of tuning into its system. The company has a working lab radio: satellite and repeater signals in, music out. It is now in what it describes as the "chip fabrication mode," leading to converting the lab radio prototype into chips. According to XM, these should be commercially available during the second quarter of 2001, with transmission beginning commensurate with receiver availability.

SYSTEM SPECS

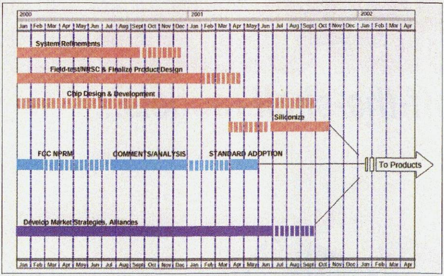
The signal is divided into an A and B side. The output is 4 Mb, which can be thought of as 2 Mb per side, plus padding and error-correction bits; thus, it is not a 4 Mb signal when it is sent, but the data content is 2 Mb. The A and B sides go to the satellites via an X-band uplink, returning as an S-band downlink. Both links are time division multiplex quadrature phase-shift keying (TDMQPSK)-modulated, going directly to the car. If the signal goes through a repeater, the repeater does an in-band receive and transmit with an amplification and change in the modulation scheme, from TDMQPSK to coded orthogonal frequency division multiplex (COFDM). The repeaters act as a single network, and the signal then is repeated out to the car.

The same information content comes over each of the two satellites and through the repeater. The radio can receive all three signals and is indifferent to which one it receives. The receiver is smart enough to select the best signal on a BER basis. This process is transparent to the user, who is unaware of which signal is being processed. In fact, the radio may switch back and forth rapidly, depending on signal quality.

The repeaters are mostly 2 kW, with approximately 10 percent of them slightly higher in power. In general, about 70 percent of the repeaters will be on a tower, monopole or building. Range is heavily dependent on environment. Placed on Mount Wilson in Los Angeles, a repeater might cover 20 miles. The same unit in New York City might reach five blocks. XM has already signed leases for 500 of the 1500 locations it needs, and the company indicates the remaining leases are coming in at a rate of 200 to 300 per month.

The 4-Mb datastream is divided into 8-kb primary channels, with every application working in some multiple

[Continued on page 42]



▲ *Fig. 5 LDR's IBOC realization program time line.*

of a primary channel. There is an overhead allocation of 2 kb for each channel, providing a way to do things like sending information on stocks in parallel with, and transparent to, listening to music. This capability is used as what is called "program-associated data" so that, for instance, the artist and song title of the piece being played appear on the display. Whatever can be digitized can be displayed.

A digital system has many capabilities, but just because they are available, it does not follow that they will be used. As Wormington puts it, "We're a broadcast system — what we send, we send to everybody. We could use the system for point-to-point applications, but it's an inefficient way of using it, because it is like taking a message and broadcasting it over every radio station. Digitally it can do a lot of things; but from a business point of view there are only a few things we will concentrate on. Right now, we're putting out 4 Mb of data, and the bit doesn't care what it translates to. In this case, we're having it translate to music and talk. We can do a lot with it; the question is what we can make money on, and right now music and talk are it — that is our business plan."

As for GPS or any other ancillary data source, XM is not considering it. "GM and Honda are very interested in telematics, but our system is designed to be a 4-Mb pipe to the car and that's it." Wormington added that a car radio manufacturer like Delphi Delco might choose to implement other data sources such as GPS or cellular, and integrate the systems. "We'll be a part of it, but aren't planning on doing the whole package. We don't make the radios, just facilitate their manufacture."

Like others, while admiring it, Wormington believes the value lies not in the technology, but in the improvement in programming. "People are going to hear radio like they think radio ought to be. Because we are nationwide, we don't have to appeal to a broad audience in a narrow geographic area and can focus on very narrow listener niches and provide the music that they love. Before, you could never have focused so exclusively on specific demographic sectors. People can make a business out of providing for narrowly focused musical tastes for $9.95 a month."

Of course, the big question is what the timeline is for an actual launch of services, and there does not yet appear to be a definitive timeframe. Experts like DRE's Miller believe that by the time systems are finally rationalized, field-tested, fine-tuned and taken to the receiver manufacturer (who then, and only then, will gear up for production), it may take as long as two years. ***Figure 5*** shows a milestone chart for LDR's IBOC realization program.

BUT WILL THEY COME?

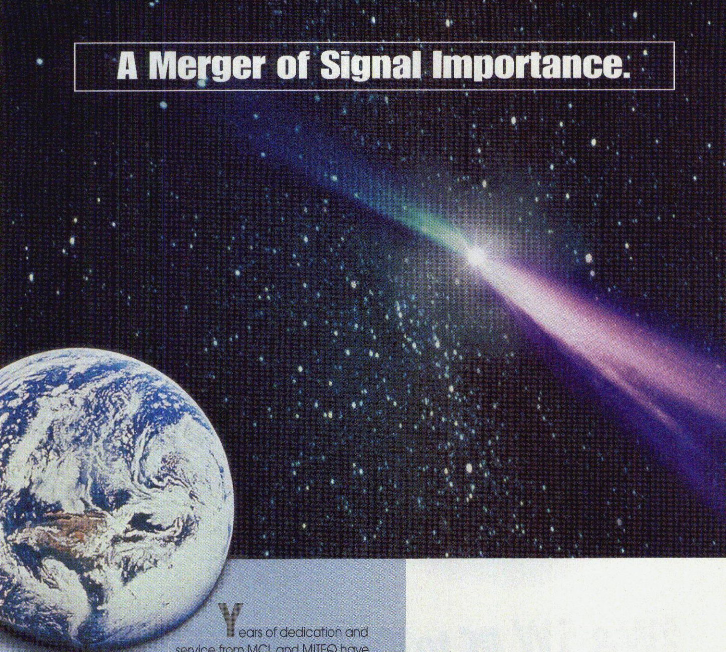
The movie *2001: A Space Odyssey* has one of the most inspired scenes in film history. In it, man's distant ape ancestor tosses into the air in triumph the bone tool that has given him supremacy over his environment and, as it spins skyward, it transmutes into a space vehicle in Earth orbit — an elegant encapsulation of humanity's million-year arduous climb toward civilization.

The concept of digital radio brings to mind the culmination of that difficult evolution. While there is nothing technologically revolutionary about it, the ingenuity and application of existing technologies — the marriage of satellites, high frequency, terrestrial repeating networks, large-scale integration on the IC side, decoding and encryption techniques — to offer a capability that did not exist before is mind-boggling.

Some in the business wax poetical about it, like Delphi Delco's Erickson, "I frequently drive to the foothills in Tennessee and Kentucky, and go through several hours during which it's impossible to get a single radio station. Now, for the first time, people everywhere will be able to listen to the music and talk they want. They'll have more choices and reliability, as well as nationwide information services. The technology's promise is its message."

As Hamlet muttered, albeit in a somewhat different context, "'Tis a consummation devoutly to be wished." My satellite TV service boasts 220 channels. When channel-surfing, I am often awed by the incredible progress mankind has made since that long-gone ape creature tossed that bone on its way to the stars. We have acquired the ability to casually speed a radio signal off on a 46-thousand-mile journey, enabling me to receive anywhere on the planet and in the comfort of my own home, two channels that regale me with *I Love Lucy* in glorious black and white, as well as *Roseanne* and *The Love Boat*. It gives me three channels that try to sell me things I do not want or need, 20 that show me movies that were old before I was born, five that urge me to redecorate my budoir and prepare a gourmet meal, 16 that carry sports (often the same event) and so on, ad nauseam.

CD radio promises enormous potential, as did television and the Internet. However, if past performance of the use given to these resources is any indication, the promise should be taken with an extra hefty pinch of salt. ■


A Merger of Signal Importance.

THAAD System Development Contract Awarded

Raytheon Co. has been awarded a contract from Lockheed Martin Co. to design, develop and manufacture three Engineering and Manufacturing Development radars for the Theater High Altitude Area Defense (THAAD) system. The award is valued in excess of $1.4 B and includes the hardware design, development and manufacture of six Battle Management/Command, Control, Communications and Information Tactical/Shelters Groups and related engineering support.

The THAAD radar is an X-band, phased-array, solid-state system. Using high power transmit/receive modules and advanced signal processing and data processors, the radar provides surveillance, detection, target tracking and kill assessment of threats. The three radars awarded under this contract are a follow-on to the successful two THAAD User Operational Evaluation System radars provided to the US Army in 1996.

The THAAD program is an integrated system consisting of launchers, missiles, battle management and control, and radars, and is the upper tier of the Army's two-tier theater missile defense concept. The higher altitude and wide area protection furnished by the THAAD system interface with the lower tier Patriot Air and Missile Defense system to provide a complete missile defense of critical and high value assets.

UK to Seek Alternative to MR TRIGAT Anti-tank Guided Weapon

The UK Defence Secretary has notified the UK's European partners in the Medium Range Anti-tank Guided Weapon system (MR TRIGAT) collaboration that the UK has decided not to proceed with the Industrialization and Production phase of the program. The lack of progress on the program since the UK indicated a willingness to proceed last summer is cited as evidence that there will be further and unacceptable delay and uncertainty in the program whose service date is already 10 years later than originally planned. The Defence Department has decided that the UK's operational requirements for a modern anti-tank weapon will be best met by an alternative national program and is investigating such a possibility.

MR TRIGAT is a crew-portable Medium Range Anti-tank Guided Weapon system planned to replace MILAN in the armed forces of the UK, France, Germany, the Netherlands and Belgium. UK collaboration on the TRIGAT programs began in the mid-1970s, and the Full Development phase started in 1988 with an in-service date (ISD) of 1995. The most recent ISD is 2005.

The Industrialisation and Production memorandum of understanding (MoU) had been agreed to in 1998. The UK, Germany and France signed the MoU in 1999, but the Netherlands and Belgium have yet to do so. Aerospatiale Matra Missiles was the prime contractor for the Industrialization and Production phase; Matra Bae Dynamics was the major UK subcontractor. To date, expenditures on MR TRIGAT have been approximately £100 M. It is estimated that procuring an alternative system to MR TRIGAT will save more than that amount over 10 years.

Multiyear Javelin Anti-tank Weapon System Contract Awarded

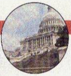
The US Army has awarded the Raytheon-Lockheed Martin Javelin Joint Venture a $1.2 B multiyear contract for the production of Javelin anti-tank weapon systems. The contract extends over four years beginning in 2000, and includes the delivery of 11,805 missiles, 2968 command launch units (CLU), 1990 student and field tactical trainers, and other associated equipment. Javelin is currently in full-rate production under a multiyear contract awarded in 1997, and is in service with US Army and US Marine Corps units.

The Javelin medium-range, anti-tank missile system is a one-man transportable and employable fire-and-forget missile system that permits a single infantryman to engage any armored vehicle at ranges up to 2.5 kilometers. It replaces the wire-guided Dragon missile in Ranger and Special Operations units, infantry and engineer battalions, and armored scout platoons.

Raytheon, the leader of the joint venture, will provide system engineering and support for the joint venture and produce the CLU, missile guidance electronic unit and system software. Its Missile Systems business unit in Tucson, AZ will be the primary Javelin work site. Lockheed Martin will provide missile engineering and production support in its Orlando, FL facility; produce missile seekers in Ocala, FL; and perform missile all-up-round assembly in Troy, AL.

FCC Decision Extends Approval of AirCell Airborne Cellular Service

In a recent decision, the Federal Communications Commission (FCC) sided with AirCell Inc. and its 21 cellular carrier partners and ended a contentious proceeding between the AirCell group and seven of the US' largest cellular services carriers. The FCC's decision reaffirmed AirCell's public safety benefits and the viability of its communication technology. In addition, the Commission extended AirCell's operating authority by an additional two years.



NEWS FROM WASHINGTON

The dispute between AirCell and the group of cellular carriers began in 1997 when the FCC's Office of Experimental Technology (OET) interrupted AirCell's experimental operations after appeals from several of the carriers. Subsequent extensive FCC-supervised tests in July 1997 verified the non-interfering nature of AirCell's technology, and the FCC OET lifted its restriction and permitted AirCell to resume operations.

In late 1998, the FCC's Wireless Technology Bureau granted AirCell and its partners a two-year exemption of the FCC's prohibition on the use of cellular phones in airborne aircraft. Under that exemption, AirCell was able to provide airborne cellular service to mobile terminals installed on general aviation aircraft using 800 MHz cellular frequencies in cooperation with licensed carriers. In its recent decision, the FCC found that there was no available evidence to support the claim that AirCell service is likely to cause harmful interference with ground-based cellular systems and ruled that the public safety benefits associated with the AirCell system were substantial. The ruling effectively extends the life of AirCell's authority to provide air-to-ground cellular service.

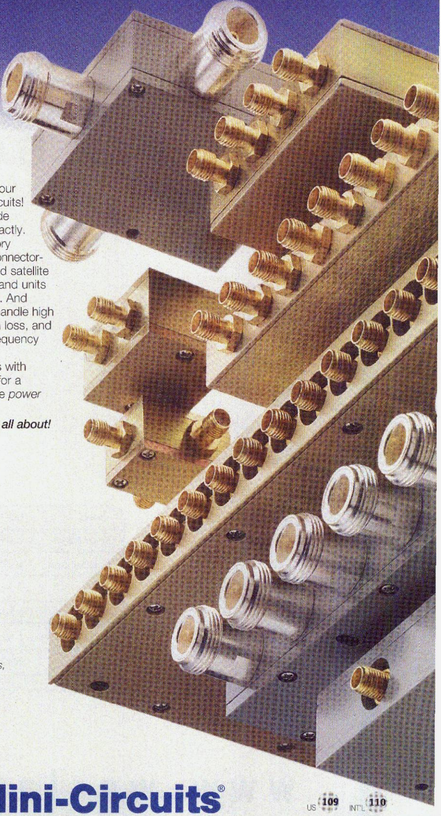
AirCell presently operates 84 cellular sites nationwide and has partnerships with 21 cellular service providers. The company plans to expand its network to approximately 150 sites and 25 service partners so that it can offer full nationwide service.

Global Hawk Advanced Concept Technology Demonstration Reviewed

A report from the General Accounting Office (GAO), "Progress of the Global Hawk Advanced Concept Technology Demonstration" (GAO/NSIAD-00-78), reviews the results of the High Altitude Unmanned Aerial Vehicle Advance Concept Demonstration with respect to the performance and cost objectives of the program. To assess the military utility of the Global Hawk, the US Air Force has been demonstrating prototype aircraft since June 1999. To date, the aircraft has demonstrated basic flying capabilities but has not had sufficient testing to determine whether it can successfully conduct reconnaissance missions on a regular basis. In October 1999, the Air Force reported prototype flights at altitudes over 66,000 feet for more than 27 hours. At the end of January, however, only 260 of 1200 planned flight test hours had been completed. While it appears possible that the aircraft may meet its performance goals, its escalating cost is a real concern. Neither the Department of Defense nor the Global Hawk contractor expects to achieve the $10 M flyaway price goal for the second group of 10 production vehicles. A July 1999 projection places that cost at $15.3 M, $500 K higher than the July 1998 estimate. ■

POWER DIVIDERS

0.47 to 10GHz



2 to 32 Way *from* $49.95 (1-9)

Looking for a "perfect fit" power divider for your 50 or 75 ohm design...*fast?* Just call Mini-Circuits! Our quick response and wide variety can provide on-target performance to match your needs exactly. That's because we've developed a vast inventory of low cost/high value SMA, BNC, and Type-N connectorized units covering cellular, GSM, ISM, PCS, and satellite bands. Select from 2 to 32way models, wide band units and microstrip designs going down to 470MHz. And Mini-Circuits power dividers are built tough to handle high matched power with good VSWR, low insertion loss, and high isolation between ports. For even lower frequency applications, check out our family of torroidal transmission line power splitters and combiners with frequencies as low as 500Hz. If you're looking for a better blend of usability and affordability, put the *power* of Mini-Circuits to work for you today!

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

Model	No. Of Models	Freq. Range (GHz)
2WAY-0°	151	0.50-10.0
2WAY-90°	4	1.00-4.20
2WAY-180°	2	1.00-2.49
3WAY	41	0.50-4.20
4WAY	83	0.47-8.40
5WAY	6	0.80-1.98
6WAY	25	0.80-5.00
7WAY	4	1.00-1.99
8WAY	62	0.50-8.40
9WAY	3	0.80-4.80
10WAY	11	0.75-2.40
12WAY	9	0.50-4.20
14WAY	1	0.90-0.99
16WAY	28	0.47-4.80
32WAY	1	0.95-1.75

For detailed model numbers, specifications, and prices, consult our web site, RF/IF Designer's Guide, or call Mini-Circuits.

Mini-Circuits®

US 109 INT'L 110
CIRCLE READER SERVICE CARD

P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661 For quick access to product information see MINI-CIRCUITS CATALOG & WEB SITE

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

Martin Streetly, International Correspondent

EADS Wins US Radar Contract

The European Aeronautic, Defence and Space (EADS) Co.'s Ulm, Germany-based Airborne Systems unit has been awarded a US$11.9 M contract by the US Navy (USN) that covers the supply of components for its AN/APG-65 radar programme. EADS' connection with APG-65 is based on the former DaimlerChrysler Aerospace's licence production of the radar for use in the Luftwaffe's (German Air Force) F-4 Phantom upgrade programme that began during 1987. Work on the USN contract is expected to be completed during 2002.

R&S Signs with Honeywell on Joint Radio Marketing Venture

German contractor Rohde & Schwarz (R&S) has entered into a joint marketing agreement with US contractor Honeywell that covers the promotion of its M3AR (series 6000) military radio in the North American market. R&S describes the Multiband, Multimode, Multirole Airborne Radio (M3AR) as a software-driven device that operates in the 30 to 40 MHz frequency range and can transmit digitised voice and data at high data rates. The equipment is further described as lightweight and available in cockpit or separately controlled configurations. Equipment control is by means of an MIL-STD bus.

South African Contractor Re-brands

Starting 1 September, South African defence electronics contractor GST was expected to trade as Grintek EWATION following Grintek's agreement with the former DaimlerChrysler Aerospace with regard to the merging of their respective ground-based signals intelligence (SIGINT) and communications jamming business lines. Now a part of EADS, DaimlerChrysler is understood to have hived off its ground-based electronic warfare (EW) line into the new Ewation GmbH EADS subsidiary. As currently structured, Ewation GmbH has a staff of 500, and the combined Ewation/Grintek EWATION product line (which includes power amplifiers and HF/VHF communications jammers as well as SIGINT equipment) will be internationally trademarked as MRCMR (Monitoring, Reconnaissance, Countermeasures) products.

Australia Buys SIRFC

As part of the US-Australian government-to-government Advanced Integrated Aircraft Survivability Technology (AIAST) programme, Australia has procured an example of ITT's AN/ALQ-211 Suite of Integrated Radio Frequency Countermeasures (SIRFC) with which to conduct ongoing systems-related, co-operative research, development and engineering with the US Army. ALQ-211 was selected for AIAST because it represents a next-generation modular, open architecture, integrated EW system. As part of the effort, a digital model of SIRFC has already been integrated into a UH-60 Blackhawk helicopter simulator by the Australian Defense Science and Technology Organisation. The integrated model allows pilots and engineers to work with SIRFC technology in the areas of sensor fusion, threat warning, situational awareness and electronic countermeasures. Launched during 1998, AIAST is expected to run until 2004.

UK Looks for New Fast Jet IMPC

The UK's Ministry of Defence has issued a requirement for a new fast jet defensive aids suite (DAS) package (the Integrated Multi-Platform Countermeasures (IMPC) system) based on the Royal Air Force's (RAF) recent operational experience in the Balkans and the Persian Gulf. Analysts have suggested that a key driver in the IMPC programme is the service's switch from predominantly low level operations to those at medium altitude. Expressions of interest in the programme were due by 29 September, with the tight time scale reflecting the urgency being placed on the effort and the likelihood of any IMPC solution selected being based on off-the-shelf equipment. The new DAS will include on- and off-board countermeasures (possibly including towed active decoys) and a missile approach warner.

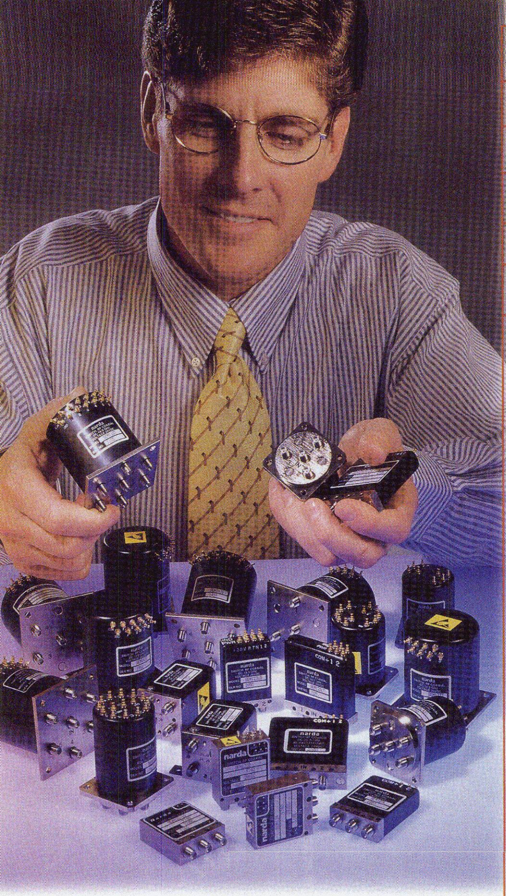
As its name suggests, IMPC will be applicable to a number of airframes (effectively, the RAF's Tornado, Harrier and, possibly, Jaguar strike aircraft) and is, therefore, required to be modular to facilitate mission-specific fits and maximum utilisation of common system elements. Likely bidders include BAE Systems, Northrop Grumman and Thomson Racal Defence. The RAF's strike Tornados are currently fitted with the Skyshadow radar jamming pod, a BAE Systems radar homing and warning receiver, and a BOZ 100 series countermeasures dispensing system (CMDS) pod; its Harriers are fitted with a BAE Systems Zeus integrated radar jamming and warning system together with a CMDS. The Jaguar light strike aircraft carries the Phimat CMDS pod and an updated variant of the former Westinghouse ALQ-101(V) radar jammer.

W1 Communications Satellite Set for September Launch

The European Telecommunications Satellite (EUTELSAT) Organisation's W1 fixed and broadcast communications satellite was scheduled to be launched aboard an Ariane rocket on 6 September. Developed by Europe's multinational Astrium space conglomerate, W1 has a launch mass of 3250 kg and is equipped with a payload comprising 28 transponders that operate in the 10.95 to 11.2 GHz and 11.45 to 11.7 GHz frequency bands. Transponder applications include business communications, Internet-based services and television transmission services, and the devices can be switched between fixed (up to 20 transponders) and steerable (up to 12) coverage. The fixed-coverage (termed fixed widebeam) footprint takes in Europe, North Africa and the Middle East from a 10° East orbital location. Available channel bandwidths are 40 MHz (four transponders), 54 MHz (eight), 62 MHz (four) and 72 MHz (12), and the vehicle utilises a 32 m solar array that will still offer DC spacecraft power of 7 kW at the end of the satellite's 12-year design life. The W1 bus is based on a variant of Astrium's EUROSTAR design, 31 examples of which have been procured to date.

HAI Encouraged to Develop EW Capability

Greek aerospace contractor Hellenic Aerospace Industries (HAI) is being encouraged to develop an EW capability following the Greek Ministry of Defence's decision to procure a DAS for its F-16 Block 50 Plus aircraft from national sources rather than from the international defence industry. Prior to this decision, Thomson-CSF, Elisra and Raytheon were known to have been bidding for the $200 M programme. Alongside this effort, HAI is also involved in the upgrading of 10 existing Greek Mirage 2000 combat aircraft to the Mirage 2000-5 Mk 2 standard. Here, the national contractor will undertake the necessary work, which involves modifications to both the aircraft's radar and DAS. Sources suggest that the EW equipment to be installed may incorporate elements from the equipment package Thomson-CSF, Matra BAe Dynamics France and Italian contractor Elettronica have developed for the Mirage 2000-9 aircraft being supplied to the United Arab Emirates. Existing Greek Mirage 2000s are fitted with a variant of the Thomson-CSF/Matra BAe Dynamics Integrated Countermeasures Suite. ■



Ask if we have a switch in stock and you'll get our stock answer: "Yes."

It's easy for us to be so positive. Our shelves are overflowing with the largest number of stocked electromechanical (SEM) switches in the industry. With more than 40 different top quality switch types, Narda covers everything from satellite, cellular and wireless communications to avionics, ATE and military applications.

Narda gives you the best of both worlds: the convenience of off-the-shelf availability and lower cost. Along with this, you'll benefit from the wide range of innovative, proprietary features we've incorporated into Narda switches, many of which are patented.

In addition, you get more than an assurance of Narda's quality and reliability. You get our guarantee. Narda guarantees operation of one-million to two-million cycles per switch position with virtually no performance degradation.

Beyond all this, Narda has stocked up on something else that's quite valuable. Experience. Over the last 50 years, we've satisfied thousands of customers. Shouldn't you be the next one? Call us at **631-231-1700**.

NQA ISO9001 REGISTERED COMPANY

narda
microwave-east
an L3 communications company

It's Narda to be precise.

www.nardamicrowave.com

CIRCLE 132 ON READER SERVICE CARD

N50
N50

New Consortium Aims to Make TV More Personal and Interactive

Microsoft Corp., DIRECTV Inc. and THOMSON multimedia have announced an alliance to bring a new advanced RCA® DIRECTV™ system with the new Microsoft® Ultimate TV™ service to market. The RCA DS4290-RE system with Ultimate TV and DIRECTV service is the first direct broadcast satellite (DBS) television platform that integrates DIRECTV programming, digital video recording, interactive television and Internet access in one package. The package will permit viewers to watch two shows on DIRECTV at the same time (picture-in-picture), watch one show while recording a second and record more than 30 hours of digital-quality programming for later viewing in their own personal lineup. Viewers will be able to choose from more than 500 hours per week of interactive television, respond to promotions with a remote control, and send and receive e-mail.

The DS4290RE receiver incorporates two DIRECTV satellite tuners and a hard disk drive for digital video recording. In addition, it provides a digital audio output, a standard V.90-capable modem for Internet communications and two USB ports that are planned to support printers as well as keyboards and broadband network interfaces such as DSL modems. The receiver package includes a digital satellite receiver, an 18-inch dish antenna with dual-output LNB and a universal remote control. The receiver with the two television services was expected to be available for retail purchase by the last quarter of this year.

New Venture to Provide Vehicle Telematics Services

Ford Motor Co. and QUALCOMM Inc. have announced the creation of Wingcast, a new company to develop and deliver wireless mobility and information services that will equip cars and trucks with voice, entertainment and safety services and Internet access. Ford cars and trucks will be the initial recipients of these newly developed products and services. Ford expects that more than one million of its vehicles will be so equipped by the end of 2002, more than three million by 2003 and virtually all of its cars and trucks by the end of 2004.

Wingcast expects to combine QUALCOMM's CDMA wireless technology with Ford's telematics and consumer experience to provide consumers with seamless access to applications and services in their vehicles such as communications, information, navigation, entertainment, safety and security. The company's first offerings are scheduled for introduction in late 2001. Nissan is also working with Ford and QUALCOMM to bring Wingcast services into some of its luxury vehicles and may extend their application to a broader selection of Nissan and Infiniti vehicles in the future.

Ford and QUALCOMM each own equity in Wingcast under undisclosed terms. Cartell, a Michigan-based supplier of telematics equipment to automakers, is a minority stakeholder in the company. Initial Wingcast services will be available in North America over cdmaOne™ digital wireless networks. Advanced offerings requiring high speed wireless data will become available as third-generation cdma2000 and wideband CDMA networks are implemented.

First In-flight Bluetooth Wireless Technology Test is Successful

AirCell Inc. and Motorola Inc. have announced the successful completion of the world's first in-flight test of Bluetooth wireless technology. Current Federal Communications Commission (FCC) rules prohibit the use of personal cellular phones while airborne due to potential interference with terrestrial wireless networks, but AirCell has developed an FCC-approved in-flight cellular link that avoids interference with terrestrial cell sites. The systems rely on hard-wired handsets within the aircraft that are widely deployed in commercial fleets. The test combined Bluetooth technology links between personal communications devices like wireless phones and laptops with the fixed AirCell air-to-ground link within the aircraft. The system is expected to drastically reduce the cost of phone calls made while airborne and, at the same time, provide a variety of advanced services such as fax, e-mail and Internet access.

Globalstar Introduces Satellite Telephone Service in Russia

Globalstar has introduced its satellite telephone service in Russia, bringing wireless telecommunications service to virtually the entire country and introducing it into nearly 40,000 communities that presently have little or no access to wireless or wireline telephone service. GlobalTel, the exclusive provider of Globalstar service in Russia, will use its gateway in Moscow to offer basic telephone services including voice and short messaging service (SMS) and, in early 2001, will offer fax and data service. Later this year, gateways in Novosibirsk and Khabarovsk will be on line to provide service to central and eastern Russia, respectively, expanding Globalstar's coverage to virtually the entire country from the Baltic Sea to the Pacific Ocean. In addition to covering nearly all of Russia's land areas, Globalstar will provide service up to 200 miles off of the country's coastlines to commercial and

private maritime vessels as they travel outside the coverage area of traditional cellular and radio services.

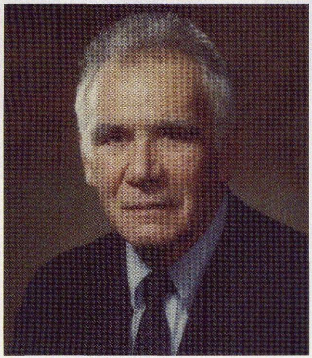
GlobalTel will market Globalstar products and services through its regional providers and distribution network as well as through its sales office in Moscow. Phone units are being offered at prices starting at US$999, and call rates within Russia range from US$1.19 to $1.99 per minute.

CDMA-800 and PCS-1900 Expected to Lead Base Station Growth

A report from the Cahners In-Stat Group, "Towers, Towers, Everywhere: 2000 Worldwide Base Station Forecast," estimates that the global count of 800 and 900 MHz cellular and 1800 and 1900 MHz PCS, PDC base stations will grow at a compound annual growth rate (CAGR) of 30.4 percent through 2004. During that period, the report predicts that CDMA-800 and PCS-1900 installations will grow at rates of 48.9 and 35.3 percent, respectively, to lead the market. TDMA-1900 is expected to be very close to the leaders in third place.

The report forecasts that the number of US base stations will grow 17.5 percent this year and, at that level, account for the majority of new installations in the Americas. Canada's base station count is also expected to grow this year but, since its high population centers already have good coverage, no significant additional growth is forecast. During the next four years, South America's share of the Americas market is expected to increase from its current 21.8 percent to 50.2 percent. In Europe, the current dominance of GSM/DCS-1800 is expected to limit growth. Europe's market share at the end of 2004 is forecast to decrease by 10 percent. The report notes further that the significant year-to-year decline of analog in Europe is likely to take it to the point of non-existence by the end of 2001 and that DCS-1800 will be growing at a faster rate than GSM-900.

In other areas, the study finds that Japan, with 8.6 percent of total worldwide base stations in 2000, is likely to see that share drop to 3.7 percent in 2004. Russia is identified as one of the few geographic areas to enjoy significant analog growth, which is expected to peak in 2004 and begin a moderate decline as digital technology begins to replace it. The anticipated surge in new subscribers in third-world nations is also expected to contribute to the dynamic growth in base stations through 2004 and beyond. China, in particular, is expected to contribute heavily to this growth. For additional information, contact Kirsten Skedd, Cahners In-Stat (480) 609-4534 or e-mail: kskedd@instat.com.. ■



Marion E. Hines, a pioneer in microwave semiconductors and one of the "Grand Old Men" of the industry, died on August 25. He was 82 years old.

Marion was born in Bellingham, WA and received his BS and MS degrees in electrical engineering from the California Institute of Technology. After serving in the US Army Air Force during World War II, he was employed on the technical staff at Bell Laboratories until 1960, when he joined Microwave Associates Inc. (now M/A-COM). He was still employed as a consultant to M/A-COM when he passed away.

Marion was a prolific contributor. He published more than 50 technical papers and was awarded more than 40 patents. He published landmark papers on semiconductor theory and circuits, ferrite devices, time domain theory and analysis, mixer theory and many practical circuit designs and devices. He was a Life Fellow of the IEEE and winner of the IEEE Lamme Medal, as well as the Electron Devices Society J.J. Ebers Medal, the IEEE Centennial Medal and the Microwave Theory and Techniques Society Microwave Career Award. He won the MTT-S Microwave Prize for best paper of the year in 1972 and again in 1978. He is the only person to win it twice.

I am fortunate to have worked with Marion for 23 years. Over that time, he continually amazed me with his intellectual curiosity, inventiveness and creativity. He was responsible for many of the developments and products that made the company successful, from sophisticated semiconductors to practical, low cost designs for police radar detectors. During all of this, he was a patient mentor to many of us. Above all, he was a wonderful gentleman. He is already missed.

Harlan Howe, Jr.

INDUSTRY NEWS

■ **Anaren Microwave Inc.**, Syracuse, NY, has acquired substantially all of the assets of **Ocean Microwave Corp.**, a privately held New Jersey-based manufacturer of ferrite isolators and circulators. Anaren will operate the Ocean Microwave business through its newly formed subsidiary, **Anaren Power Products Inc.** The acquisition will be accounted for as a purchase acquisition.

■ **VoiceStream Wireless Corp.** has entered into a definitive agreement to acquire **Powertel Inc.** The transaction will substantially expand VoiceStream's all-digital GSM wireless coverage in the southeastern US.

■ The **Laird Group Plc** (parent of **APM Inc.**) has announced plans to acquire **Instrument Specialties Co. Inc.** for $257 M plus debt. The acquisition was conditional on Laird Group shareholders' approval at a meeting scheduled for August 25.

■ **Frequency Electronics Inc. (FEI)**, Mitchel Field, NY, has signed a definitive agreement to purchase **Gilliam S.A.**, a privately held Belgian company that develops and manufactures wireline telecom synchronization, network monitoring and power supply products. FEI will pay approximately $8.5 M in cash and 200,000 shares of FEI stock for the stock of Gilliam. The transaction was expected to close by the end of September.

■ **Illinois Superconductor Corp. (ISC)** has consummated its acquisition of **Spectral Solutions Inc.**, pursuant to a merger agreement executed and announced in May. Richard Herring, CEO of Spectral Solutions before the merger, has been added to ISC's board of directors.

■ **Spirent Communications**, Eatontown, NJ, has acquired **InfoSOFT Technologies Inc.**, Ft. Worth, TX. With the acquisition, Spirent now offers a full range of wireless test and deployment solutions that enable CDMA handset manufacturers and network operators to quickly develop and roll-out next-generation products and services.

■ **Alamosa PCS Holdings Inc.** has signed definitive agreements to merge **Sprint PCS** affiliates **Roberts Wireless Communications LLC** and **Washington Oregon Wireless LLC** into its operations. The combined transactions will result in a new entity named **Alamosa Holdings Inc.** and are expected to close by December 31.

■ **SandCraft Inc.** has changed the company's business model to manufacture, market and distribute products for the high performance needs demanded by the communications, consumer and office automation markets. The company's ultra-high performance MIPS-compatible central processing units will be manufactured and marketed under the SandCraft brand name. Previously, SandCraft licensed intellectual property and designs.

[Continued on page 58]

■ **TEMIC Semiconductors** has changed its name to **Atmel Wireless & Microcontrollers** to emphasize the name of its European shareholder. Along with the new name, the company has introduced a new logo.

■ **Stratos Lightwave Inc.** has acquired additional manufacturing space adjacent to its Chicago headquarters. The 60,000-square-foot building will be used to increase the space dedicated to manufacturing gigabit-speed optical transceivers and fiber-optic products.

■ RF and microwave filter designer and manufacturer **K&L Microwave Inc.**, a division of **Dover Corp.**, has expanded its manufacturing facilities to include a new building that will make available 64,000 square feet of additional space.

■ Superconducting RF product supplier **Illinois Superconductor Corp.** will open a new office in Japan. The office will be headed by Derek Schneideman, former president and representative director of Gateway Japan KK.

■ **Space Electronics Inc. (SEi)** has completed its acquisition of **Shason Microwave Corp.'s Instruments Group**. The addition provides SEi with the ability to offer RF/microwave components and modules for satellite applications. The acquisition also includes a unique product line of automated test equipment.

■ **Unitek Miyachi Corp.** has formed **Unitek Miyachi International Ltd. (UMI)**, a corporate holding company that will oversee and coordinate strategy and business planning, global product and marketing integration, next-generation technology and product development, corporate finance and administration, and future acquisitions for all of its business units. In related news, Unitek Miyachi has formed a new multinational accounts group, which was necessitated by the company's rapidly expanding international sales growth and the need for dedicated focus on the management of key global accounts.

■ Advanced RF technology developer **Silicon Wave Inc.**, San Diego, CA, has formed an advisory board of wireless communications experts to consult with the company's executive management team on such matters as business strategy, technical trends and regulatory developments.

■ **Bartley RF Systems Inc.**, Amesbury, MA, has created a new corporate logo to reflect its growth and current position in the wireless network equipment marketplace. The new identity coincides with the company's move to a 78,000-square-foot facility, which houses more than 250 employees, up from its original nine in 1995.

■ **Motorola Inc.** has moved its largest volume assembly and test manufacturing facility for high power RF products from Seremban, Malaysia to Kuala Lumpur, Malaysia. The move provides growth opportunities for

[Continued on page 60]

manufacturing RF power devices that are required to continue to meet the needs of customers and the wireless market.

■ **IFR Systems Inc.** has signed major distribution agreements with **LeCroy Corp.**, Geneva, Switzerland, for distribution of test products in Europe. Under the partnership, IFR will be the exclusive distributor for LeCroy's test and measurement products in Spain and Portugal, while LeCroy will become a key distributor for IFR's test and measurement products in Italy.

■ **Richardson Electronics Ltd.** has signed a worldwide distribution agreement with **ANADIGICS Inc.** Under the terms of the agreement, Richardson will become ANADIGICS' first distribution channel to market and sell the company's wireless, fiber, and cable and broadcast RFIC product lines.

■ **E*TRADE Group Inc.** has formed an alliance with **Sprint PCS** to provide clear, mobile access to E*TRADE's wireless trading capabilities and applications via Internet-ready Sprint PCS phones and the Sprint PCS Wireless Web.

■ **RF Micro Devices Inc.**, Greensboro, NC, has collaborated with **Atmel Corp.**, San Jose, CA, to produce reference designs based on the IEEE802.11b 11 Mbps wireless local area network standard. Together, the companies are providing complete reference designs to qualified customers, including schematics, layout files and bills of materials.

■ **Rogers Corp.** has captured more than 90 percent of the market in Taiwan for high frequency circuit materials used in the manufacture of Ku-band low noise block downconverters (LNB) in direct satellite TV systems. Taiwan has eight major LNB manufacturers who supply a significant portion of the LNBs needed worldwide.

■ **SSB Technologies Inc.'s Stealth Microwave** division has received ISO 9001:1994 certification for the design, development and manufacture of microwave amplifiers for the wireless communications industry.

■ **Universal Voltronics Corp.**, Mt. Kisco, NY, has achieved full ISO 9001 certification.

■ According to the recently published "Broadband-to-the Home Services, Equipment and Components Market Forecast," residential broadband services revenue will reach $175 B in 2009. The revenue obtained from providing all types of residential broadband services to North America will grow from $48.1 B to $174.8 B during the same period. This increase is in addition to narrowband residential communications services revenue, which is expected to advance from $52.4 B to $130 B during the forecast period.

■ **ANADIGICS Inc.**, Warren, NJ, has shipped more than 100 million broadband RFICs for cable systems and fiber-optic networks. The increased development of fiber-optic infrastructure to support rising demand for Internet bandwidth as well as emerging two-way digital cable services have resulted in a strong demand for broadband solutions.

■ **First Source Inc.**, San Jose, CA, a national distributor of RF, microwave, wireless, cellular and millimeter-wave components, celebrated its fifteenth year in business at the company's annual sales meeting.

FINANCIAL NEWS

■ **Molex Inc.** reports record sales of $614.6 M for the fourth quarter, ended June 30, compared to $445.9 M for the same period last year. Net income was $65 M (33¢/share), compared to $50 M (26¢/share) for the fourth quarter of 1999.

■ **Andrew Corp.** reports record sales of $259.2 M for the third quarter, ended June 30, compared to $186.1 M for the same period last year. Net income was $20.9 M (26¢/diluted share), compared to $14.7 M (18¢/diluted share) for the third quarter of 1999.

■ **REMEC Inc.** reports sales of $63 M for the second quarter, ended July 28, compared to $47.3 M for the same period last year. Net income was $3.2 M (7¢/diluted share), compared to a net loss of $2.8 M (7 ¢/diluted share) for the second quarter of 1999.

■ **ANADIGICS Inc.** reports record sales of $47.5 M for the second quarter, ended July 2, compared to $30.5 M for the same period last year. Net income was $6.6 M (21¢/diluted share), compared to $2 M (8¢/diluted share) for the second quarter of 1999.

■ **Cree Inc.** reports record sales of $33.4 M for the fourth quarter, ended June 25, compared to $18.3 M for the same period last year. Net income was $11.4 M (30¢/diluted share), compared to $4 M (12¢/diluted share) for the fourth quarter of 1999.

■ **Norsat International Inc.** reports sales of $27.5 M for the second quarter, ended June 30, compared to $13.5 M for the same period last year. Net loss was $5.3 M (21¢/share), compared to a net loss of $493 K (2¢/share) for the second quarter of 1999.

■ **Robinson Nugent Inc.** reports sales of $25.1 M for the fourth quarter, ended June 30, compared to $18.9 M for the same period last year. Net income was $1.7 M (32¢/share), compared to $1.2 M (24¢/share) for the fourth quarter of 1999.

■ **Alamosa PCS Holdings Inc.** reports sales of $17.2 M for the second quarter, ended June 30, compared to $35.1 K for the same period last year. Net loss was $12.9 M (21¢/share), compared to a net loss of $4 M (8¢/share) for the second quarter of 1999.

■ **SEMX Corp.** reports sales of $12.67 M for the second quarter, ended June 30, compared to $11.8 M for the same period last year. Net income was $609 K (8¢/diluted share), compared to $991 K (16¢/diluted share) for the second quarter of 1999.

[Continued on page 62]

HITTITE INTRODUCES A NEW MMIC LINE....

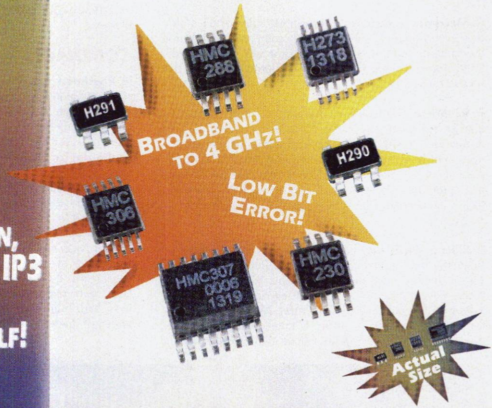
DIGITAL ATTENUATORS!

2, 3, OR 5 BIT CONTROL

POSITIVE BIAS, +3V TO +5V

LOW DISTORTION, TO +54 dBm IP3

OFF - THE - SHELF!



7 LOW COST DIGITAL ATTENUATORS COVERING DC - 4 GHz *

Part Number	Features	Freq. Range (GHz)	Atten. Step Size(dB)	Ref. Insertion Loss (dB)	Bit Error (dB)	Input IP3 (dBm)	Package Area (mm²)
HMC273MS10G	5 Bit, 1 to 31 dB Pos. Bias	0.7 - 3.7	1, 2, 4, 8, 16	2.4	± 0.5	+ 48	14.8
HMC307QS16G	5 Bit ,1 to 31 dB Neg. Bias	DC - 4	1, 2, 4, 8, 16	2	± 0.5	+ 44	29.4
HMC306MS10	5 Bit, 0.5 to 15.5 dB Pos. Bias	0.7 - 3.7	0.5, 1, 2, 4, 8	1.8	± 0.25	+ 52	14.8
HMC230MS8	3 Bit, 2 to 28 dB Pos. Bias	0.75 - 2	4, 8, 16	1.8	± 0.5	+ 46	14.8
HMC288MS8	3 Bit, 2 to 28 dB Pos. Bias	0.7 -3.7	2, 4, 8	1.5	± 0.3	+ 51	14.8
HMC291	2 Bit, 4 to 12 dB Pos. Bias	0.7 - 4	4, 8	0.9	± 0.2	+ 54	9
HMC290	2 Bit, 2 to 6 dB Pos. Bias	0.7 - 4	2, 4	0.6	± 0.2	+ 52	9

** DATA IS MIDBAND TYPICAL.*

DATA SHEETS ARE AVAILABLE ON - LINE!

PRODUCT SPECIFICATIONS ARE GUARANTEED, -55 °C TO +85 °C...

Request Our FEB 2000 Catalog

Hittite MICROWAVE CORPORATION

www.hittite.com

PHONE: 978 250 3343 ◆ FAX: 978 250 3373

12 Elizabeth Drive, Chelmsford, MA 01824 USA

VISA MasterCard WE ACCEPT

TÜV ISO 9001

CIRCLE 61 ON READER SERVICE CARD

AROUND THE CIRCUIT

Ansoft Corp. reports sales of $8.7 M for the first quarter, ended July 31, compared $6.9 M for the same period last year. Net income was $202 K (2¢/diluted share), compared to a net loss of $311 K (3¢/diluted share) for the second quarter of 1999.

Merrimac Industries Inc. reports sales of $5 M for the second quarter, ended July 31, compared $5.1 M for the same period last year. Net income was $40 K (2¢/diluted share), compared $82 K (5¢/diluted share) for the second quarter of 1999.

RF Micro Devices Inc. intended to offer, subject to market and other conditions, $250 M of convertible subordinated notes due 2005 (plus an additional amount of up to $50 M at the option of the purchasers) in a private placement. The notes will be convertible into the company's common stock at the option of the holder, at a price to be determined. The offering was expected to close in August.

Silicon Wave Inc. has completed its fourth round of financing with nearly $52 M infused into the company. The round includes new investments from 3Com Ventures, Access Technology, Alps Electric Co. Ltd., GTG Ventures, Intersil Corp., JMG Triton, Nexus Capital Partners, Sands Brothers Venture Capital, Senvest International and SIDUS, and allows Silicon Wave to continue its innovations, including highly integrated chips, systems and software for Bluetooth wireless technology.

MediaQ Inc. has completed its third round of venture capital financing, securing $23.4 M. New investors include Weston Presidio Capital, El Dorado Ventures, Infineon Technologies, Summit Accelerator Fund and ViVentures. MeidaQ intends to use the capital to fund the development of ICs for Web terminals/pads, hand-held personal digital assistants, communicators and smart phones.

CONTRACTS

Raytheon Co., Lexington, MA, has been awarded a contract valued in excess of $1.4 B by Lockheed Martin Co. to design, develop and manufacture three engineering and manufacturing development radars for the Theater High Altitude Defense System. The contract also includes the hardware design, development and manufacture of six battle management/command control, communications and information tactical/shelters groups and related engineering support.

Cree Inc., Durham, NC, has received contracts from several Asian and European customers totaling $70 M for shipments through September 2001. Included in these contracts is a one-year purchase agreement with Osram Opto Semiconductors GmbH and Co. for standard brightness, high brightness and small chip silicon carbide light-emitting diodes and wafer products. The Osram agree-

[Continued on page 64]

TUSONIX

A World Leader in Ceramic EMI/RFI Components

...and a broad range of fixed and variable ceramic capacitors

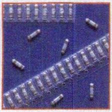
- **Technology**...EMI/RFI Components based on extensive Ceramic Dielectric Technology.
- **Innovation**...Surface Mount Filters reduce board count by replacing multiple components.
- **Delivery**...We meet customer needs with proven on-time performance.
- **Quality**...Quality Management System registered by UL to ISO 9001.
- **Value**...Cost Effective Solutions.

www.tusonix.com

TUSONIX

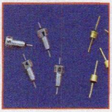
- 7741 N. Business Park Drive
  Tucson, Arizona 85743
- 520-744-0400 FAX: 520-744-6155
- email: sales@tusonix.com

Microwave Products



Surface Mount EMI Filters

- Square Design For Easy Handling
- Small Size (8X2.1mm)
- Reduces Component Count
- Capacitance Up To 8200pF
- Insertion Loss Of 70dB At 1GHz
- Attractively Priced



Miniature EMI Filters

- Small Size (4-40 or M3 Thread)
- Capacitance Up To 50,000pF
- Broad Range of Applications
- Attractively Priced

TUSONIX, INC. UL REGISTERED FIRM ISO 9001 A5924

Authorized Stocking Distributors:

- PALtronics 1-800-387-7969
- **Penstock 1-800-736-7862**
- Resco 1-800-638-1242
- RS Electronics 1-313-525-1155
- **TTI 1-800-225-5884**

ment is the largest product contract signed in the history of the company.

■ **Andrew Corp.**, Orland Park, IL, has received an initial $3 M order as part of a $23 M letter of agreement for the development and supply of single-channel PCS-TDMA linear power amplifiers to Lucent Technologies Inc. Andrew was expected to deliver the first consignment of prototype amplifiers to Lucent in September and will move into full production at the beginning of 2001.

PERSONNEL

■ Applied Epi Inc. has named **Brett D. Heffes** chief financial officer. Most recently, Heffes was VP of corporate development and treasurer for Department 56 Inc.

■ Silicon Wave Inc. has elected **Bruce Edwards** and **Dave Rickey** to its board of directors. Edwards currently serves as president and CEO and is a member of the board of directors at Powerwave Technologies, Irvine, CA. Rickey is currently president and CEO of Applied Micro Circuits Corp., San Diego, CA.

■ **Yahya Rahmat-Samii** and **Anand Gopinath** have joined Altra Broadband Inc.'s board of technical directors. Rahmat-Samii is the chairman of UCLA's electrical engineering department; Gopinath is a professor of electrical engineering at the University of Minnesota.

■ Alamosa PCS Holdings Inc. has appointed **Tony Sabatino** senior VP of engineering and network operations, and **Loyd Rinehart** senior VP of corporate finance. Previously, Sabatino was the national RF engineering director at Sprint PCS; Rinehart was chief financial officer at Affordable Residential Communications.

■ **Lars Jehrlander** has been appointed head of business area Allgon Systems. Previously, Jehrlander was VP of the mobile communication business at Ercisson in Brazil.

■ GIL Technologies has promoted **Jerry Moran** to the newly created position of VP, global sales and marketing. Previously, Moran was the regional sales manager for the company.


▲ Bernard Cahlander

■ **Bernard Cahlander** has been named VP and general manager of VertexRSI's Santa Clara, CA facility. Cahlander will be responsible for the overall direction of the facility's systems business.

■ GHz Technology Inc. has appointed **Charles Leader** VP, operations. Previously, Leader held senior positions in manufacturing and engineering at Agilent Technologies and Avantec Inc.

■ In preparation for its initial public offering, American Microsystems Inc. has appointed **Michael C. Reilly** to the newly created position of treasurer. Reilly joins the company from Anacomp Inc. and has more than 12 years of experience in treasury management.

■ Lindgren RF Enclosures Inc. has named **Bob Piemonte** sales manager for industrial products. Piemonte, a former Lindgren employee, brings 15 years of sales and marketing experience to the company.


▲ Bill Nicklin

■ Stellex Communications has appointed **Bill Nicklin** international sales manager. Nicklin assumes responsibility for the sales of Stellex RF and microwave components through a network of representatives and distributors in Europe, the Middle East, India and Africa.

■ Marconi Applied Technologies has appointed **Hal Spooner** director, Satcom Operations. Previously, Spooner was the acting director of sales and marketing, regional sales manager and product marketing manager at Litton Electron Devices.

■ Stanford Microdevices has appointed **Norm Hilgendorf** director of marketing for standard products. Prior to joining the company, Hilgendorf was VP and general manager of Richardson Electronics' solid-state division and business unit manager for wireless products.


▲ Lisa G. Blais

■ ITT Industries, Cannon has named **Lisa G. Blais** general manager of its C&K Components switch products business. Most recently, Blais was C&K's VP, sales and marketing.

■ NEC Electronics Inc. has promoted **Omid Milani** to assistant general manager of the Displays and Energy Devices Strategic Business Unit. Previously, Milani was senior manager of the Flat Panel Displays Group at the company.


▲ Brent A. Fischthal

■ Quad Systems Corp. has named **Brent A. Fischthal** APS product manager. Previously, Fischthal served as product marketing specialist for Universal Instruments Corp.

■ Wyle Electronics has named **Dave Hartman** and **Chuck Kunai** division managers for the company's Minneapolis and Houston divisions, respectively. Hartman joined the company as division manager in Houston in 1999; Kunai most recently served as the company's south central region strategic business manager.

■ Micro Networks Corp. has appointed **John N. Gau, Jr.** principal SAW design engineer. Gau joins the company from TOKO America Inc.'s SAW Filter Design Center.

[Continued on page 66]

■ Aeroflex Laboratories has added **James R. Guinaw** to the marketing and sales staff for Instrument Products. Guinaw has held senior positions with Hassir Corp., Grumman Corp. and Telephonics Corp.

■ BTC Electronic Components has named **Kerry Hathaway** account executive in its Apopka, FL sales office. Previously, Hathaway was with PCD as an inside sales manager.

NEW MARKET ENTRY

■ **Universal Microwave Corp. (UMC)** is a new company formed to design and manufacture high performance VCOs, ceramic resonator oscillators and synthesizers for the wireless market. UMC is located at 2339 Destiny Way, Odessa, FL 33556 (877) 375-9332, fax (727) 376-7271.

REP APPOINTMENTS

■ **Sprague-Goodman Electronics Inc.**, Westbury, NY, has appointed **Soquelec Telecommunications**, Montreal, Quebec, Canada, to represent its products in Quebec, Ontario and the Maritime Provinces. In addition, the company added **Diamond Advanced Components**, Norcross, GA, and **Integra Electronics**, Orange, CA, to its franchised distributor network.

■ **Universal Microwave Corp.** has named three firms to represent its VCOs and synthesizers in the US. **dBm Technical Sales** will cover New England, **Youngewirth & Olenick** will cover Arizona and New Mexico, and **Trionic Associates** will cover Long Island, New York City and New Jersey.

■ **mmWave Technologies Inc.**, Ottawa, Ontario, Canada, has signed a vendor contract with **Karl Suss America**, adding to its communication test and measurement line card.

■ **Coleman Microwave Co.**, Edinburg, VA, has made several new rep appointments, including **Applied Technical Sales and Marketing**, San Juan Capistrano, CA, to cover Southern California; **E. Reid Miller Corp.**, Saratoga, CA, to cover Northern California; and **Lear Associates**, Richardson, TX, to cover Texas and Oklahoma.

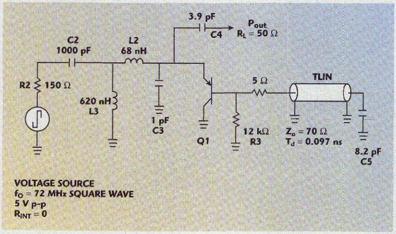
WEB SITE

■ **Murata Electronics North America** has made available a free EMI filter selection simulator on its Web site at www.murata.com. The noise suppression-measuring service aids design engineers in the process of selecting EMI filters by replicating the conditions of their circuit to evaluate the performance of various filters.

A High Order Frequency Multiplier for Low Power Applications

Direct frequency multipliers are commonly used in applications where the added phase noise or circuit complexity of a phase-locked loop is undesirable. At power levels above 1 mW, varactors or step recovery diodes can supply the needed power directly, but generally require RF drive power levels that are incompatible with the low currents and voltages in modern portable products. An injection-locked oscillator (ILO) can supply the desired harmonic efficiently, but it will continue to deliver output power at the wrong frequency if the tuning is incorrect due to aging, or if the input level becomes insufficient to lock the oscillator at the desired multiple. There is no comparable threshold problem if an overdriven amplifier is used as a harmonic generator; however, both the output power and DC-to-RF efficiency are likely to become impractically small for large values of multiplication N.

Fig. 1 The direct frequency multiplier's schematic.



The circuit shown in ***Figure 1***, along with its conceptual model, avoids these problems. Since no DC bias is provided for Q_1, there is no measurable RF output power when the fundamental frequency input signal is removed. The output is a damped sinusoid; hence, the output power can be concentrated in a few spectral lines clustered around the desired harmonic, rather than in the wideband comb spectrum characteristic of an impulse generator or overdriven amplifier.

BACKGROUND

It is assumed that the input to a broadband (impulse) frequency multiplier is a CW input signal $A_0\cos(2\pi F_R t + \phi_0)$ and that the output is observed only after the DC bias terms at all internal nodes have reached their steady-state values. When the multiplier output is sampled at a rate $F_{SAMP} > 2F_R$, its output frequency components will be aliased down to the frequency band from DC to F_R. The sampler output will

[Continued on page 70]

D.R. Lang
Comtech/EFData
Tempe, AZ

be limited to F_R provided the multiplier output consists of only integral multiples of the input frequency and is free of spurious (nonharmonically related) components. Stated another way, the phase offset values ϕ_n in the multiplier output spectrum $A_n\cos(N2\pi F_R t + \phi_n)$ must be stationary between successive cycles of the input reference signal.

An ILO consists of a (generally) narrowband oscillator, which has an intrinsic or unlocked frequency F_{UL} close to the desired, locked output frequency F_O. The ILO is provided with an additional input port for insertion of a reference signal $F_R = F_O/M$. When M = 1, the structure is termed an injection-locked amplifier (ILA). When an ILO is used as a multiplier, the reference frequency is injected into the oscillator feedback loop with sufficient amplitude to reset the ϕ_n terms between input cycles, and the ILO output effectively consists only of $F_O = MF_R$. Numerous papers describe the design and adjustment of ILOs.[1]

The multiplier input signal at F_R is nominally a square wave from a CMOS or equivalent logic buffer used as a low impedance voltage source. Since the duty cycle of most system reference clocks is close to 50 percent, this value is used in the analysis. The DC component of the clock signal is blocked, and R_3 allows forward bias of Q_1 only during the negative-going half of the reference cycle. No general significance is claimed for the choice of the collector for the grounded terminal of Q_1. At the operating frequency used in the original design, this configuration required a smaller load admittance transformation ratio than alternate topologies evaluated.

The initial design procedure parallels that of any one-port oscillator. The circuit elements are adjusted to meet the minimum requirements for oscillation at F_O as

$$\mathrm{mag}\left[\Gamma_D\right] = \frac{1}{\mathrm{mag}\left[\Gamma_L\right]} \tag{1}$$

$$\mathrm{ang}\left[\Gamma_D\right] = -\mathrm{ang}\left[\Gamma_L\right] \tag{2}$$

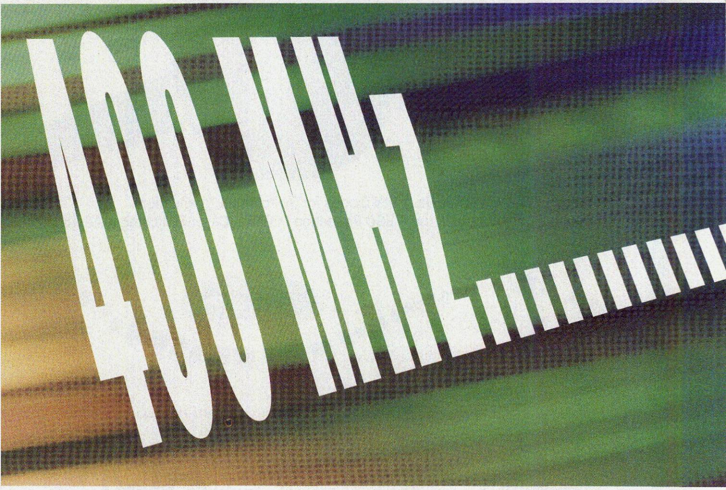
where Γ_D and Γ_L represent the reflection coefficients of the oscillator and load, respectively.

Next, the effects of the active and passive component variations within the oscillator and load are examined to verify that no reasonable combination of Γ_D and Γ_L near F_O violates the Kurokawa criteria for steady-state oscillator stability.[4,5] These criteria are sufficient but not necessary for steady-state stability at a specific frequency and power level. When Γ_D can be accurately represented as impedance $R_D \pm jX_D$ (series resonant oscillator), the first criterion is

$$\left[\frac{\delta X_L(\omega)}{\delta\omega}\bullet\frac{\delta R_D(A)}{\delta A}-\frac{\delta R_L(\omega)}{\delta\omega}\bullet\frac{\delta X_D(A)}{\delta A}\right]>0 \tag{3}$$

Two empirically based simplifying assumptions generally apply:

$$\frac{\delta X_D(A)}{dA}\cong 0 \tag{4}$$



$$\frac{\delta R_D(A)}{\delta A} > 0 \quad \text{(active device gain compression)} \quad (5)$$

Therefore,

$$\frac{\delta X_L(\omega)}{\delta\omega} \bullet \frac{\delta R_D(A)}{\delta A} > 0 \quad (6)$$

and

$$\frac{\delta X_L(\omega)}{\delta\omega} > 0 \quad \text{for stable oscillation} \quad (7)$$

When Γ_D can be represented as an admittance $G_D \pm jB_D$, the shunt resonant counterpart of Equation 3 applies such that

$$\left[\frac{\delta G_L(\omega)}{\delta\omega} \bullet \frac{\delta B_D(A)}{\delta A} - \frac{\delta B_L(\omega)}{\delta\omega} \bullet \frac{\delta G_D(A)}{\delta A}\right] < 0$$

The dual versions of the simplifying assumptions in Equations 4 and 5 are

$$\frac{\delta B_D(A)}{\delta A} \cong 0 \quad (8)$$

$$\frac{\delta G_D(A)}{\delta A} > 0 \quad (9)$$

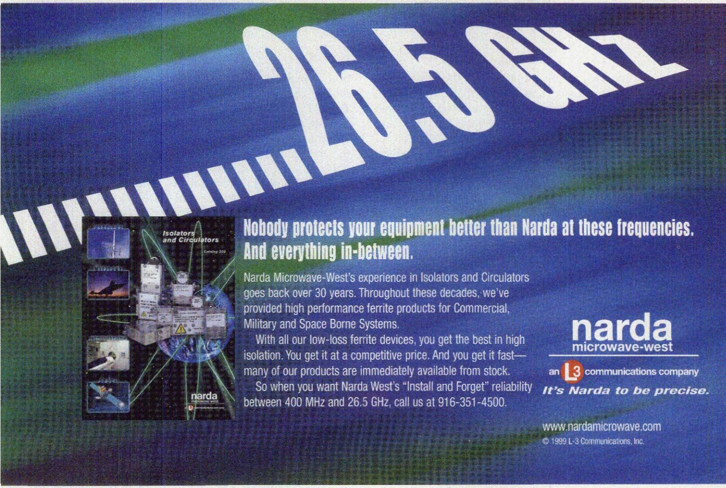
and the admittance form of the result of Equation 7 is

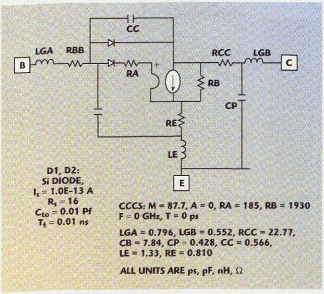
$$\frac{\delta B_L(\omega)}{\delta\omega} > 0 \text{ for stable oscillation.} \quad (10)$$

The criterion of Equation 3 is, for example, sufficient to ensure that when an initial operating point $[P_O(Z_L), F_O(Z_L)]$ migrates to a new point $[P_O(Z_{L2}), F_O(Z_{L2})]$ due to a change in load impedance $Z_{L2} = Z_L + \delta Z$, the oscillator will return to $[P_O(Z_L), F_O(Z_L)]$ when $\delta Z = 0$. (For example, the oscillator tuning will not exhibit hysteresis or moding.)

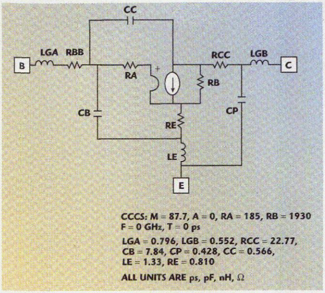
The idealized categorization of an oscillator as essentially series or shunt resonant may affect the choice of load topology. Consider a series resonant oscillator terminated with a shunt resonant load, where

$$\begin{aligned}
Z_D &= R_D + jX_L - jX_C \\
Q_A &= \frac{X_L}{-R_D} \\
&= \frac{X_C}{-R_D} \text{ at } F_O \\
Y_L &= G_L - jB_L + jB_C \\
Q_B &= \frac{B_L}{-G_D} \\
&= \frac{B_C}{-G_D} \text{ at } F_O
\end{aligned}$$





▲ *Fig. 2 The BJT nonlinear model for PSpice.*



▲ *Fig. 3 The BJT linear model.*

TABLE I

MODEL'S SMALL-SIGNAL S PARAMETERS

	S_{11}	S_{21}	S_{12}	S_{22}
mag[S_{kk}] RMS error	0.0505	0.0141	0.1280	0.0731
ang[S_{kk}] RMS error (°)	7.36	2.83	20.20	13.30

Frequency range for S-parameter matching = 0.2 to 4.0 GHz, 0.1 GHz steps
At each frequency, the contribution to the net RMS value is:
mag[S_{kk}] error = ((model mag[S_{kk}] – measured mag[S_{kk}])/measured mag[S_{kk}])^2
ang[S_{kk}] error = (model ang[S_{kk}] – measured ang[S_{kk}])^2

Now Y_U is defined as the admittance of the previously described network, measured at the shunt end, with only G_L removed. It is easy to verify that for arbitrarily closely spaced frequencies F_1 and F_2, Q_A and Q_B ($Q_A > Q_B$) can be determined such that $Y_{UF1} = Y_{UF2}$; that is, oscillation is possible on both frequencies. When $Q_A < Q_B$, the slope of $\delta B_U(\omega)/\delta\omega$ is dominated by the shunt elements and no frequency ambiguity exists. If the above exercise is repeated with a shunt resonant oscillator terminated with a series resonant load, where Z_U is the impedance looking into the load end with R_L removed and Q_A and Q_B are as previously defined, then frequency ambiguity exists for $Q_B > Q_A$, and conversely. An example of a series topology oscillator incorrectly terminated with a shunt resonant load (and its resulting undesirable tuning behavior) is provided by Hamilton.[6]

DESIGN DETAIL

The following design procedure is for a multiplier currently used in volume production for equipment qualified over the –40° to +65°C environment. For this design, F_R = 72 MHz, N = 20 and $P_O \geq -15$ dBm at F_O = 1440 MHz, and the nominal current demand is 6 mA at +5 V. In the end application, an inexpensive surface acoustic wave (SAW) bandpass filter was used to suppress the $N \leq 19$ and $N \geq 21$ harmonics. The SAW filter port impedance Z_L is poorly defined outside of a narrow bandwidth centered on the desired N = 20 harmonic.

Since the Spice parameters of the MMBR901 bipolar junction transistor (BJT) were not readily available, a modified hybrid-pi bipolar model,[3] shown in ***Figure 2***, was created. In this model, both D_1 and D_2 are ideal Si diodes with negligible junction capacitance. With both the base resistance and the dynamic resistance of D1 replaced by R_A, element optimization is used to force the model's small-signal S parameters to match the published device S parameters to an accuracy sufficient for the time domain simulation. ***Figure 3*** shows the BJT's linear model. The model's small-signal S parameters are listed in ***Table 1***.

With C_4 omitted, Γ_D is quite accurately represented by a shunt topology. A one-port Touchstone linear analysis of the multiplier circuit verified that $Re[Y_D] > 0$ from 100 MHz to 10 GHz (excluding the operating band) and $Re[Y_D] + Re[Y_L] < 0$ within the operating band (1440 ± 100 MHz) after optimization of TLIN, C_5, C_4 and C_3. As with any active circuit, failure to verify that potentially unstable regions are confined to the desired frequency band creates a risk of spurious signal generation. Although the decision to insert C_4 at this port appears to be a violation of the criterion in Equation 10, the specific broadband input impedance of the SAW filter transformed through C_4 was sufficiently close to the required shunt topology Γ that stability was ensured.

Next, the multiplier is modeled using a time domain simulator (such as PSpice) to verify output level, biasing and drive margin. The negative-going transition of V_S at the start of the on period defines the initial amplitude and phase offset terms A_n and ϕ_n for the sinusoidal burst. During the off period, Q_1 is inactive and undesired contributions to the stationary values of ϕ_n are minimized to the extent that the harmonic amplitudes A_n decay to negligible levels between reference cycles. The net series impedance of C_2, R_2 and L_2 is made large enough that the

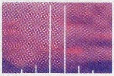
[Continued on page 75]

HIGH IP3 MIXERS

+30dBm IP3

5 to 2500MHz from $14.95 (1-24 qty.)

The popularity of wireless communication services is soaring, but when signal overcrowding creates intermodulation distortion... Mini-Circuits has the solution! Our full range of low distortion, high IP3 SYM mixers provide the muscle it takes to ***suppress noisy intermods*** and unwanted signals. At the same time, these affordable surface mount solutions achieve low conversion loss and excellent L-R, L-I isolation. Developed for both analog and digital use, applications include airphone, cellular and cordless phones, radar, satellite, FM Broadcast, ISM, PCS, and PCN. Achieve the high performance your customers expect. Specify low loss, high IP3 SYM mixers from Mini-Circuits. It's the *clear* choice!



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

TYPICAL SPECIFICATIONS:

Model	Freq. (MHz)	IP3 Midband (dBm)	Isolation (dB) L-R	Isolation (dB) L-I	Conv. Loss Midband (dB)	Price $ea. Qty. 1-24
SYM-18H	5 -1800	30	45	40	5.75	16.85
SYM-15VH	10 -1500	31	45	35	6.5	27.95
SYM-25DHW	80-2500	30	37	33	6.4	24.95*
SYM-14H	100-1370	30	36	30	6.5	14.95
SYM-10DH	800 -1000	31	45	29	7.6	17.80
SYM-22H	1500 -2200	30	33	38	5.6	18.75
SYM-20DH	1700-2000	32	35	34	6.7	14.95

All models are surface mount and available in tape and reel.
LO=+17dBm except SYM-15VH LO=+23dBm

ACTUAL SIZE

****SYM-25DHW: 1000 Quantity Price Only $6.45 Ea.***

Mini-Circuits®

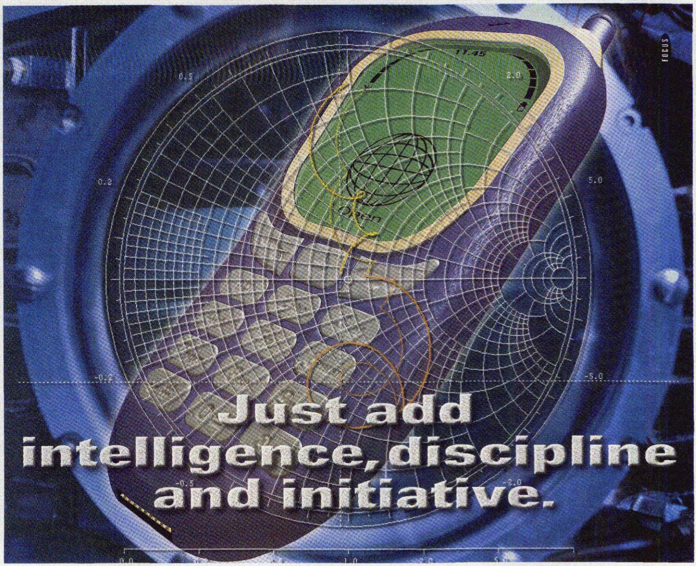
US 111 INT'L 112
CIRCLE READER SERVICE CARD

P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661 For quick access to product information see MINI-CIRCUITS CATALOG & WEB SITE

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

ISO 9001 CERTIFIED

F 320 Rev A


Just add
intelligence, discipline
and initiative.

effect on Z_D is negligible, C_2 and R_2 are adjusted so that the average current through Q_1 does not exceed the desired supply limit and the combination of C_2 and L_2 determines the RF pulse width. Small changes (20 percent or less) in the duty cycle have very little effect on output power. For the fractional pulse width ratio T_{pw} used (0.27), the multiplier output spectrum is wide enough that no tuning or selection of TLIN or C_5 is required. Some suggested limiting values of remaining components are listed in ***Table 2***.

Figure 4 shows the output of a PSpice simulation for the 1440 MHz multiplier using the nonlinear BJT model. For practical cases, modeling the output burst envelope as a damped exponential function is consistent with both time domain simulations and physical measurements. Equations 11 to 21 and ***Figure 5*** define the parameters used in the Fourier representations of both the baseband and RF burst exponential function. If the available time domain simulator has discrete Fourier transform capability, the spectral output amplitudes can be evaluated directly. If not, the amplitude and width of the RF output pulse envelope can be visually estimated and Equations 11 to 21 applied to obtain the harmonic amplitudes.

$$\text{Tpw}/T_1 = \beta \bullet 2.4464 = \text{pulse width ratio at Vmax/2} \quad (11)$$

$$\beta = \text{Tpw}/(T_1 \bullet 2.4464) \quad (12)$$

Baseband pulse:

$$\text{Vmax} = 1/(2 \bullet \beta \bullet \exp(1))$$

Burst pulse:

$$\text{Vmax} = 1/(\beta \bullet \exp(1)) \quad (13)$$

$$X_m = m \bullet 2 \bullet \pi \bullet \beta \quad (14)$$

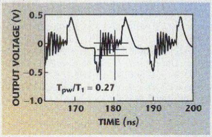
$$\text{Mag}_m = 1/(1 + (X_m)\text{^}2) \quad (15)$$

$$\text{Ang}_m = 2 \bullet \text{ATAN2}(1, X_m) \quad (16)$$

TABLE II

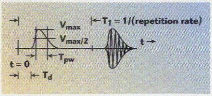
MULTIPLIER COMPONENT VALUES

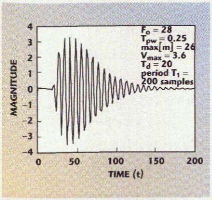
Element	Initial Value
R_2	$V_{dd}/(4I_{PEAK})$
R_3	$V_{dd}\beta/I_{PEAK}$
L_3	$L_3 \geq 5R_2/(2\pi F_R)$
C_2	$C_2 \geq 4T_{PW}I_{PEAK}/V_{dd}$
L_2	$L_2 \leq R_2/(2\pi F_R)$
L_3	$L_3 \geq 5Z_D/(2\pi F_R)$
C_5, TLIN	$F_o \cong 1/2\pi\sqrt{C_5 Z_0 \tan\theta/2\pi F_o}$



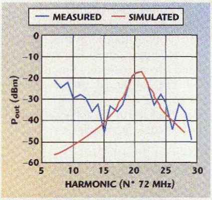
▲ *Fig. 4 PSpice simulation of the 1440 MHz multipler using the nonlinear model.*

Fig. 5 Parameters used in the exponential envelope function. ▼





▲ *Fig. 6 An example of the burst waveform.*



▲ *Fig. 7 Measured vs. simulated output spectrum.*

TABLE III

MEASURED SIDEBAND LEVELS

F_{offset} (Hz)	£ (dBc/Hz)
100	–80
300	–82
1000	–101
3000	–109
10000	–114
30000	–114
100000	–116

$$BI_m = Mag_m \bullet \cos(Ang_m) \tag{17}$$

$$BQ_m = Mag_m \bullet \sin(Ang_m)$$

$$m = 1, 2, \ldots P, Fo > P \tag{18}$$

where Fo is in units of cycles per T1 period

and $t <= T_1$.

Exponential burst waveform amplitude =

$$\Sigma BI_m \bullet \cos((t - T_d) \bullet (Fo + m) \bullet 2\pi/T_1)$$
$$+\Sigma BI_m \bullet \cos((t - T_d) \bullet (Fo - m) \bullet 2\pi/T_1)$$
$$-\Sigma BQ_m \bullet \sin((t - T_d) \bullet (Fo - m) \bullet 2\pi/T_1)$$
$$+\Sigma BQ_m \bullet \sin((t - T_d) \bullet (Fo + m) \bullet 2\pi/T_1)$$
$$+1.0 \bullet \cos((t - T_d) \bullet Fo \bullet 2\pi/T_1) \tag{19}$$

Exponential baseband waveform amplitude =

$$0.5 + \Sigma BI_m \bullet \cos((t - T_d) \bullet m \bullet 2\pi/T_1)$$
$$+\Sigma BQ_m \bullet \sin((t - Td) \bullet m \bullet 2\pi/T_1) \tag{20}$$

The scaling constant 2.4464 in the fractional pulse width expression is the difference between the two t parameter values for which the pulse amplitude is half the maximum value such that

$$0.500 = [\exp(1)t_1 \bullet \exp(-t_1)]$$
$$= [\exp(1)t_2 \bullet \exp(-t_2)]$$

where

$t_2 = 2.67834\ldots$
$t_1 = 0.23196\ldots$

and

$t_2 - t_1 = 2.4464\ldots$

Assuming $R_L = 50\ \Omega$, the power levels of the $\pm m^{th}$ sidebands are then computed directly as

$$P(dBm) = 10\log_{10}(1000^*(Vpeak/Vmax)^\wedge 2 \bullet (BI_m{}^\wedge 2 + BQ_m{}^\wedge 2)/(50^*2)) \tag{21}$$

where Vpeak = 0.5 • (the measured or simulated peak-to-peak RF output magnitude) and Vmax is defined by Equation 13.

Note that Equations 11 to 21 are listed in a format that is directly insertable into a spreadsheet such as Excel. An example of the burst waveform is shown in ***Figure 6***.

Both the calculated spectrum of the time domain simulation and the measured spectrum are plotted in ***Figure 7***. The measured spectrum includes both the active multiplier contribution and the harmonics due to the square wave reference waveform coupled directly through C_2, C_4, L_2 and R_2.

The phase noise of the above multiplier was evaluated by comparing its performance with that of a 1440 MHz brute force multiplier utilizing limiting diodes and gain stages. Both multipliers were driven by the same 72 MHz phase-locked crystal oscillator reference source; no significant difference between the output phase noise spectra of the two multipliers was observed. The sideband levels measured for both multipliers are listed in ***Table 3***.

CONCLUSION

A direct frequency multiplier has been described that is suitable for high order, low power multiplier applications. A modified model using PSpice was used to optimize the required circuit component values and analyze the multiplier's performance. The resulting multiplier's phase noise performance compared favorably with a brute force multiplier at 1440 MHz. ■

References

1. Vasil Uzunoglu, "Oscillator Network Performs a Diverse Range of Functions," *Microwaves & RF*, August 1996, pp. 115–128.
2. Edmar Camargo, *Design of FET Multipliers and Harmonic Oscillators*, Artech House, 1998.
3. Jose E. Schutt-Aine, "Determination of a Small-signal Model for Ion-implanted Microwave Transistors," *IEEE Transactions on Electron Devices*, Vol. ED-30, No. 7, July 1983, pp. 750–758.
4. K. Kurokawa, "Some Basic Characteristics of Broadband Negative Resistance Oscillator Circuits," *Bell System Technical Journal*, July–August 1969, pp. 1937–1955.
5. Robert Soares (editor), *GaAs MESFET Circuit Design*, Artech House, 1988, pp. 350–355.
6. Steve Hamilton, "Microwave Oscillator Circuits," *Microwave Journal*, Vol. 21, No. 4, April 1978, pp. 63–84.
7. *Advanced Bipolar Transistor Modeling Techniques*, Hewlett-Packard Application Note 1201-4, July 1991.
8. *Harmonic Generation Using Step Recovery Diodes and SRD Modules*, Hewlett-Packard Application Note 920.

David R. Lang *is a principal member of the technical staff at Comtech/EFData. Prior to joining Comtech, Lang served with Adaptive Broadband and Motorola, specializing in RF/microwave circuit design for both military and cellular products. His most recent work includes the detailed development and design of commercial, C- and Ku-band satellite terminal systems.*

SOLR CALIBRATION FOR GROUNDED COPLANAR WAVEGUIDE LINES

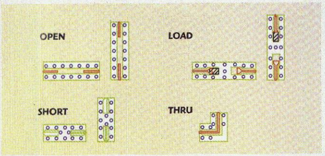
This article examines short-open-line-reciprocal (SOLR) calibration of grounded coplanar waveguide (GCPW) lines. The calibration is made possible by using the WinCal™ software. The standards used for the calibration, including a knee type of discontinuity, were measured and the results are described. The measured standards are shown after the calibration process, and a measured 90° bend is compared with predictions made by the Sonnet™ EM simulator. The results confirm that SOLR is a valid calibration procedure.

The first step in any vector network analyzer (VNA) probe measurement is the calibration process. There are several well-known methods to calibrate the instrument to the tip of the probes or to some reference plane away from the probes. Calibration types such as thru, reflect, line (TRL); short, open, load, thru (SOLT); and line, reflect, match (LRM) have proved to be accurate and relatively easy to perform, but with one common restriction: The probes must be in line. The SOLR calibration makes no assumptions about the transmission standard used other than that it must be reciprocal ($S_{12} = S_{21}$). A significant advantage of this permutation of the SOLT calibration is that it is applicable to orthogonal probing systems where the thru standard is difficult to implement. In an orthogonal probing environment, a transmission line with a 90° bend suffices for the reciprocal standard. The SOLR technique was suggested by Ferrero[1] and has been implemented in Cascade Microtech's WinCal software.[2] Basu and Hayden[3] provide a good overview of the basics of this technique.

This article presents an effort to achieve an acceptable SOLR calibration on GCPW lines using the WinCal software. Some basic theory is given for those individuals interested in the concepts behind the SOLR method, and the definitive process of standard definitions is described. After each calibration process, the standards were measured and examined to explore calibration accuracy.

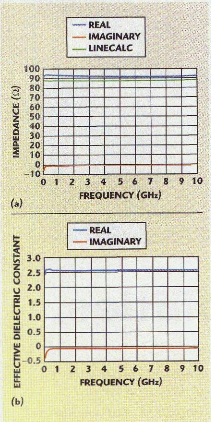
[Continued on page 80]

SHAY GROSS, LAWRENCE P. DUNLEAVY AND THOMAS M. WELLER
*University of South Florida, Department of Electrical Engineering, Wireless and Microwave (WAMI) Program
Tampa, FL*

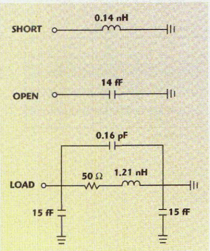


▲ *Fig. 1 GCPW SOLR calibration standards.*

Fig. 2 The GCPW line's (a) characteristic impedance and (b) effective dielectric constant. ▼



▼ *Fig. 3 SOLR standard models.*



CALIBRATION STANDARDS STRUCTURES

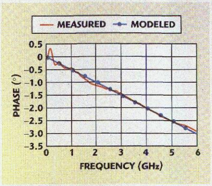
The calibration standards structures used in this research (and shown in ***Figure 1***) are the same as those previously presented by the authors.[4] The four standards are GCPW lines fabricated on an FR-4 substrate with an effective dielectric constant of 2.57 and a characteristic impedance of 92 Ω. The actual characteristic impedance of the lines was measured using MultiCal™ and Cap™ software by NIST and is shown in ***Figure 2***.[5] Those results showed a good comparison to predictions made using Linecalc™ software.[6]

One of the important issues of SOLR calibration using the WinCal software is to know exactly the capacitance introduced by the open standard, the inductance introduced by the short standard and the inductance introduced by the load standard. The models utilized for the three standards are shown in ***Figure 3***. The model element values were found through optimization to data measured using a reliable TRL calibration. The optimization process was accomplished using EESof Series IV,[6] and the results are shown in ***Figures 4***, ***5*** and ***6***.

RESULTS

The calibration parameters were computed and downloaded to a Wiltron 360 VNA using WinCal, and the various standards were re-measured, this time with SOLR calibration. The calibration process was repeated a number of times until the results were consistent. No two calibrations can ever be identical due to repeatability errors, noise and drift in the system, but the results appeared to be consistent and reliable.

The best way to examine the validity of a calibration is to measure the same device under test using an additional calibration method and compare the results. Since special structures that are required for any additional calibration methods were not available, an alternative way to check the validity of the SOLR calibration is simply to observe the results and examine them with regard to the expected/calculated values. This way it can be determined if the calibration is fairly accurate, but not how accurate it is compared to any other method.



▲ *Fig. 4 Phase comparisons for the open standard.*

Fig. 5 Phase comparisons for the short standard. ▼

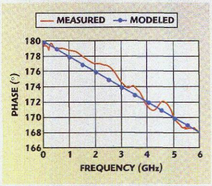
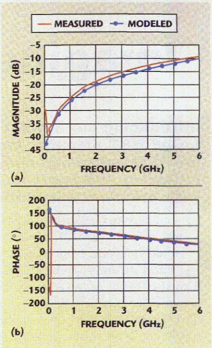
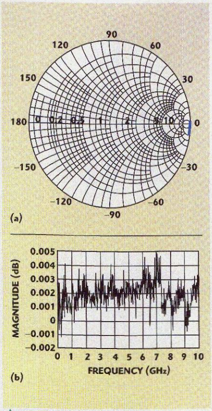


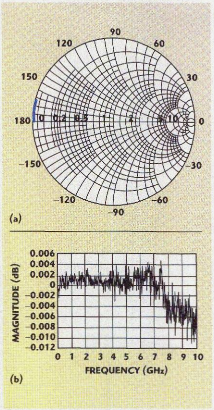
Fig. 6 Magnitude and phase comparisons for the load standard. ▼



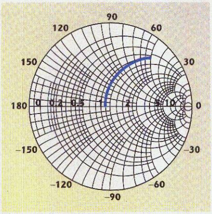
[Continued on page 82]



▲ Fig. 7 The open standard's S_{11} measurement.



▲ Fig. 8 The short standard's S_{11} measurement.



▲ Fig. 9 The load standard's S_{11} measurement.

First, by looking at the measured open standard data, as shown in ***Figure 7***, it can be seen that the reflected signal is less than ±0.005 dB with a phase of less than 5°, compared to an ideal case of 0 dB/0°. The same trend is observed when the short standard is examined. ***Figure 8*** shows that the reflected signal is less than ±0.011 dB with a phase of 12°. The results are not as good as in the case of the open; the phase seems to be somewhat higher than expected, but is still in an acceptable range.

Next, the load standard is examined. Looking at the Smith chart representing S_{11} of the load, as shown in ***Figure 9***, it is clear that the load resembles a 50 Ω resistor with a parasitic series inductance. By selecting a single set of measured data from the load, with a known frequency and the normalized imaginary value, it is possible to calculate the value of the parasitic inductance such that

f = frequency at sampled data point
= 10 GHz

Load impedance at sampled data point:

$$\text{Resistor} = 50\,(1.00756 + j1.52283)\ \Omega = 50.378 + j76.141\ \Omega \text{ (unnormalized)}$$

$$jX = j\omega L \quad (\omega = 2\pi f)$$

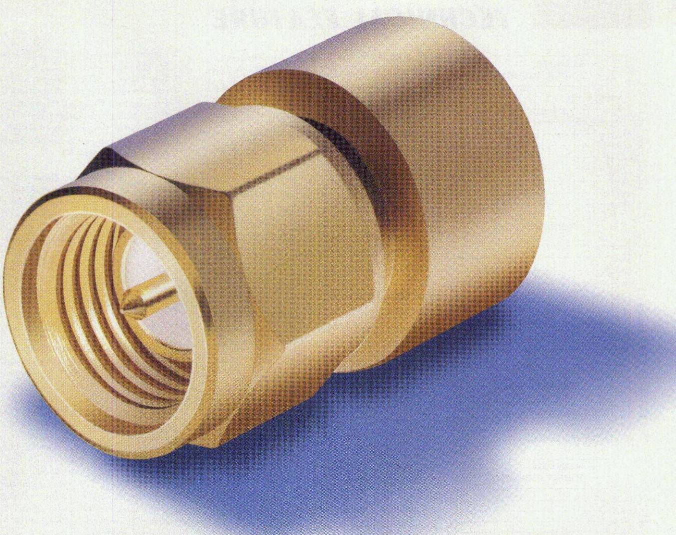
where

$$X = \text{Im(resistor)}$$

$$L = \frac{X}{\omega} \quad \Rightarrow \quad L = 1.212\ \text{nH}$$

Note that the measured resistance of the load is 50.378 Ω compared to 50.4 Ω, which was measured directly on the resistor using an ohmmeter.

[Continued on page 84]



DC up to 20GHz TERMINATIONS from $9.95 (qty.1-9)

From FM to cellular to satellite communication circuits, these terminations end all...the broadband KARN-50, ROSE-50, and ANNE-50 terminations from Mini-Circuits. Until now, microwave terminations were usually very expensive, especially custom designs for higher frequencies. But thanks to quantum leaps in design and manufacturing techniques by Mini-Circuits, you could replace high priced units with these versatile 50 ohm solutions and obtain features such as low VSWR, usability to 20GHz, and rugged construction to withstand severe mechanical vibration and shock, from the low price of only $9.95ea.(qty.1-9). And high quantity pricing is even more amazing! Finally! Cost effective, high performance microwave terminations...off-the-shelf! Call Mini-Circuits today.

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

KARN-50
N Type Male Connector
$11.95 qty.1-9
$7.49 qty.1000

Freq. Range (GHz)	Return Loss (dB, Typ)
DC to 2	45
DC to 4	35
DC to 6	28

ROSE-50
SMB Plug Connector
$9.95 qty.1-9
$7.35 qty.1000

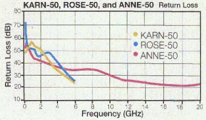
Freq. Range (GHz)	Return Loss (dB, Typ)
DC to 2	45
DC to 4	35
DC to 6	28

ANNE-50
SMA Male Connector
$11.95 qty.1-9
$7.49 qty.1000

Freq. Range (GHz)	Return Loss (dB, Typ)
DC to 4	40
4 to 10	30
10 to 20	20

ANNE-50CN
with 3 1/2" Chain & Cap
$13.95 qty.1-9
$9.49 qty.1000

Note: Power ratings at 70°C: ANNE-50 and ROSE-50 is 0.50W, derate linearly at 0.005W/°C from 70°C to .35W at 100°C. KARN-50 is 2W, derate linearly at 0.025W/°C to 1.25W at 100°C.



Mini-Circuits®

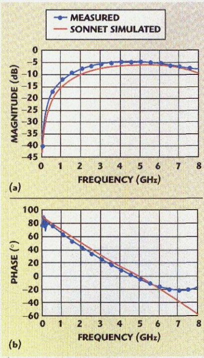
US 113 INT'L 114
CIRCLE READER SERVICE CARD

P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661 For quick access to product information see MINI-CIRCUITS CATALOG & WEB SITE

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

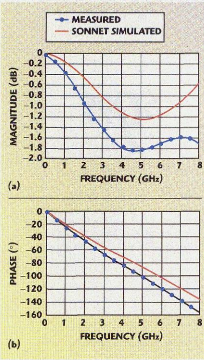
ISO 9001 CERTIFIED

F 258 Rev C



▲ *Fig. 10 S_{11} of a knee structure.*

▼ *Fig. 11 S_{21} of a knee structure.*



Furthermore, the measured reactance is 1.212 nH compared to 1.210 nH, the value of the series inductance used in the load's model. The model for the load was based on a TRL measurement and an optimization process; the fact that both reactances agree increases the confidence in the SOLR calibration.

Perhaps the most interesting results are those shown in ***Figures 10*** and ***11***. Using the Sonnet Suite EM simulator,[7] the knee type of the previously shown structure was simulated. The same knee was measured with the SOLR calibration and compared to the simulated results. The S_{11} results are in a good agreement through 6 GHz, with some noticeable phase deviation above that. The S_{21} results show tracking in shape through the same frequency; however, there is more loss in the measured data. It is surmised that the loss is due to radiation and conductor losses that were not accounted for in the EM simulation.

CONCLUSION

The measurement results show that a good SOLR calibration using GCPW lines is feasible. Orthogonal on-wafer measurements were successfully completed with an SOLR right-angle calibration. The use of a bend in the orthogonal calibration does not appear to cause significant error. In the case where WinCal is used for the SOLR computation, an important step is to make sure that accurate models for the standards are in hand; otherwise, the calibration will not succeed. It is crucial to make sure that the optimized standard models rely on an accurate reference calibration to guide the process.

ACKNOWLEDGMENT

The authors would like to thank Linda Jaffe of Cascade Microtech for making WinCal available, Leonard Hayden of Cascade Microtech for his valuable review comments, Jim Rautio of Sonnet for providing the em™ software and Bert Schmitz of M/A-COM, Roanoke, VA, for providing the GCPW test structures used here and in a related project funded by the same organization. ■

References

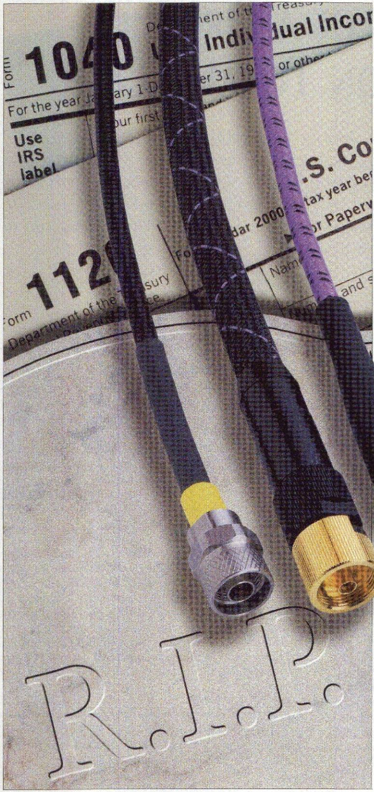
1. A. Ferrero, "Two-port Network Analyzer Calibration Using an Unknown Thru," *IEEE Microwave and Guided Wave Letters*, Vol. 2, No. 12, December 1992, pp. 505–507.
2. Cascade Microtech, 2430 NW 206th Ave., Beaverton, OR.
3. S. Basu and L. Hayden, "An SOLR Calibration for Accurate Measurement of Orthogonal On-wafer DUTs," *1997 MTT-S International Microwave Symposium Digest*, Denver, June 1997.
4. S. Gross and L. Dunleavy, "PC Board Characterization Using Accurate Hybrid Probing Techiques," *53rd ARFTG Conference Digest*, 1999.
5. Agilent Technologies Inc., 3000 Hanover St., Palo Alto, CA.
6. R.B. Marks and D.F. Williams, "Characteristic Impedance Determination Using Propagation Constant Measurement," *IEEE Microwave Guided Wave Letters*, Vol. 1, No. 6, June 1991, pp. 141–143.
7. Sonnet Software, 1020 Seventh North St., Suite 210, Liverpool, NY.

Shay Gross *received his BSc and MSc degrees in electrical engineering from the University of South Florida, Tampa, in 1998 and 2000, respectively. His research focused on passive components modeling. Currently, Gross is employed by Intel Corp. in Israel.*

Lawrence P. Dunleavy *received his BSEE degree from Michigan Technological University in 1982, and his MSEE and PhD degrees in 1984 and 1988, respectively, from the University of Michigan. He has worked in industry for E-Systems and Hughes Aircraft Company and was a Howard Hughes Doctoral Fellow. In 1990, he joined the electrical engineering department at the University of South Florida, where his is now an associate professor. From August 1997 to August 1998, he enjoyed a sabbatical research appointment with the Microwave Metrology Group of the National Institute of Standards and Technology (NIST) in Boulder, CO. His current research interests are in the area of accurate microwave and millimeter-wave measurements, measurement-based active and passive component modeling, MMIC design, and wireless systems characterization and CAD. Dunleavy is a senior member of IEEE, and is very active in the IEEE MTT Society and the Automatic RF Techniques Group (ARFTG). He has authored or co-authored more than 60 technical articles.*

Thomas M. Weller *received his BS, MS and PhD degrees in electrical engineering in 1988, 1991 and 1995, respectively, from the University of Michigan, Ann Arbor. He is currently an assistant professor in the electrical engineering department at the University of South Florida, Tampa. His research involves micromachining applications for microwave and mm-wave circuits, packaging, electromagnetic modeling and mm-wave sensors. Weller was a co-recipient of the 1996 Microwave Prize from the IEEE MTT Society, and has published more than 40 papers in his field.*

Now there are three things you can absolutely count on.



Gore Microwave Test Assemblies... A Sure Bet.

Gore offers a wide variety of cable assembly options to meet your test equipment and network analyzer needs. For over 20 years Gore has provided reliable and dependable microwave test assemblies to the industry.

PHASEFLEX™ Assemblies

PHASEFLEX assemblies provide superior phase and amplitude stability in a ruggedized, flexible package. Phase matched and replaceable interface options are available in configurations operating from DC to 26.5GHz. Off-the-shelf assemblies are available on your doorstep within days for standard configurations in 24", 36", and 48" lengths.

NEXT GENERATION® Assemblies

Gore's NEXT GENERATION vector network analyzer cables are the industry standard for precision test applications through 65GHz. They provide superior accuracy and repeatability for critical test measurements. NEXT GENERATION assemblies ensure superior phase and loss stability in a crush-proof, torque resistant housing, with an autolimiting bend radius. Quick turnaround for standard length assemblies, 25" and 38", is also available.

1 (800) 445-GORE
in North America or
+49/9144-6010
in Europe
Visit our website at: www.gore.com

Creative Technologies Worldwide

EFFECTS OF A DRIVER'S ACLR ON TOTAL ACLR

The effects of a driver's adjacent-channel leakage ratio (ACLR) on the total ACLR have been tested to investigate the relationship between the ACLR of a driver and a device under test (DUT). The ACLR test results show that the degradation in ACLR is 4.1 to 4.5 dB when both ACLR values are the same. If the difference in ACLR values between a source and a DUT is 12 to 12.5 dB, then there is no degradation in total ACLR.

The capacity of a CDMA system is determined in part by system noise and interference. The system performances are linked to adjacent-channel interference ratio (ACIR) values. ACIR is defined as the ratio of the total power transmitted from a source to the total interference power affecting a victim receiver, resulting from both transmitter and receiver imperfections. The imperfections of the receiver and transmitter are adjacent-channel selectivity (ACS) and ACLR, respectively. ACS is a measure of a receiver's ability to receive a signal at its assigned channel frequency in the presence of a modulated signal in the adjacent channel. Therefore, ACS is the ratio of the receiver filter attenuation on the assigned channel frequency to the receiver filter attenuation on the adjacent-channel frequency. ACLR determines how much the transmitted power is allowed to leak into the first and second neighboring carriers. If the ACLR is low, the efficiency of the spectrum and the capacity of the system are decreased.

All transmitters contain nonlinear components, such as amplifiers and mixers. The output signals of a transmitter consist of amplified input signals and distortion signals caused by the nonlinear characteristics of components in the transmitter. Distortion signals generated in nonlinear components are called intermodulation distortion (IMD). ACLR directly relates to the linearity of a transmitter. Even though the linearity of a transmitter is high, if the purity of the input signal of the transmitter is low, the purity of the output signal of the transmitter becomes low. In this article, the effects of an input signal's ALCR on the ACLR of the output signal of a transmitter are presented. ACLR test results show how the ACLR of the output signals of an amplifier can be determined by the ACLR of the input signal and amplifier.

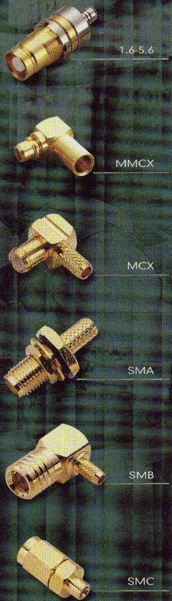
The linearity of an amplifier for analog transmitting systems is sufficiently represented as IMD and measured with a two-tone IMD test. However, the real signal in a digital mobile system has a different cumulative distribution function from that of tone signals. Therefore, the linearity of an amplifier for a digital mobile system should be tested using an actual signal generated from the signal source for the digital mobile system or the

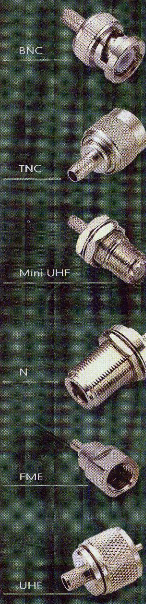
[Continued on page 89]

SANGGEE KANG AND HEONJIN HONG
Electronics and Telecommunications Research Institute (ETRI)
Taejon, Korea
SUNGYONG HONG
Chungnam National University
Taejon, Korea

Focus US

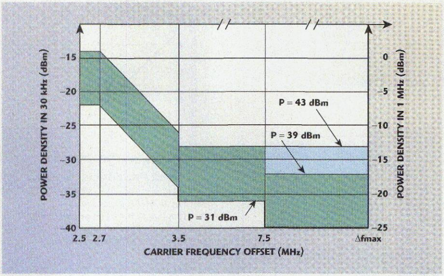
To support the demanding needs of microwave and RF applications, capital reinvestment for machinery and tooling is a top priority.
The production capacity and capability of Chin Nan is second to none.





Distributor in FL
FLORIDA RS TECHNOLOGY
3379-A SW 42nd Avenue, Palm City, FL 34990
TEL:(561)221 8188 FAX:(561)221-1095
E-mail:info@flrst.com

CHIN NAN® PRECISION ELECTRONICS CO., LTD.
NO. 22-1 JEN-HO ROAD, TAINAN, TAIWAN, R.O.C.
TEL:886-6-2678303 FAX:886-6-2678337
E-Mail:market @ chinnan.com.tw
Web Site:http//www.chinnan.com
Web Site:http//www.chinnan.com.tw



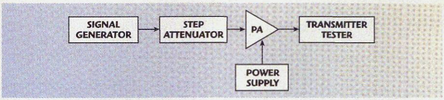
▲ *Fig. 1 Base station output power spectrum mask.*

transmitter of the digital mobile system in order to exactly measure the linearity.

Recently, the adjacent-channel power ratio (ACPR) of a transmitter has been used for describing the linearity of the transmitter in a digital mobile system. The measured ACPR values are dependent on the resolution bandwidth. Therefore, ACPR is a meaningful value only with regard to resolution bandwidth (RBW). ACPR does not represent the real power leaked into adjacent channels because it does not include the performance of the receiving filter of a victim receiver. However, ACLR includes the performance of the receiving filter of a victim receiver. Therefore, ACLR is used for describing the linearity of a transmitter in the Third-generation Partnership Project (3GPP) specifications.

Figure 1 shows the spectrum mask of a transmitter, described in the 3GPP specification, according to the output power of the transmitter. The simulation results that compare the ACLR measurement using a raised-root cosine (RRC) filter with a 0.22 rolloff factor (with the ACPR measurement using a 30 kHz RBW) show that the difference between each measurement is 5.6 dB for a 5 MHz offset and 1.52 dB for a 10 MHz offset. Therefore, the ACLR measurement is performed with a proper instrument equipped with an RRC filter with a 0.22 rolloff factor.

The ACLR requirements of a base station described in the 3GPP specifications are 45 dB for ACLR1 (measured at ±5 MHz offset from the center frequency of the assigned channel) and 50 dB for ACLR2 (measured at ±10 MHz offset from the center frequency of the assigned channel).[1,2]



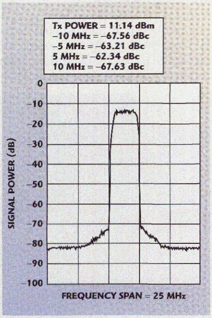
▲ *Fig. 2 Block diagram for ACLR testing.*

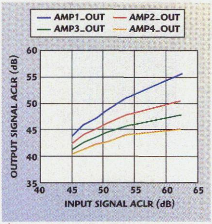
TABLE I

THE AMPLIFIER'S ELECTRICAL PERFORMANCE

Frequency range (MHz)	2000 to 2200
P_{out} at 1 dB compression (dBm)	32
OIP3 (dBm)	47
Gain (dB)	20 ±0.3
NF (dB)	3

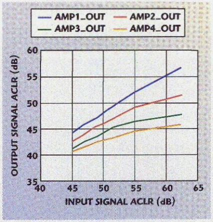
Fig. 3 The W-CDMA signal used for testing the amplifier's ACLR. ▼

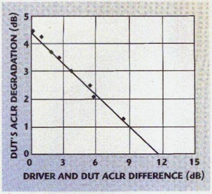




▲ *Fig. 4 ACLR1 at the amplifier's output port at +5 MHz offset.*

Fig. 5 ACLR1 at the amplifier's output port at –5 MHz offset. ▼





▲ *Fig. 6 ACLR degradation as a function of the difference between an input signal and an amplifier's ACLR (input ACLR > amplifier ACLR).*

The ACLR requirements are derived from the ACIR, causing a one percent capacity loss in the system.[3] However, ACLR2 has less of an effect on system performance than ACLR1; therefore, this work focuses on the relationship between the driver's and the DUT's ACLR1.

The high power amplifier mainly determines the linearity of a transmitter. The ACLR specifications described in 3GPP require a linear power amplifier. Even though a linear power amplifier has high ACLR, the ACLR of the input signal of the linear power amplifier is low, thus the ACLR of the output signal of the linear amplifier also becomes low. Therefore, the effect of the transmitter's input signal ALCR on the output signal's ACLR must be considered to implement the transmitter. In addition, it must be determined that the required ACLR of a signal generator does not affect the ACLR of the amplifier in testing the ACLR of a power amplifier.

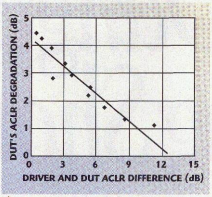
TEST RESULTS

Figure 2 shows the block diagram for the ACLR test. The signal generator and transmitter tester meet the requirements of 3GPP specifications. The electrical performance of the amplifier used in the ACLR test is listed in ***Table 1***.

Figure 3 shows the spectrum of the wideband CDMA (W-CDMA) signal used for the amplifier's ACLR test. ACLR1 of the signal is 62.34 dB for +5 MHz offset and 63.21 dB for –5 MHz offset. ***Figures 4*** and ***5*** show ACLR1 values at the output port of the amplifier with respect to the ACLR value of the input signal and amplifier at ±5 MHz offset, respectively. In general, the nonlinear characteristics of components are not symmetric to the center frequency of output signals in the spectrum domain. Therefore, measurements of the nonlinear characteristics are performed at low and high frequency offsets from the center frequency of output signals. The amplifier's ACLR1 is controlled by adjusting the bias voltage of the amplifier. The controlled ACLR1 value of the amplifier for 5 MHz offset is 55.67, 50.55, 47.95 and 45.10 dB, respectively. In the case where the amplifier's ACLR1 is 55.67 dB, the ACLR1 of the input signal must be 47 dB above to meet the 45 dB ACLR1 requirement. If the amplifier's ACLR1 is 47.95 dB, then the ACLR1 of the input signal must be 51 dB above to keep the ACLR1 requirement in 3GPP. The controlled ACLR1 amplifier values for –5 MHz offset are 56.55, 51.50, 48.45 and 45.72 dB, respectively.

The degradation in ACLR1 according to the difference between the ACLR1 of the input signal and the amplifier is presented. The data are obtained using the ACLR1 values given in the previous two plots. ***Figure 6*** shows the degradation in the amplifier's ACLR1 when the ACLR1 of the

[Continued on page 92]



▲ *Fig. 7 ACLR degradation as a function of the difference between an input signal and an amplifier's ACLR (amplifier ACLR > input ACLR).*

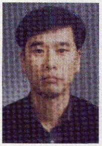
input signal is better than the ACLR1 of the amplifier; ***Figure 7*** shows the case where the input signal is less than the ACLR1 of the amplifier. In general, the ACLR of the input signal is better than that of the amplifier. The degradation from the amplifier's ACLR1 is ≈ 4.5 dB when both ACLR1 values are the same. If the ACLR1 of the input signal is 12 dB above or better than the ACLR1 of the amplifier, then there is no degradation in the amplifier's ACLR. Therefore, the ACLR1 requirement of a signal generator used to measure the ACLR1 of an amplifier is approximately 12 dB greater than the ACLR1 of the amplifier. The data show the degradation in the input signal's ACLR1 when the ACLR1 of the amplifier is better than that of the input signal. In this case, the degradation in the signal's ACLR is approximately 4.1 dB when the ACLR1 of the input signal is the same as that of the amplifier. If the ACLR1 of the amplifier is 12.5 dB greater than that of the input signal, then there is no degradation from the ACLR1 of the input signal. Thus, how much the ACLR degradation occurs in transmitters or amplifiers can be predicted.

CONCLUSION

The effects of the ACLR characteristics of a driver and amplifier on total ACLR have been tested. The ACLR test results show that the degradation in ACLR1 is 4.1 to 4.5 dB when the ACLR of the input signal is the same as that of an amplifier. If the ACLR1 of the input signal is 12 to 12.5 dB greater than that of an amplifier, then the total ACLR1 is the same as that of the amplifier. Therefore, to measure the ACLR1 of an amplifier, a signal source that has an ACLR 12 to 12.5 dB higher than that of the amplifier must be used. Test results presented in this article are useful for determining the required ACLR specification of base station transmitters that compose a baseband modulator, frequency upconverter and power amplifier to meet 3GPP ACLR requirements. These ACLR test results also can be useful for user equipment. ■

References

1. 3GPP TS 25.104, Radio Transmission and Reception (FDD) v3.2.0.
2. 3GPP TS 25.141, Base Station Conformance Testing (FDD) v3.1.0.
3. Harri Holma and Antti Toskala, *WCDMA for UMTS Radio Access for Third Generation Mobile Communications*, John Wiley & Sons, 2000.



Sanggee Kang *received his MSEE from the Dankuk University, Seoul, Korea, in 1994. He joined Samsung Semiconductor & Telecommunication as a design engineer in 1988. Since 1994, he has been involved in the research and development of RF systems for mobile communications at ETRI in Taejon, Korea. His major research interests are high power amplifiers and linear power amplifiers for mobile communications.*

Heonjin Hong *received his MSEE from the Chungnam National University, Korea in 1990. Since 1990, he has been involved in research and development of RF systems for mobile communications at ETRI in Taejon, Korea. His major research interests are linear transmitters and receivers for mobile communications*

Sungyong Hong *received his doctorate degree in electronic engineering in 1994 from KAIST, Korea. From 1994 to 1996, he worked as an R&D manager at Korea Sangshin Electric. In 1996, he joined the radio science & engineering department at the Chungnam National University in Korea. His research interests are in the area of high frequency circuit design for mobile communication.*

Asymptotic Behavior of Cosine Windows

The asymptotic behavior of the even-cosine series windows presented here reveals that the series has an asymptotic decay 6 dB/octave higher than the odd-cosine series. The coefficients of the series are determined for the condition of maximum asymptotic decay, and the frequency response plots of the series are given.

It is well known that an ideal rectangular bandpass filter requires an impulse response of infinite duration, which is unrealizable in practice. Truncating this infinite impulse response after a certain time duration results in undesirable ripples (known as Gibb's ripples) in the passband and stopband. Windows (finite even time functions), when multiplied with the infinite impulse response of the ideal rectangular filter, tend to smooth the Gibb's ripples in the frequency response; however, this improvement is at the cost of widening the transition width. A window is characterized in the frequency domain in terms of its mainlobe width, peak sidelobe response and asymptotic decay. The widely used window functions are the Dolph-Chebyshev window, kaiser window, Gaussian window and cosine windows. An exhaustive discussion on windows has been provided by Harris[1] and Nuttall.[2]

The cosine windows comprise a wide range of window functions, including the Hanning, Hamming and Blackman windows,[1] the cosine temporal weightings,[2] and the odd- and even-cosine series.[3] Nuttall[2] discusses the criteria for maximizing asymptotic decay and minimizing the sidelobe peaks, along with the tradeoff in achieving one characteristic at the expense of the other. The odd-cosine series functions presented by Malocha and Bishop[3] are the same as the cosine temporal weightings,[2] with the coefficients of the series determined by minimizing the sidelobe peaks. The coefficients of the even- and odd-cosine series functions are further refined in Kulkarni and Lahiri[4] to obtain improved sidelobes. The even- and odd-cosine series have an even and odd number of kernels in their respective frequency responses as described by Malocha and Bishop.[3]

This article presents the asymptotic behavior of the even-cosine series and compares it with that of the odd-cosine series. The findings reveal that the even-cosine series has a 6 dB/octave higher asymptotic decay of the sidelobes than the odd-cosine series.

Asymptotic Behavior When Decay Is Maximized

The asymptotic behavior of the odd-cosine series (or the cosine temporal weightings) has been explained in past literature.[2] The asymptotic behavior of the even-cosine series has not been discussed previously and is presented here. For this purpose, the even-cosine series is expressed in the time and frequency domains as [4]

$$h_{N2}(t) = \sum_{n=0}^{N-1} b_n \cos\left[\frac{(2n+1)\pi t}{T}\right], \; |t| \le \frac{T}{2} \quad (1)$$

[Continued on page 98]

Raghavendra G. Kulkarni
Bharat Electronics, HMC Division
Bangalore, India

$$H_{N2}(f) = \frac{T}{2}\sum_{n=0}^{N-1} b_n \left[\frac{\sin\left(\pi f T - \frac{(2n+1)\pi}{2}\right)}{\left(\pi f T - \frac{(2n+1)\pi}{2}\right)} + \frac{\sin\left(\pi f T + \frac{(2n+1)\pi}{2}\right)}{\left(\pi f T + \frac{(2n+1)\pi}{2}\right)} \right] \quad (2)$$

where the time domain function, h_{N2}, exists only in the interval from $-T/2$ to $T/2$. The coefficients b_n are real and positive and are determined by the criteria applied on the sidelobes of the frequency function H_{N2}.

The function H_{N2} is rearranged in a convenient form for this discussion as

$$H_{N2}(f) = \left[\frac{\cos(\pi f T)}{2\pi T f^2}\right] \bullet \sum_{n=0}^{N-1} (-1)^{n+1} b_n (2n+1) \bullet \left[1 + \frac{(2n+1)^2}{4T^2 f^2} + \frac{(2n+1)^4}{16 T^4 f^4} + \ldots\right] \quad (3)$$

after recognizing that the term $[1 - \{(2n+1)^2/4T^2f^2\}]^{-1}$ has been expressed in a power series. Note from Equation 3 that when the first term in the series is not equal to zero such that

$$\sum_{n=0}^{N-1} (-1)^{n+1} b_n (2n+1) \neq 0$$

the function decays as $1/f^2$, resulting in a 12 dB/octave decay. Note that the minimum asymptotic decay that can be obtained with the even-cosine series is 12 dB/octave; for cosine temporal weightings[2] it is 6 dB/octave. However, if

$$\sum_{n=0}^{N-1} (-1)^{n+1} b_n (2n+1) = 0 \quad (4)$$

and if the second term (numerator part) is non-zero such that

$$\sum_{n=0}^{N-1} (-1)^{n+1} b_n (2n+1)^3 \neq 0$$

the function will decay as $1/f^4$, giving a 24 dB/octave decay. In the same way, if the first two terms in the power series vanish such that

$$\sum_{n=0}^{N-1} (-1)^{n+1} b_n (2n+1) = 0$$

$$\sum_{n=0}^{N-1} (-1)^{n+1} b_n (2n+1)^3 = 0 \quad (5)$$

and the third term is not equal to

[Continued on page 102]

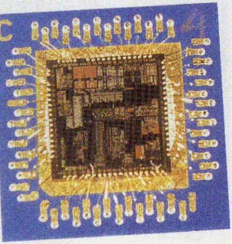
Application Profile

How Do I Make Bluetooth Wireless Products Small and Inexpensive??

Use the Integrated ASIC LTCC Modules from National Semiconductor Using DuPont Green Tape™ and Fine-Line Technology.

An integrated ASIC? Inexpensive?? Tell me more!!!

National Semiconductor leads the way in Bluetooth, Cell Phone and other wireless applications in applying LTCC to integrated wireless modules. National's latest advances in LTCC manufacturing technology, combined with DuPont's advances in Green Tape™, Fodel® Compositions and thick film conductor materials, have established a new low-cost standard for wireless modules.



LOW-COST LTCC

LTCC is the least expensive alternative for your RF wireless design. Consider that the LTCC raw material is inorganic (earth oxides) versus the alternatives — organic (oil). Also, the process is scalable in panel size as the manufacturing volume increases, thereby drastically reducing cost per square inch.

LTCC has the highest passive integration capability of any active/passive component board-level system. More passive components in the LTCC and not on top of the module, resulting in less space utilized and the lowest system cost solution.

THE INTEGRATED ASIC

With the capability of DuPont's Fodel® fine-line technology, active components can be flip-chip mounted to the LTCC module. The high frequency characteristics of the entire vertical structure can be modeled, and performance optimized. Also, results have shown higher-yielding DC interconnects, improved Q on edge-coupled, edge-sensitive structures, and more consistent electromagnetic results in RF structures. The resultant module performance is optimized, space minimized, and the resultant cost 25% to 50% below competing technologies.

LTCC has come to lead the wireless revolution, and offers the lowest-cost, smallest-size, and highest-performance solution to your wireless design. National's LTCC foundry technology offers you the fastest design-to-volume format. Proto cycle times in less than seven days, flexible manufacturing lines accommodating design and capacity changes without delivery interruption, 30-day ramp to volume — all this plus complete assembly and test services that support the full line of DuPont Green Tape™ products.

National: Doing what we do best — prototype turns in 7 days; state-of-the-art technology; and low-cost/high-volume QS9000 manufacturing.

For more information, call National at (949) 380-2054 or visit the National LTCC website at http://www.national.com/ltcc.

National Semiconductor®

DUPONT®

GREEN TAPE™ FODEL® BIROX® DIFFUSION PATTERNING™ LUXPRINT®

TABLE I

PARAMETERS RESULTING FROM MAXIMIZING ASYMPTOTIC DECAY OF ODD- AND EVEN-COSINE SERIES

Function	Mainlobe Width	Peak Sidelobe (dB)	Asymptotic Decay (dB/Octave)	Coefficients
Odd Series				
H_{11}	±1/T	–13.0	–6	1
H_{21}	±2/T	–31.5	–18	1, 1
H_{31}	±3/T	–46.7	–30	1, 4/3, 1/3
H_{41}	±4/T	–60.9	–42	1, 3/2, 3/5, 1/10
Even Series				
H_{12}	±1.5/T	–23.0	–12	1
H_{22}	±2.5/T	–39.3	–24	1, 1/3
H_{32}	±3.5/T	–53.1	–36	1, 1/2, 1/10
H_{42}	±4.5/T	–67.8	–48	1, 3/5, 1/5, 1/35

zero, as in

$$\sum_{n=0}^{N-1}(-1)^{n+1} b_n (2n+1)^5 \neq 0$$

then the function will decay as $1/f^6$, resulting in a 36 dB/octave decay.

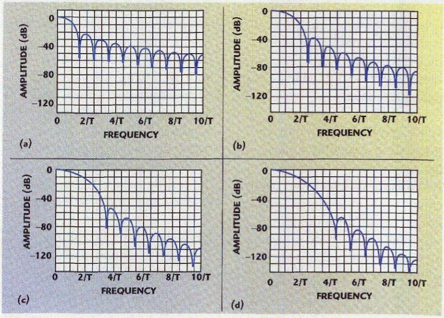
From the discussion on unique coefficients,[4] note that $b_0 = 1$ and only b_1 can be determined, leading to a two-term even-cosine series. From Equation 5, only b_1 and b_2 can be determined, and a three-term cosine series results. The coefficients of the even-cosine series up to four terms are determined and listed in ***Table 1*** along with mainlobe width, peak sidelobe level and asymptotic decay. The frequency domain plots of H_{12} to H_{42} are shown in ***Figure 1***. Comparing the asymptotic decays of the even- and odd-cosine series from the table, note that for a given N, the even-cosine series has a 6 dB/octave higher decay of sidelobes than the odd-cosine series.

With the condition of maximizing asymptotic decay, the odd- and even-cosine series together can be represented by a single expression as

$$h_k(t) = \cos^k\left(\frac{\pi t}{T}\right) \tag{6}$$

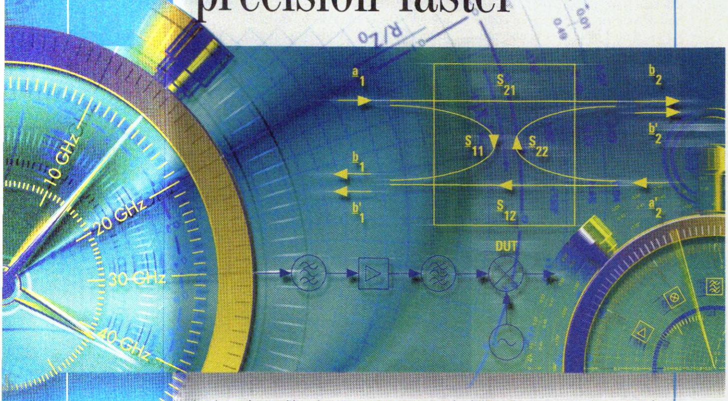
where k assumes integer values. When k is odd, the even-cosine series is obtained; when k is even, the odd-cosine series results. The window function given in Equation 6 is called the cosine powered window, or Hanning window.[1]

Fig. 1 Frequency response of even-cosine series for maximum asymptotic delay for (a) N = 1, (b) N = 2, (c) N = 3 and (d) N = 4.



[Continued on page 104]

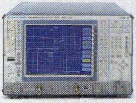
We make precision faster



Network Analysis from 10 MHz to 20 GHz

Loosing patience with an instrument on your bench because it's too slow? Why not try our new Vector Network Analyzer ZVM, with measurement times down to 500 µs per point or a dynamic range of more than 130 dB.

After all, it performs measurements on any kind of frequency-converting devices like synthesizers, mixers and receivers at little effort. Its versatile handling of swept harmonics, intermodulation and spurious measurements on amplifiers and mixers will amaze even the seasoned professional.



Thanks to special calibration techniques for wafers and test fixtures, together with de-embedding functions, ZVM offers undreamed of advantages in design and production of amplifiers and filters. Highlight minimum cost and maximum precision in the way you develop and produce your components and systems – try ZVM.

Just ask for full details.

ROHDE&SCHWARZ

Discover more: **www.rohde-schwarz.com**

◆ **Argentina** (14) 3 31 16 85 ◆ **Australia** (2) 97 48 01 55 ◆ **Austria** (1) 6 02 61 41 ◆ **Belgium** (2) 7 21 50 02 ◆ **Brazil** (11) 55 05 21 77 ◆ **Bulgaria** (2) 9 63 43 34 ◆ **Canada** (613) 592 80 00 ◆ **Chile** (2) 2 77 50 50 ◆ **China** (10) 64 31 28 28 ◆ **Czech Republic** (2) 24 32 20 14 ◆ **Denmark** 43 43 66 99 ◆ **Finland** (9) 47 88 30 ◆ **France** (1) 41 36 10 00 ◆ **Germany** (089) 4 12 91 37 74 ◆ **Greece** (1) 7 22 92 13 ◆ **Hong Kong** 25 07 03 33 ◆ **Hungary** (1) 2 03-02 82 ◆ **India** (11) 4 61 52 85 ◆ **Indonesia** (21) 5 76 16 02 ◆ **Italy** (6) 41 59 81 ◆ **Malaysia** (3) 7 03 55 03 ◆ **Mexico** (5) 5 59 76 77 ◆ **Netherlands** (30) 6 00 17 00 ◆ **New Zealand** (4) 2 32 32 33 ◆ **Norway** 23 17 22 50 ◆ **Pakistan** (51) 26 30 72 ◆ **Philippines** (2) 8 13 29 31 ◆ **Poland** (22) 8 60 64 90 ◆ **Portugal** (21) 4 12 35 90 ◆ **Romania** (1) 4 10 68 46 ◆ **Russian Federation** (095) 2 34 49 62 ◆ **Saudi Arabia** (1) 4 65 44 78 ◆ **Singapore** 28 7 68 22 ◆ **Slovenia** (61) 1 23 46 51 ◆ ***South Africa*** (11) 7 86 36 47 ◆ **Spain** (91) 3 34 10 70 ◆ **Sweden** (8) 6 05 19 00 ◆ **Switzerland** (31) 9 22 15 22 ◆ **Taiwan** (2) 23 91 10 02 ◆ **Thailand** (2) 8 80 93 45 ◆ **Turkey** (216) 3 85 19 17 ◆ **United Kingdom** (1252) 81 13 77 ◆ **USA** Tektronix Tel (800) 4 26 22 00, www.tek.com ◆

CIRCLE 155 ON READER SERVICE CARD

ASYMPTOTIC BEHAVIOR OF SIDELOBES WHEN THE SIDELOBE PEAKS ARE MINIMIZED

When the condition of minimizing sidelobe peaks is used for determination of coefficients of the even-cosine series, then Equation 4 is not satisfied and the inequality expression governing the coefficients

$$\sum_{n=0}^{N-1}(-1)^{n+1}b_n(2n+1)\neq 0$$

prevails. The coefficients b_n are given in the literature.[4] With these coefficients the asymptotic decay achievable is 12 dB/octave. However, for the criteria of minimizing sidelobe peaks, the odd-cosine series presents a 6 dB/octave decay of the sidelobes.[2] Thus, the even-cosine series has a 6 dB/octave higher decay of the sidelobes when compared with the odd-cosine series. **Table 2** lists various parameters along with the asymptotic decay of the sidelobes for an even- and odd-cosine series for the condition of minimizing sidelobe peaks. The values of peak sidelobes are obtained using the results in the literature.[4]

TABLE II
PARAMETERS RESULTING FROM MINIMIZING SIDELOBE PEAKS OF ODD- AND EVEN-COSINE SERIES

Function	Mainlobe Width	Peak Sidelobe (dB)	Asymptotic Decay (dB/Octave)
Odd Series			
H_{11}	±1/T	–13.2	–6
H_{21}	±2/T	–41.1	–6
H_{31}	±3/T	–67.7	–6
Even Series			
H_{12}	±1.5/T	–23.0	–12
H_{22}	±2.5/T	–52.7	–12
H_{32}	±3.5/T	–80.6	–12

CONCLUSION

The asymptotic behavior of an even-cosine series has been presented and compared with the odd-cosine series. It was found that the even-cosine series has a 6 dB/octave higher asymptotic decay than the odd-cosine series. The coefficients of the series were determined for the condition of maximum asymptotic decay. The frequency responses of the series up to the fourth order were also shown.

ACKNOWLEDGMENT

The author thanks the management of Bharat Electronics for supporting this work. ■

References

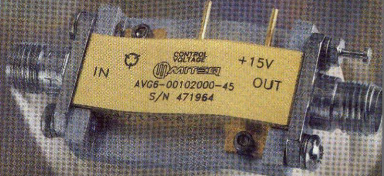
1. F.J. Harris, "On the Use of Windows for Harmonic Analysis with the Discrete Fourier Transform," *Proceedings of the IEEE*, Vol. 66, January 1978, pp. 51–83.
2. A.H. Nuttal, "Some Windows with Very Good Sidelobe Behavior," *IEEE Transactions on Acoustics, Speech and Signal Processing*, Vol. ASSP-29, No. 1, February 1981, pp. 84–91.
3. D.C. Malocha and C.D. Bishop, "The Classical Truncated Cosine Series Functions with Applications to SAW Filters," *IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control*, Vol. UFFC-34, January 1987, pp. 75–85.
4. R.G. Kulkarni and S.K. Lahiri, "Improved Sidelobe Performance of Cosine Series Functions," *IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control*, Vol. 46, March 1999, pp. 464–466.

Raghavendra G. Kulkarni *received his BE degree in electronics and communications from Karnatak University in 1979, his MTech degree from Indian Institute of Technology, Madras in 1982 and his PhD degree from Indian Institute of Technology, Kharagpur in 1998. He joined the HMC Division of Bharat Electronics, Bangalore in 1982 and since then has been engaged in the design and development of SAW devices. He won the company's R&D award in 1989 for his work on SAW filters. Kulkarni has authored several technical papers in the area of SAW devices and has applied for two patents. He is a member of IMAPS-India and IEEE. Currently, Kulkarni is working as a manager guiding SAW device development activities in Bharat Electronics' HMC Division.*

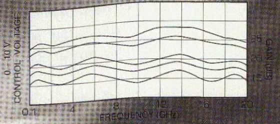
VARIABLE GAIN AMPLIFIERS

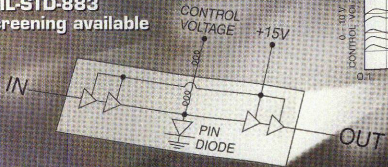
FEATURES

- Gain can be continuously adjusted (0–15 dB) by applying a 0–10 VDC control voltage
- Ideal for broadband receiver AGC & CFAR circuits
- Hermetically sealed
- Various bandwidth, gain, noise figure and power options available
- MIL-STD-883 screening available



TYPICAL DATA





3 YEAR WARRANTY

MODEL	FREQUENCY RANGE	GAIN	GAIN FLATNESS	NOISE FIGURE	VSWR IN/OUT	OUTPUT POWER @ 1 dB Comp.	NOM. DC POWER
AVG4-00100400-14	.1–4	28	±1.00	1.4	2.0:1	+10	150
AVG4-00100600-15	.1–6	28	±1.00	1.5	2.0:1	+10	150
AVG4-00100800-18	.1–8	26	±1.50	1.8	2.0:1	+10	175
AVG4-02000800-20	2–8	32	±1.25	2.0	2.0:1	+10	175
AVG5-04000800-12	4–8	30	±1.00	1.2	2.0:1	+10	150
AVG5-00101800-35	.1–18	24	±2.50	3.5*	2.5:1	+10	175
AVG6-00102000-45	.1–20	24	±2.50	4.5*	2.5:1	+10	250
AVG4-06001200-19	6–12	24	±1.50	1.9	2.0:1	+10	175
AVG4-06001800-25	6–18	22	±2.00	2.5	2.3:1	+10	185
AVG6-02001800-40	2–18	25	±2.25	4.0	2.5:1	+10	250

* Noise figure increases below 500 MHz.

Note: All above specifications are with 0 dB attenuation.

For additional information, please contact Naseer Shaikh at (631) 439-9259 or nshaikh@miteq.com

www.miteq.com

NQA ISO 9001 REGISTERED COMPANY

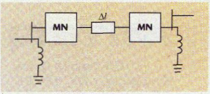
MITEQ
100 Davids Drive
Hauppauge, NY 11788
TEL.: (631) 436-7400
FAX: (631) 951-4338/436-7430

Distortions in Cascaded MMIC Power Amplifiers

This article presents an experimental investigation of the influence of a second harmonic phase delay between two cascaded GaAs MESFET MMIC power amplifiers (PA) on the total distortion characteristic. Two-tone intermodulation distortion (IMD) products may vary by several decibels through the saturation region, depending on the value of the series feedback source inductance used in both stages. In addition, an improvement of several decibels in ACPR values at moderate output power levels for digitally modulated standards may be reached with the proper choice of a phase delay.

Many methods exist for the linearization of RF/microwave PAs.[1–4] In most cases, these methods are applicable to high power amplifiers taking into account their cost, size, weight and power consumption. For low- and mid-power portable PAs, these issues can play a decisive role in the choice of the required circuit. Thus, PA circuit-level linearization techniques may be more attractive to achieve low distortion characteristics.[3,5–7] It is known that the main source of IMD in a PA is typically the cubic term of the PA transfer characteristic. These distortions may be compensated for by utilizing a second harmonic adjustment.[3,4,8] This goal may be quite easily achieved with discrete components. However, purchased MMIC utilization complicates the task. This article describes a simple way to adjust distortions in a set of cascaded MMIC PAs.

Fig. 1 The analyzed circuit.

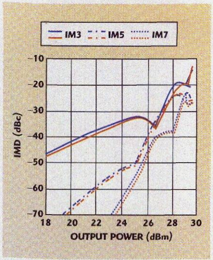


PHASE-DELAYED INTERSTAGE ADJUSTMENT

Figure 1 shows the interstage circuit between cascaded MMIC FET PAs. The only transmission line length in the circuit may be adjusted. It is known[4] that the PA output signal spectral purity may be improved by careful adjustment of the gain and phase shift of the second harmonic path. For maximum improvement, the power required for the second harmonic should be high enough (7 dB below that of the fundamental in the example[4]). It is also known that the series source inductance can decrease IMD in the PA and simultaneously facilitate a low noise amplifier (LNA) in-

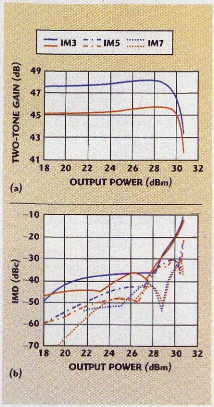
[Continued on page 108]

Oleksandr Gorbachov
and Yie-Der Shen
Hexawave Inc.
Hsinchu, Taiwan, R.O.C.

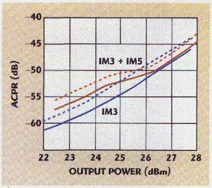


▲ *Fig. 2 IMD products for the low inductance circuit.*

Fig. 3 The high inductance circuit's (a) gain and (b) IMD products. ▼



put and noise matching condition[8] with increased in-band stability. Taking these issues into account, it can be concluded that a drive MMIC PA with bad linearity must be utilized and the line length adjusted to achieve the best total distortion characteristics of the complete MMIC set. The power produced by the final stage of the drive PA and the gain of the first stage of the second PA should have sufficient values to achieve this performance.



▲ *Fig. 4 ACPR for the high inductance circuit.*

MEASUREMENT RESULTS

Measurements have been performed for a set of 3.5 GHz GaAs MESFET MMIC PAs to evaluate how much improvement of distortion characteristics may be achieved. The series feedback source inductance in both stages may be varied due to the non-via chip structures used.

First, the minimum possible inductance values were chosen. ***Figure 2*** shows the two-tone extreme intermodulation characteristics resulting from adjustment of the line length over a wide margin. The difference in the line length between extreme values corresponds to a quarter-wavelength at the second harmonic. Accordingly, the amplifier's small-signal, single-tone gain is 42 dB at P1dB = 28.8 dBm and 40.7 dB at P1dB = 29.7 dB. The drain bias voltage is 7 V DC.

Next, both series inductances were increased by two to three times. Both drive and power MMIC PA stages were tuned for the highest linearity by operating as separate stages and tested using wideband 50 Ω input and output transmission lines. These two stages are combined through the variable-length transmission line, and the extreme values of the two-tone gain and IMD for the complete set are shown in ***Figure 3***. Again, the line length corresponds to a quarter-wavelength at the second harmonic. The single-tone P1dB values are equal to 30.7 dBm for both cases. The input return loss values are better than 14 dB for both stages.

A great difference in characteristics is observed in the two data plots. In the first case, the variation of IMD products is quite small through the entire range of output power. Only a small difference can be observed for high power levels. However, it can be explained by an improvement of matching conditions for the input port of the power stage elevating P1dB. (As a reference, the input return loss value is 5 to 6 dB.) In the second case, the variation of IMD products is perceptibly high at mid-power levels with clearly observed sweet spots.[6,7] At power levels close to P1dB and at the saturation region, the variation noted is very small. At some power levels, the IMD product difference reaches 5 to 7 dB. It should be noted that the circuits have different bias conditions. For both cases, the gate voltages were adjusted to achieve a maximum P1dB value.

Mid-power levels are important for operating within digitally modulated communication standards. ***Figure 4*** shows the calculated results of ACPR[10] for the 4.096 Mchips wideband CDMA standard. Calculations have been carried out taking into account only the IM3 (solid line) and IM3 + IM5 (dashed line) influence. The statistical drive signal has a logarithmic-normal distribution with a 2 dBm RMS power value (a close approximation of a one-user channel). A 2.5 dB improvement in ACPR value is observed through a wide range of output powers. This value corresponds completely to the gain difference between the extreme cases. For case 1, the analysis does not show any difference in ACPR value with the same output power back off. Comparing case 1 and case 2, a larger difference between adjacent IMD products for case 2 and more perceptible sweet spots due to the frequency-dependent negative feedback circuit (out-of-band harmonic termination adjustment[6,11]) are observed.

The drive stage for the set in case 2 was substituted for the low inductance stage for the set in case 1 (with less linearity). Improvements of 2 to 3 dB for IM3 and 5 to 7 dB for IM5 and IM7 were achieved at wide enough power levels close to saturation. Thus, the proposed MMIC set has perceptibly improved the distortion characteristics and spectral purity for CDMA signals without any additional filtering and amplifying stages for the second harmonic.[4] Note that no attempt was made to reach the highest linearity by adjust-

[Continued on page 110]

ing the input and output matching networks. The operation of the complete set is similar to using predistortion.[1] By using this approach, it was determined that the first stage of a power MMIC should have fairly low gain to achieve better results. This fact is in contrast to commonly used design rules when the first stage of a multistage PA is usually tuned for high gain.

CONCLUSION

The method of adjustment of the second harmonic phase delay between two cascaded MMIC PA stages has been investigated. It was shown that the choice of a drive stage with bad linearity and a simple inductive feedback circuit at the input of the power stage allows the complete amplifier set to have an ACPR improved by 2 to 3 dB through a wide range of the output power for digitally modulated signals. This approach can be used for portable low cost circuits in different wireless communication systems. ■

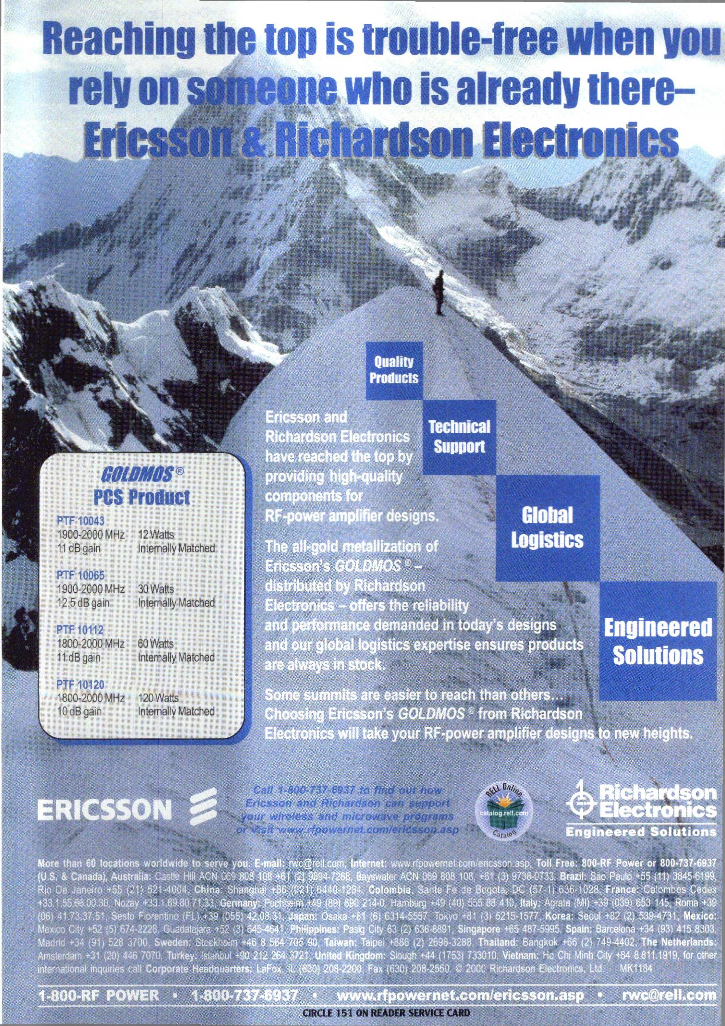
References

1. A. Katz, "SSPA Linearization," *Microwave Journal*, Vol. 42, No. 4, April 1999, pp. 22–44.
2. S. Andreoli, H.G. McClure, P. Banelli and S. Cacopardi, "Digital Linearizer for RF Amplifiers," *IEEE Transactions on Broadcasting*, Vol. 43, March 1997, pp. 12–19.
3. M.R. Moazzam and C.S. Aitchison, "A Low Third Order Intermodulation Amplifier with Harmonic Feedback Circuitry," *1996 IEEE MTT-S International Microwave Symposium Digest*, June 1996, pp. 827–830.
4. D. Jing, W.S. Chan, S.M. Li and C.W. Li, "New Linearization Method Using Interstage Second Harmonic Enhancement," *IEEE Transactions on Microwave and Guided Wave Letters*, Vol. 8, No. 11, November 1998, pp. 402–404.
5. T. Iwai, S. Ohara, H. Yamada, Y. Yamaguchi, K. Imanishi and K. Joshin, "High Efficiency and High Linearity InGaP/ GaAs HBT Power Amplifiers: Matching Techniques of Source and Load Impedance to Improve Phase Distortion and Linearity," *IEEE Transactions on Electron Devices*, Vol. 45, No. 6, June 1998, pp. 1196–1200.
6. N.B. de Carvalho and J.C. Pedro, "Large Signal IMD Sweet Spots in Microwave Power Amplifiers," *1999 IEEE MTT-S International Microwave Symposium Digest*, June 1999, Vol. 2, pp. 517–520.
7. J.A. Higgins and R.L. Kuvas, "Analysis and Improvement of Intermodulation Distortions in GaAs Power FETs," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 28, No. 1, January 1980, pp. 9–17.
8. S.A. Maas, *Nonlinear Microwave Circuits*, Artech House, Norwood, MA, 1988.
9. *Using the ATF-10236 in Low Noise Amplifier Applications in the UHF through 1.7 GHz Frequency Range*, HP Application Note 1076.
10. O. Gorbachov, "IMD Products and Spectral Regrowth in CDMA Power Amplifiers," *Microwave Journal*, March 2000, Vol. 43, No. 3, pp. 96–108.
11. V. Aparin and C. Persico, "Effect of Out-of-band Terminations on Intermodulation Distortion in Common-emitter Circuits," *1999 IEEE MTT-S International Microwave Symposium Digest*, June 1999, Vol. 3, pp. 977–980.

Oleksandr Gorbachov *received his PhD degree in electrical engineering from Kiev Polytechnic Institute in 1990. Currently, he is employed by Gatax Technology Co., Nei-Hu, Taipei, Taiwan, R.O.C.*

Yie-Der Shen *received his PhD degree in electrical engineering from Stanford University. Currently, he is VP at Hexawave Inc., Hsinchu, Taiwan, R.O.C.*

CHECK OUT OUR WEB SITE AT www.mwjournal.com


Reaching the top is trouble-free when you rely on someone who is already there–
Ericsson & Richardson Electronics
Quality Products
Technical Support
Global Logistics
Engineered Solutions
Ericsson and Richardson Electronics have reached the top by providing high-quality components for RF-power amplifier designs.
The all-gold metallization of Ericsson's GOLDMOS® – distributed by Richardson Electronics – offers the reliability and performance demanded in today's designs and our global logistics expertise ensures products are always in stock.
Some summits are easier to reach than others... Choosing Ericsson's GOLDMOS® from Richardson Electronics will take your RF-power amplifier designs to new heights.
GOLDMOS®
PCS Product
PTF 10043
1900-2000 MHz 12 Watts
11 dB gain Internally Matched
PTF 10065
1900-2000 MHz 30 Watts
12.5 dB gain Internally Matched
PTF 10112
1800-2000 MHz 60 Watts
11 dB gain Internally Matched
PTF 10120
1800-2000 MHz 120 Watts
10 dB gain Internally Matched
ERICSSON
Call 1-800-737-6937 to find out how Ericsson and Richardson can support your wireless and microwave programs or visit www.rfpowernet.com/ericsson.asp
RELL Online catalog.rell.com Catalog
Richardson Electronics
Engineered Solutions
More than 60 locations worldwide to serve you. E-mail: rwc@rell.com, Internet: www.rfpowernet.com/ericsson.asp, Toll Free: 800-RF Power or 800-737-6937 (U.S. & Canada), Australia: Castle Hill ACN 069 808 108 +61 (2) 9894-7288, Bayswater ACN 069 808 108, +61 (3) 9738-0733, Brazil: São Paulo +55 (11) 3845-6199, Rio De Janeiro +55 (21) 521-4004, China: Shanghai +86 (021) 6440-1284, Colombia, Sante Fe de Bogota, DC (57-1) 636-1028, France: Colombes Cedex +33.1.55.66.00.30, Nozay +33.1.69.80.71.33, Germany: Puchheim +49 (89) 890 214-0, Hamburg +49 (40) 555 88 410, Italy: Agrate (MI) +39 (039) 653 145, Roma +39 (06) 41.73.37.51, Sesto Fiorentino (FL) +39 (055) 42.08.31, Japan: Osaka +81 (6) 6314-5557, Tokyo +81 (3) 5215-1577, Korea: Seoul +82 (2) 539-4731, Mexico: Mexico City +52 (5) 674-2228, Guadalajara +52 (3) 645-4641, Philippines: Pasig City 63 (2) 636-8891, Singapore +65 487-5995, Spain: Barcelona +34 (93) 415 8303, Madrid +34 (91) 528 3700, Sweden: Stockholm +46 8 564 705 90, Taiwan: Taipei +886 (2) 2698-3288, Thailand: Bangkok +66 (2) 749-4402, The Netherlands: Amsterdam +31 (20) 446 7070, Turkey: Istanbul +90 212 264 3721, United Kingdom: Slough +44 (1753) 733010, Vietnam: Ho Chi Minh City +84 8.811.1919, for other international inquiries call Corporate Headquarters: LaFox, IL (630) 208-2200, Fax (630) 208-2550. © 2000 Richardson Electronics, Ltd. MK1184
1-800-RF POWER • 1-800-737-6937 • www.rfpowernet.com/ericsson.asp • rwc@rell.com
CIRCLE 151 ON READER SERVICE CARD

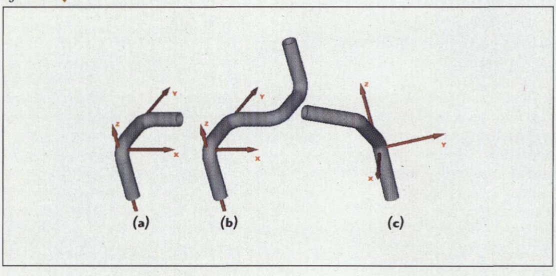
A Dual Polarization, Phase-compensated Waveguide Bend System

This article describes a waveguide bend system that preserves amplitude and phase for all polarizations over a very wide frequency range. Although the idea for this system appears to be very simple, the author has not seen a description of it published in the microwave literature.

BEND SYSTEM APPLICATIONS

This bend system finds applications in dual- or circular-polarized microwave systems where it is important to preserve the relative phase of all field components through the bend system. For example, in a reflector antenna, the bend system can enable the orthomode transducer or polarizer to be located away from the feedhorn. This configuration is an advantage in certain antenna systems. Utilizing this bend system, circular polarization can be propagated with good axial ratio through the system, dual linear polarizations can be propagated with good cross-polarization isolation and complex waveguide runs can be accommodated.

Fig. 1 Three configurations of the waveguide bend system.



DESIGN DESCRIPTION

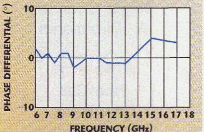
A waveguide with a square, circular or quad-ridged cross section is used as the transmission line. A carefully made waveguide of this type can propagate orthogonal linear polarizations with good polarization isolation. Each individual bend is made using this type of transmission line.

The waveguide bend system consists of two identical bends in cascade. The second bend is joined to the first with a straight section of this transmission line and rotated 90° with respect to the plane of the first bend. The individual bend angle can have any value. ***Figure 1***

[Continued on page 114]

John M. Seavey
Seavey Engineering Associates
Pembroke, MA

TECHNICAL NOTE



▲ *Fig. 2 Differential phase of orthogonally polarized fields.*

shows examples of three waveguide bend configurations.

Each bend creates a differential phase shift between the orthogonal polarized fields. This differential phase shift can reach very large values in practice. The amount of differential phase shift depends strongly on the effective radius of curvature of the swept bend, waveguide dimensions and frequency. This effect can seriously degrade the cross polarization of the microwave system. Therefore, a single bend in which orthogonal polarizations propagate is not used.

The second bend fully compensates for this differential phase shift. This result is due to the 90° rotation of the second bend. (For example, a vertical field undergoes an E-bend and then an H-bend; a horizontal field undergoes an H-bend and then an E-bend.) Therefore, the total differential phase shift for both field components is identical as long as the two bends are identical and this symmetry is preserved.

Moment method analysis of a pair of simple 90° mitered square waveguides demonstrates excellent differential phase shift and amplitude over more than an octave bandwidth, even though the impedance match of each bend is not optimum. ***Figure 2*** shows the phase differential of orthogonally polarized fields vs. frequency for the bend configuration depicted in Figure 1a.

IMPEDANCE MATCHING AND MODING

Although the symmetrical arrangement of the bend pair preserves the differential phase shift, each bend also must be designed to have a good impedance match and to control higher order mode generation. This capability requires swept or mitered bends using good design practices.[1] If the individual bends are poorly matched or generate higher order modes, amplitude and phase degradation can occur.

POSSIBLE CONFIGURATIONS

This system can enable the waveguide run to change direction in many ways. Possible structures include the use of four 90° bends with the input on the +z-axis and the output on a translated +z-axis (or –z-axis) (Figure 1b), the use of four bends of any angle for a general rotation of the input on the +z-axis to any other compound output angle and the use of only two bends of any angle with the input on the +z-axis and the output at any compound angle above the x-y plane (Figure 1c).

In the general case of two bends, the planes of linear polarizations will be rotated by the bend angle. A four-bend system can compensate for this polarization rotation. Circular polarization axial ratio, sense and isolation will not be changed by the bend pairs. This effect can be utilized to form a rotational joint.

CONCLUSION

A little-known, but interesting, microwave geometry has been presented, which can be used in dual-polarized or circular-polarized waveguide runs. The waveguide bend system can preserve amplitude and phase for all polarizations over a wide frequency bandwidth. ■

Reference

1. N. Marcuvitz, *Waveguide Handbook*, McGraw-Hill, 1951, pp. 312–322 and 333–335.

John M. Seavey *received his BS degree in physics from MIT in 1958. For more than 40 years, he has been responsible for a wide range of antenna development programs. In 1981, he established Seavey Engineering Associates Inc. in Pembroke, MA. This firm is engaged in commercial antenna development and manufacturing. Seavey holds eight patents and has published many technical articles.*

ISM VS. SPREAD SPECTRUM — AVOIDING THE FCC

The Federal Communications Commission (FCC) recognizes two types of devices that intentionally emit RF energy: communications equipment and everything else. The first category includes AM/FM, TV, point-to-point, satellite, cell phones, taxi radios, CB, garage door openers and anything else that uses radio waves to convey intelligence, broadly construed. The everything-else category is properly called industrial, scientific and medical (ISM) equipment. It includes devices used for heating, ionization of gases, mechanical vibration, particle acceleration, hair removal and any other noncommunications application of radio waves. Household examples include microwave ovens, jewelry cleaners and ultrasonic humidifiers. Industrial applications cover a wide range of cooking, heating and ionization devices.

CONTENDING FOR SPECTRUM

Both ISM and radio communications require spectrum, and both obtain it from the FCC. For decades after the FCC opened in 1935, enough bandwidth was available to give exclusive allocations to all who wanted them. Isolating ISM into bands of its own made particular sense, because some ISM equipment generates high power radio noise that otherwise threatens sensitive communications equipment.

As communications technologies evolved toward higher frequencies, so too did ISM. Today, 11 distinct ISM bands range from 7 MHz to 245 GHz. ISM equipment can legally operate at any power level in these bands. Indeed, ISM is the only FCC-regulated service having no in-band limits whatsoever (other than RF safety limits). ISM equipment is also permitted to operate outside the designated bands; however, there its RF emissions are limited to relatively low levels.

The demand for spectrum has accelerated, and now far exceeds the supply. During the 1980s, the FCC allocated the last available frequencies below 1 GHz, and since then has filled the gaps up to approximately 40 GHz. Many applications prefer the 0.5 to 5 GHz range, where antenna size, propagation and cost factors are favorable for communications. When demand continued to mount after all of those frequencies were assigned, the FCC had little choice but to require that services share their spectrum allocations.

One form of sharing has been commonplace for decades. The FCC's Part 15 rules

[Continued on page 118]

MITCHELL LAZARUS
Fletcher Heald & Hildreth PLC
Arlington, VA

have long allowed unlicensed communications transmitters to operate at low power throughout the spectrum, except for certain restricted bands. Early examples included garage door openers and remote-control toys and, later, cordless telephones. Traditional Part 15 devices operate at a few microwatts, with a useful range of only a few meters.

The main benefit of Part 15 operation is flexibility. Where licensed users must usually file with the FCC to move or install a transmitter, a Part 15 user simply powers up the equipment. But the flexibility comes at a price. A Part 15 device must accept incoming interference, no matter how severe, from any other service. Moreover, a Part 15 device must shut down if it causes harmful interference to almost any other service. These rules discouraged applications that require any significant reliability from using Part 15. Licensing was slow and inconvenient, but it bought protection from interference.

SPREAD SPECTRUM ARRIVES

In 1985, the FCC approved spread spectrum modulation under Part 15. A spread spectrum transmitter distributes its signal over more spectrum than it otherwise would need to carry the data payload. Because the spread-out signal puts low average energy onto any one frequency, it causes little interference to other users. In addition, because the receiver is active over a wide bandwidth, it is relatively immune to interference from a conventional narrowband transmitter.

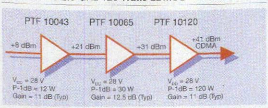
The FCC authorized spread spectrum at the unprecedented (for Part 15) output power of 1 W and put it in the 915, 2450 and 5800 MHz ISM bands. These three bands, sometimes called the "junk bands," would be crowded even without spread spectrum. They are heavily used by ISM, including tens of millions of microwave ovens and industrial devices. All three bands are allocated for amateur use and for conventional Part 15 operations at milliwatt levels. A vehicle location service operates throughout the 915 MHz band. Various parts of the 2450 MHz band are used for local positioning, private land mobile radio and downlinks in the Mobile Satellite Service. The US government has significant radar and military operations in all three bands.

Spread spectrum radio was slow to catch on. The FCC revised the rules in 1990 and again in 1997, each time opening new options for manufacturers. Prices gradually came down, while data rates went up to 2 Mbps. The mid-1990s saw a developing market in niche applications. The picture changed suddenly in 1998, when an FCC rule interpretation pushed data speeds to 11 Mbps. Overnight, spread spectrum became competitive with wire-in-the-wall office local area networks.

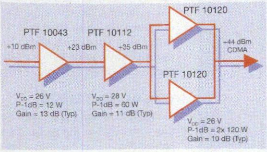
Today, approximately \$1.5 B worth of spread spectrum wireless equipment operates in every sector of the economy, including retail, transportation, utilities, manufacturing, health care and finance. Half the transac-

[Continued on page 120]

PCS - 1.9 to 2.0 GHz 120 Watts LDMOS



PCS - 1.9 to 2.0 GHz 240 Watts LDMOS



With our *GOLDMOS*™ technology (LDMOS with all-gold metalization) you get the reliability needed for todays demanding RF power amplifier designs.

The RF power team at Ericsson Microelectronics has designed a wide range of power transistors including the PTF 10065, PTF 10043, PTF 10112 and PTF 10120, providing the reliability and performance your power amplifiers require. This is an excellent line-up with the performance needed for CDMA applications.

Just call or visit our website at ***www.ericsson.com/rfpower*** *for a free copy of our product data book, short form or interactive CD.*

Ericsson Microelectronics
www.ericsson.com/microelectronics
North America
Tel: +1 877-GOLDMOS (465-3667)

International
Tel: +46 8 757 4700
Fax: +46 8 757 4776

ERICSSON

CIRCLE 48 ON READER SERVICE CARD

tions on the New York Stock Exchange are mediated by spread spectrum wireless terminals. Spread spectrum Internet access offers broadband speeds across 40 km distances. In consumer markets, spread spectrum cordless phones are commonplace, and in-home video and audio distribution systems will soon follow. The Bluetooth spread spectrum protocol will be incorporated into most wireless phones, laptops, computer peripherals, personal digital assistants and other consumer devices beginning later this year.

SPREAD SPECTRUM VS. ISM

Although relegated to last priority in the band, spread spectrum designers achieve respectable levels of reliability. Some of the applications listed above demand it. Hospitals, stock exchanges and wireless phone companies (among others) are sophisticated users who do not knowingly risk service interruptions.

On the other hand, no one can harden a communications receiver against unlimited interference. Equipment designers necessarily make assumptions about the RF environment in which their products will operate. Not unreasonably, Part 15 designers assume an environment populated with devices that comply with the FCC rules. Spread spectrum receivers today are reasonably well insulated against interference from other communications equipment and from existing categories of ISM devices, such as microwave ovens. But they remain potentially vulnerable to interference from new and different kinds of ISM equipment, such as RF lights.

In principle, ISM's priority in the band protects it absolutely against Part 15. However, in practice, the ISM industry has expressed two fears about the growth of Part 15 spread spectrum. First, some are concerned that spread spectrum may acquire enough economic and political power to impose limitations on ISM. Second, some ISM vendors worry that customers may reject ISM products that interfere with spread spectrum operation.

Both concerns are largely hypothetical so far. The only ISM product to date that raises any serious concern among Part 15 interests is RF lighting. Spread spectrum interests fear these lights will operate continuously from positions overhead and emit high levels of RF. Therefore, some manufacturers have asked the FCC to limit emissions from RF lamps. Moreover, one lighting manufacturer has told the FCC that potential customers are avoiding the product because they fear interference into their spread spectrum equipment. Other new ISM applications may raise some of the same issues.

COMMON INTERESTS

Both ISM and Part 15 will benefit if they can resolve the technical incompatibilities and competitive issues between them. However, they should do it in private, away from the FCC. Part 15 has little to gain at the FCC, whose rules make it unambiguously subordi-

[Continued on page 122]

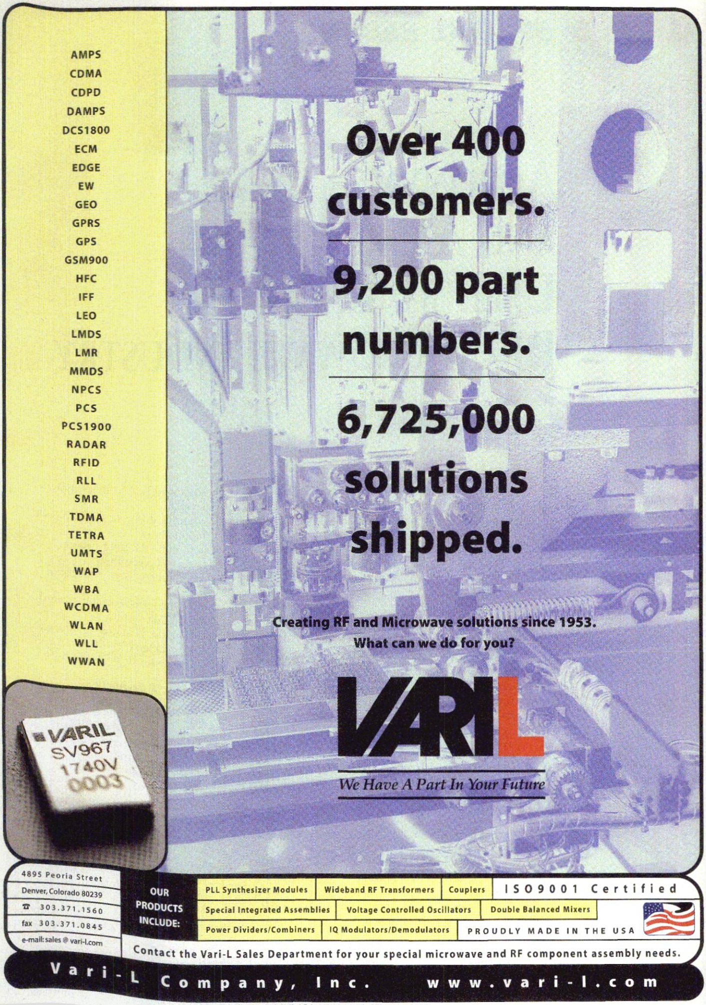
nate to ISM. No one expects the FCC to regulate any ISM product out of existence, not even RF lights. In addition, the FCC will not listen to Part 15 complaints about interference from existing ISM products that comply with the rules. At most, the FCC might limit new ISM products that pose exceptional interference threats but, even then, it will try to ensure that the products remain commercially viable.

The FCC also will not address ISM's concerns. If customers come to believe they cannot use both ISM and spread spectrum, the FCC will not stop them from choosing spread spectrum. Although Part 15 devices must accept ISM interference, Part 15 customers do not. They are free to eliminate the interference by rejecting ISM products if they think it necessary to protect their communications.

Instead of contending at the FCC, both industries will achieve better results by negotiating directly with each other. Together they can seek standards that permit ISM products to operate properly, as well as provide an RF environment hospitable to spread spectrum operations. If communications engineers can help to set the characteristics of ISM equipment in the vicinity, they can design systems that tolerate the interference well. That in turn will enable ISM vendors to assure customers that their products will not degrade spread spectrum performance. The spread spectrum industry can assist those ISM marketing efforts by certifying suitable ISM devices for compatibility with spread spectrum communications devices.

In short, customers should not be forced to choose between the two types of products. Both industries come out ahead if customers can buy and use both successfully. ■

Mitchell Lazarus *received his BSEE and MSEE from McGill University and MIT, respectively, and his PhD in experimental psychology from MIT. He also holds a law degree from Georgetown University Law Center. Currently, Lazarus is a telecommunications attorney with the firm of Fletcher Heald & Hildreth PLC in Arlington, VA. He can be reached at (703) 812-0440 or MLazarus@alum.MIT.edu.*


AMPS
CDMA
CDPD
DAMPS
DCS1800
ECM
EDGE
EW
GEO
GPRS
GPS
GSM900
HFC
IFF
LEO
LMDS
LMR
MMDS
NPCS
PCS
PCS1900
RADAR
RFID
RLL
SMR
TDMA
TETRA
UMTS
WAP
WBA
WCDMA
WLAN
WLL
WWAN
VARIL
SV967
1740V
0003
Over 400 customers.
9,200 part numbers.
6,725,000 solutions shipped.
Creating RF and Microwave solutions since 1953.
What can we do for you?
VARIL
We Have A Part In Your Future
4895 Peoria Street
Denver, Colorado 80239
303.371.1560
fax 303.371.0845
e-mail: sales @ vari-l.com
OUR PRODUCTS INCLUDE:
PLL Synthesizer Modules
Wideband RF Transformers
Couplers
ISO9001 Certified
Special Integrated Assemblies
Voltage Controlled Oscillators
Double Balanced Mixers
Power Dividers/Combiners
IQ Modulators/Demodulators
PROUDLY MADE IN THE USA
Contact the Vari-L Sales Department for your special microwave and RF component assembly needs.
Vari-L Company, Inc.
www.vari-l.com

ACRONYMS AND ABBREVIATIONS USED BY THE RF/MICROWAVE INDUSTRY

This list represents most of the acronyms and abbreviations used in *Microwave Journal* technical articles and editorial features during the last five years. The ever-growing list has proven enormously useful to our staff and should prove equally helpful to our readers, who are continually bombarded with new and confusing abbreviations for the plethora of technical terms associated with the RF/microwave industry. Although it has always been our policy to define all but the most commonly used abbreviations within each article, a central reference list can be quite helpful to everyone. The original acronym and abbreviation list was first published in the February/March 1997 issues of *Microwave Journal,* and our staff has received many positive comments and continued requests for updates.

ACC	adaptive cruise control
ACIR	adjacent-channel interference ratio
ACLR	adjacent-channel leakage ratio
ACMPA	aperture-coupled microstrip patch antenna
ACP	adjacent-channel power
ACPR	adjacent-channel power rejection
ACPR	adjacent-channel protection ratio
ACPW	asymmetrical coplanar waveguide
ACW	autonomous collision warning (system)
ADC	analog-to-digital converter
ADEOS	advanced Earth observation satellite
ADPCM	adaptive differential pulse-code modulation
ADS	automatic debiting system (auto toll collecting)
ADSL	asymmetric digital subscriber loop
AEGIS	airborne early warning ground integration system
AFP	automatic frequency planning
AGC	automatic gain control
AICC	autonomous intelligent cruise control
AM	amplitude modulation
AME	average model error
AMF	automated module fabrication
AML	amplitude modulated link
AMPS	Advanced Mobile Phone Service
AMR	adaptive multirate codex
ANA	automatic network analyzer
ANSI	American National Standards Institute
AO	acoustic-optical
APC	American Personal Communications system
API	application programming interface
APL	airport pseudolites
AR	axial ratio

[Continued on page 126]

FRANK BASHORE
Microwave Journal *Staff*

Miniature

Wideband

- Low Cost
- Optimized & Octave Bandwidths
- 0.58" x 0.80"

SYNTHESIZER

For additional information,
contact Synergy's Sales and Application team.
201 McLean Blvd., Paterson, New Jersey 07504
Phone: (973) 881-8800 Fax: (973) 881-8361
E-mail: sales@synergymwave.com
Visit our web site at http://www.synergymwave.com

SYNERGY®
MICROWAVE CORPORATION

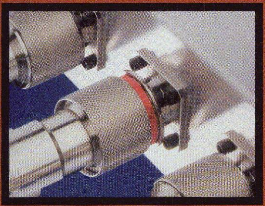
CIRCLE 176 ON READER SERVICE CARD

ARBF	adaptive radial basis function
ARM	antiradiation missile
ARMA	autoregressive moving average
ARDIS	Advanced Radio Information Service
ARFCN	absolute radio frequency channel number
ARO	active resonator oscillator
ASAP	Airborne Shared Aperture Program
ASCII	American National Standard Code for Information Interchange
ASIC	application-specific integrated circuit
ASH	amplifier-sequenced hybrid
ASK	amplitude-shift keying
ASTM	American Society for Testing and Materials
ASV	advanced safety vehicle (system)
ATC	air traffic control
ATDE	adaptive time domain equalizer
ATE	automatic test equipment
ATM	air traffic management
ATM	asynchronous transfer mode
ATPC	automatic transmit power control
AUC	authentication center
AVI	automatic vehicle identification
AVL	automatic vehicle location
AVLN	automatic vehicle location and navigation system
AWG	arbitrary waveform generator
AWG	American Wire Gauge (standard)
AWGN	additive white Gaussian noise
AWNV	all weather and night vision system
BAW	bulk acoustic wave
BCD	binary-coded decimal
BCH	broadcast channel
BCM	block-coded modulation
BER	bit error rate
BERT	bit error rate tester
BEM	boundary element method
BFL	buffered field-effect transistor logic
BFN	beam-forming network
BiCMOS	bipolar complementary metal-oxide semiconductor
BIFODEL	binary fiber-optic delay line
BJT	bipolar junction transistor
BLOS	beyond line-of-sight
BOM	bill of materials
BOR	body of revolution
BPSK	biphase-shift keying or binary phase-shift keying
BSC	base station controller
BSS	base station system
BSS	broadcast satellite service
BT	bandwidth-time product
BTS	base transceiver station
BZ	Brillouin zone
C/A	clear and acquisition code (GPS)
C-AFM	calibrated atomic force microscope
CAE	computer-aided engineering
CALLUM	combined analog locked-loop universal modulator
CATV	community antenna television

[Continued on page 128]

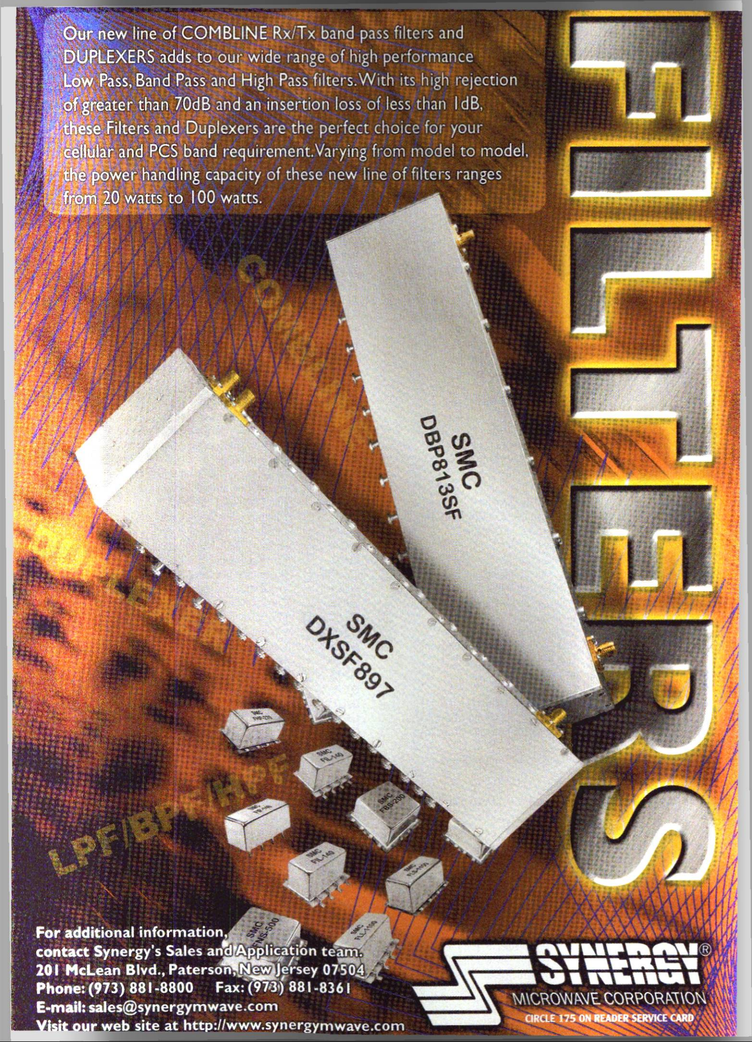
CBCPS	conductor-backed coplanar stripline
CCA	circuit card assembly
CCD	charge-coupled device
CCDF	complementary cumulative distribution function
CCK	complementary code keying
CCMT	computer-controlled microwave tuner
CCPR	co-channel power ratio
CDF	cumulative distribution function
CDMA	code division multiple access
CDPD	cellular digital packet data
CE	Conformite Europeene (European EMC standard)
CEPT	Conference on European Posts and Telecommunications administrations
CFC	chloroflourocarbon
CFR	Code of Federal Regulations
C/I	carrier-to-interference ratio
C/I	carrier-to-intermodulation ratio
CIC	controller in charge
CIM	computer integrated manufacturing
CMOS	complementary metal-oxide semiconductor
CMRF	combined mode resonator filter
CMS	combined symbol matching
C/N	carrier-to-noise ratio
CNC	computerized numerical control
CNR	carrier-to-noise ratio
CNS/ATM	Communication and Surveillance/Air Traffic Management
COFDM	coded orthogonal frequency division multiplex
COHO	coherent oscillator
COM	Component Object Model
COMINT	communications intelligence
CONUS	continental United States
COPS	complex operations per second
COTS	commercial off-the-shelf
CPCI	compact protocol control information
CPFSK	continuous phase frequency-shift keying
CPM	continuous phase modulation
CPS	coplanar stripline
CPU	central processing unit
CPW	coplanar waveguide
CQFP	ceramic quad flat pack
CRC	cyclic redundancy check
CREAM	cosmic radiation effects and activation monitors
CRTSSDA	cascaded reactively terminated single-stage distributed amplifier
CSL	coupled-slot antenna
CSM	combined symbol matching
CSMA/CD	carrier sense multiple access/collision detection
CSO	composite second order
CSP	chip scale package
CT	cordless telephone
CT-2	cordless telephone-second generation
CTB	composite triple beat
CTE	coefficient of thermal expansion
CTM	conformal transformation method

[Continued on page 130]



CTR	common technical regulations
CVD	chemical vapor deposition
CVDL	continuously variable delay line
CW	continuous wave
CWSA	constant width slot antenna
DAB	digital audio broadcast
DAC	digital-to-analog converter
DAMA	demand-assigned multiple access
D-AMPS	Digital Advanced Mobile Phone Service
DAQ	data acquisition
DAWS	Digital Advanced Wireless Service
DBF	digital beamforming
DBS	direct broadcast service
DBS	direct broadcast satellite
DCFL	direct-coupled field-effect transistor logic
DCOM	Distributed Component Object Model
DCR	downconverting receiver
DCS1800	digital communication system at 1800 MHz
DCXO	digitally compensated crystal oscillator
DDS	direct digital synthesis
DEBS	dynamic electronic bias system
DECT	Digital European Cordless Telecommunications (1880 to 1900 MHz)
DECT	Digital Enhanced Cordless Telephony (new name)
DESC	Defense Electronic Supply Center
DF	direction finding
DFB	distributed feedback
DFD	digital frequency discriminator
D-FET	depletion-mode field-effect transistor
DFT	discrete Fourier transform
DGPS	Differential Global Positioning System
DHBT	double-heterojunction bipolar transistor
DIMM	dual in-line memory module
DIN	Deutsche Industrial Norms (German standards agency)
DLRU	decoy launch/recovery unit
DLVA	detector log video amplifier
DMO	direct-mode operation
DMOS	diffused metal-oxide semiconductor
DMSP	Defense Meteorological Satellite Program
DMR	dual-mode resonators
DMUX	demultiplexer
DNL	dynamic nonlinearity
DQPSK	differential quadrature phase-shift keying
DPHEMT	double heterojunction pseudomorphic high electron mobility transistor
DPLL	digital phase-locked loop
DPSK	differential phase-shift keying
DRFM	digital radio frequency memory
DRO	dielectric resonator oscillator
DRRS	digital radio relay system
DS	direct sequence
DSC	differential scanning calorimetry
DSO	digital storage oscilloscope
DSP	digital signal processing
DSSS	direct sequence spread spectrum
DTF	distance-to-fault
DTMF	dual-tone multiple frequency
DTO	digital test oscilloscope
DTO	digitally tuned oscillator
DTX	discontinuous transmission
DUT	device under test
DVB	digital video broadcasting
DWC	digital wireless communications
EBL	electron beam lithography
EBSD	electron backscatter diffraction
EC	European Community
ECB	enhanced cellular base station
ECC	error correction code
ECC	embedded communication channel
ECL	emitter-coupled logic
ECM	electronic countermeasures
ECSD	enhanced circuit switched data
ED	electrodeposited
E/D	enhancement/depletion (mode)
EDA	electronic design automation
EDFA	erbium-doped fiber amplifier
EDGE	Enhanced Data Rate for GSM Evolution
EDM	electronic discharge machining
EEA	EU and EFTA merge unit

[Continued on page 132]



EEC	European Economic Community
EEPROM	electrically erasable programmable read-only memory
E-FET	enhancement-mode field-effect transistor
EFIE	electric field integral equation
EFTA	European Free Trade Area (Austria, Finland, Liechtenstein, Norway, Sweden and Switzerland)
EGI	embedded global positioning satellite inertial navigation system
EGPRS	Enhanced General Packet Radio System
EGSM	European Digital Extended Group Special Mobile
EHF	extremely high frequency (30 to 300 GHz)
EHTPS	extra high tension power supply
EIA/TIA	Electronics Industry Association/ Telecommunications Industry Association
EIN	equivalent input noise
EIR	equipment identity register
EIRP	effective isotropic radiated power
ELINT	electronic intelligence systems
EM	electromagnetic
EMC	electromagnetic compatibility
EMF	electromotive force
EMI	electromagnetic interference
EMR	electromagnetic radiation
EN	European Norm (EMI regulations)
ENG	electronic news gathering
ENR	excess noise ratio
EPFD	equivalent power-flux density
EPROM	erasable programmable read-only memory
ERMES	European radio message system
ERP	effective radiated power
ESD	electrostatic discharge
ESL	equivalent series inductance
ESM	electronic support measure
ESMR	extended specialized mobile radio
ESR	electron spin resonance
ESR	equivalent series resistance
ETACS	Extended Total Access Communications System (British cellular)
ETC	electronic toll collecting
ETL	embedded transmission line
ETRF	electronically tuned RF (filter)
ETS	European Telecommunications Standard
ETSI	European Telecommunications Standard Institute
ETTM	electronic toll and traffic management
EU	European Union
EUT	equipment under test
EUTELSAT	European Telecommunications Satellite
EUV	extreme-ultraviolet
EVM	error vector magnitude
EW	electronic warfare
FANS	future air navigation system
FAR	false alarm rate
FBW	fractional bandwidth
FCA	flip-chip assembly
FCC	Federal Communications Commission
FDD	frequency-division duplexing
FDDI	fiber-distributed data interface
FDFD	finite difference frequency domain
FDM	frequency division multiplex
FDMA	frequency division multiple access
FDR	frequency domain reflectometry
FDTD	finite difference time domain
FEC	forward error correction
FEM	finite element method
FEP	fluoroethylene propylene
FER	frame error rate
FET	field effect transistor
FFO	fixed-frequency oscillator
FFT	fast Fourier transform
FH	frequency hopping
FHMA	frequency hop multiple access
FHSS	frequency-hopping spread spectrum
FIR	finite-duration impulse response (filter)
FIT	failures in time
FLC	ferroelectric liquid crystals
FLOP	floating octal points
FLR	forward looking radar
FM	frequency modulation
FMC	fixed mobile convergence (service)
FMCW	frequency-modulated continuous wave (radar)
FO	fiber optic
FOBP	fractional out-of-band power
FPLMTS	Future Public Land Mobile Telecommunication Systems
FPGA	field-programmable gate array
FRA	fixed radio access
FS	free space
FSCS	frequency-selective conducting surface
FSK	frequency-shift keying
FSS	fixed satellite service
FSS	frequency-selective surface
GAM	Global Positioning System-aided munitions
GBAS	ground-based augmentation systems
GBR	ground-based radar
GCPW	grounded coplanar waveguide
GEO	geostationary earth orbit
GFSK	Gaussian frequency-shift keying
GLONASS	Global Navigation Satellite System (Russian)
GMDSS	Global Maritime Distress Signal System
GMSK	Gaussian minimum shift keying
GNSS	Global Navigation Satellite System (US)
GPIB	general-purpose interface bus
GPR	ground-penetrating radar
GPRS	General Packet Radio Service
GPS	Global Positioning System/Satellite
GSM	Global System for Mobile Communications
GSM-900	Group Speciale Mobile (European GSM)
GSO	geostationary orbit
G/T	receive antenna gain divided by noise temperature
GUI	graphical user interface
HARM	high speed anti-radiation missile
HBT	heterojunction bipolar transistor
HDSL	high bit-rate digital subscriber line
HDTV	high definition television
HEMT	high electron mobility transistor
HEO	high elliptical orbit (satellite)
HFC	hybrid fiber/coax
HFET	heterostructure field-effect transistor
HFSS	high frequency structure simulator
HGA	high gain antenna
HIPERLAN	high performance local area network
HJFET	heterojunction field-effect transistor
HLR	home location register

[Continued on page 135]

HMIC	hybrid microwave integrated circuit
HPA	high power amplifier
HPBW	half power beam width
HSCSD	high speed circuit switched data
HTS	high temperature superconductor
IBIC	interface bus interactive control
IBOC	in-band on-channel
IBW	instantaneous bandwidth
IC	integrated circuit
IDECM	integrated defense electronic countermeasures
IDFT	inverse discrete Fourier transform
IDT	interdigital transducer
IEC	International Electrotechnical Commission
IEP	ideal electric plane
IF	intermediate frequency
IFB	indirect feedback
IFF	identification friend or foe
IFM	instantaneous frequency measurement
IGBT	insulated gate bipolar transistor
IGFET	insulated gate field effect transistor
IIR	infinite impulse response (filter)
ILA	injection-locked amplifier
ILO	injection-locked oscillator
IM	intermodulation
IMD	intermodulation distortion
IMDN	Intelligent Mobile Data Network
IMEI	international mobile equipment identity
IMFET	internally matched field-effect transistor
IMP	intermodulation products
IMPATT	impact avalanche and transit time
IMR	intermodulation rejection
IMSI	international mobile subscriber identity
INMARSAT	International Maritime Satellite consortium, London
INS	inertial navigation system
INTELSAT	International Telecommunication Satellite consortium, Washington
IP	Internet Protocol
IPBO	input power backoff
IPC	Institute for Interconnecting and Packaging Electronic Circuits
IPS	integrated power systems
IQ	in-phase/quadrature
IR	infrared
IRA	impulse radiating antennas
IRM	image reject mixer
IS-95	North American cellular standard
ISAR	inverse synthetic-aperture radar
ISDN	integrated services digital network
ISI	intersymbol interference
ISM	industrial, scientific and medical (frequency bands)
ISO	International Standards Organization
ITS	intelligent transportation systems
ITM-2000	International Mobile Telecommunication 2000
ITU	International Telecommunication Union
ITU-R	ITU Radio Communications Sector

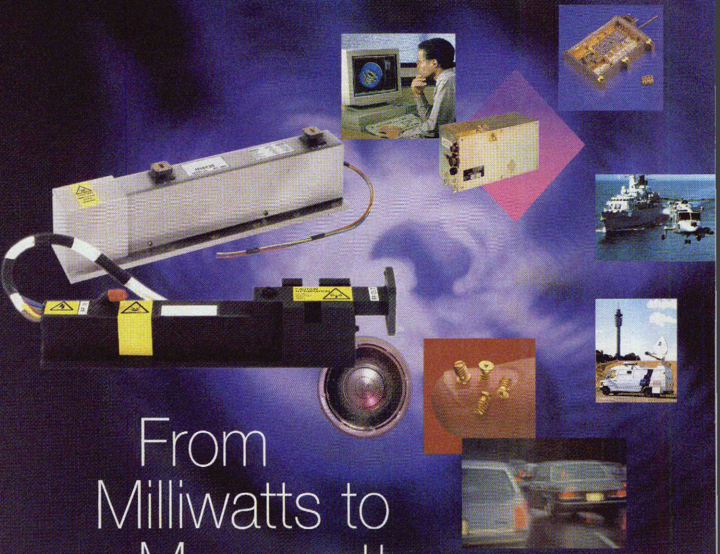
[Continued on page 137]

IVHS Intelligent Vehicle Highway System
JDC Japanese Digital Cellular system
JEDEC Joint Electron Device Engineering Council
JFET junction field effect transistor
JPEG Joint Picture Expert Group (compression standard)
KGD known good die
LAN local area network
LAAS local area augmentation systems
LAO $LaAlO_3$ (substrate)
LBC linked boundary condition
LC inductor/capacitor
LCC leadless chip carrier
LCD liquid-crystal display
LD laser diode
LDMOS laterally diffused metal oxide semiconductor
LEC liquid encapsulated Czochralski (semi-insulating substrates)
LEO low earth orbit (satellite)
LEP lumped element prototype
LHCP left-hand circular polarization
LIDAR light direction and ranging
LINC linear amplification with nonlinear components
LMCS local multipoint communications system
LMDS local multipoint distribution system
LMS location and monitoring services
LNA low noise amplifier
LNB low noise block
LNBF low noise block feed
LO local oscillator
LOS line of sight
LPE lowpass equivalent
LPF lowpass filter
LPI low probability of intercept
LRL line-reflect-line (calibration)
LRRM line-reflect-reflect-match (calibration)
LSB least significant bit
LSG large-signal gain
LSI large-scale integration
LTCC low temperature co-fired ceramic
LTCC-M low temperature co-fired ceramic on metal core
LTI linear time invariant
LTSA linear taper slot antenna
LTP long-term predictor
LUT look-up table
LVDS low voltage differential signal
MAC medium access control
MAFET Microwave and Analog Front End Technology project
MBA multi-beam antenna
MBE molecular beam epitaxy
MBPA multi-beam phased array
MCE manufacturing cycle efficiency
MCF message communication function
MCL microstrip constrained lens
MCM multichip module
MCM-C multichip module with co-fired substrate
MCPA multicarrier power amplifier
MCPW microstrip coplanar waveguide
MCT metal-oxide semiconductor-controlled thyristor
MDS multipoint distribution system
MEADS medium extended air defense system
MEMS microelectromechanical system
MESFET metal-semiconductor field effect transistor
MEO medium earth orbit (satellite)
MIC microwave integrated circuit
MIC monolithic integrated circuit
MIDAS multiple integration and defense communications satellite network
MIM metal-insulator-metal (capacitor)
MIMIC Millimeter-wave and Microwave Integrated Circuit (R&D program)
MIPS million instructions per second
MIR microwave impulse radar
MLA microwave link analyzer
MLB multilayer board
MLC main lobe clutter
MLCM multilevel coded modulation

[Continued on page 139]

MLDD matched-line directional divider
MMC metal-matrix composite
MMCA microwave multichip assembly
MMDS multichannel multipoint distribution system
MMI man-machine interface
MMI multimedia interface
MMIC microwave monolithic integrated circuit
MMW millimeter wave
MOCVD metal-organic chemical vapor deposition
MOCT multi-order cancellation technique
MODEM modulator/demodulator
MoM method of moments
MOS metal-oxide semiconductor
MPEG Motion Picture Experts Group
MPIE mixed potential integral equation
MPM microwave power module
MQW multi-quantum well
MQW-FP multi-quantum well Fabry-Perot optical transmitter
MS mobile station
MSB most significant bit
MSBVW magneto-static backward volume waves
MSC mobile switching center
MSFVW magneto-static forward volume waves
MSI medium scale integration
MSK minimum-shift keying
MSMT micro surface-mount technology
MSOP mini(micro) small outline package
MSS mobile satellite system (service)
MSSW magneto-static surface waves
MSW magnetostatic wave
MTA microwave transition analyzer
MTBF mean time between failures
MTD moving target detection
MTI moving target indicator
MTTF mean time to failure
MTTR mean time to repair
MU minimum stability factor
MUNDI multiplexed network for distributed and interactive services (UK)
MUX multiplexer
MVDS multipoint video distribution system
NADC North American Dual-Mode (or Digital) Cellular
NA numerical aperture
N-AMPS Narrowband Advanced Mobile Phone System
NAVSTAR Navigational Satellite Timing and Ranging system
NEC numerical electromagnetic code
NEMA National Electrical Manufacturers Association
NFA noiseless feedback amplifier
NGA noise gain analyzer
NGSO nongeostationary orbit
NIC network interface card (WLAN)
NIST National Institute of Standards and Technology
NMC network management center
NMOS n-channel metal-oxide semiconductor
NMR nuclear magnetic resonance
NMSE normalized mean square error
NMT Nordic Mobile Telephone system
NODS near obstacle detection system
NPR noise power ratio
NPRM notice of proposed rule making
NQR nuclear quadruple resonance
NRZ nonreturn to zero
NSA normalized site attenuation
NSOM near-field scanning optical microscopy
NSSN National Standards System Network
NTSC National Television Systems Committee
OAD optical admittance diagram
OATS open area test site
OBU onboard unit
OCDMA orthogonal code division multiple access
OCPAR optically controlled phased-array radar
OCXO oven-controlled crystal oscillator
OEIC optoelectronic integrated circuit
OEM original equipment manufacturer
OFDM orthogonal frequency division multiplex

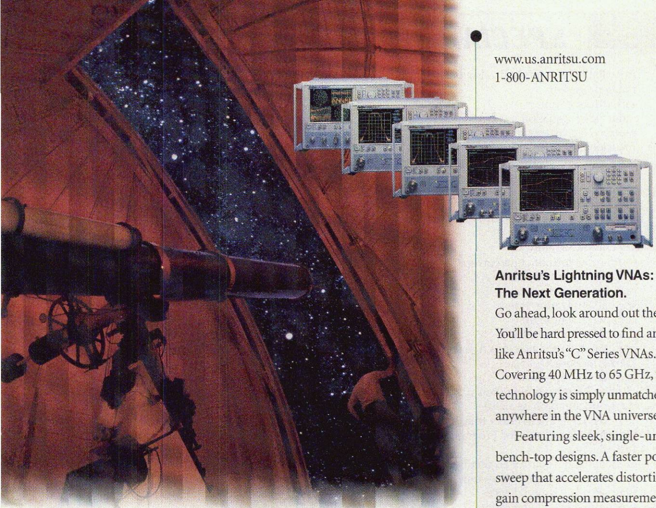
[Continued on page 141]



OFHC oxygen-free high conductivity (copper)
OFS operational fixed service
OHI one-horn interferometer
OMC operations and maintenance center
OMT orthogonal-mode transducer
OOK on-off keying
OPBO output power backoff
OPIP output power intercept point
OPLL optical phase-locked loop
OQPSK offset quadrature phase-shift keying
OSI open systems interconnection
OTDR optical time domain reflectometer
OTH over the horizon
PA power amplifier
PAA phased-array antenna
PABX private automatic branch exchange
PAC perceptual audio coder
PACS personal access communications system (US version of PHS)
pACT personal air communications technology
PAE power-added efficiency
PAL programmable array logic
PAL phase-alternation line (video)
PAM pulse amplitude modulation
PAMR Public Access Mobile Radio
PAN public access network
PBG photonic bandgap
PBX private branch exchange
PCI peripheral component interconnect (bus)
PCIA Personal Communication Industry Association
PCM pulse code modulation
PCM process control monitor
PCMCIA Personal Computer Memory Card International Association
PCN personal communications network
PCS personal communication service
PCU power conditioning unit
PD predistortion
PD pulsed Doppler
PDA personal digital assistant (portable computing)
PDC personal digital cellular
PDF probability distribution function
PDH plesiochronous-digital hierarchy
PDIP plastic dual-in-line package
PDO packet data optimized
PEBB power electronic building blocks
PEC perfect electrical conducting
PECL positive/pseudo emitter-coupled logic
PECVD plasma-enhanced chemical vapor deposition
PEEC partial element equivalent circuit
PEP primary entry point
PEP peak envelope power
PFD phase/frequency discriminator
PHEMT pseudomorphic high electron mobility transistor
PHP personal handyphone, JPHP (Japan,1895.15 to 1905.15 MHz)
PHS personal handyphone system (Japan)
PHY physical layer (WLAN)
PIC photonic integrated circuit
PIM passive intermodulation
PIN positive-intrinsic-negative (diode junction)
PLCC plastic leaded chip carrier (molded plastic)
PLD programmable logic device
PLD pulsed laser deposition
PLF polarization loss factor
PLL phase-locked loop
PLMN private land mobile network
PM phase modulation
PM polarization-maintaining (optical fiber)
PMC perfect magnetic conducting
PMD polarization mode dispersion
PML perfectly matched layer
PMOS positive metal oxide semiconductor
PMR Private Mobile Radio
PN pseudorandom noise
PNF planar near-field (range)
PON passive optical network
POCSAG Post Office Code Standardization Advisory Group (paging)

POF	plastic optical fiber
POFS	private operational fixed service
POS	Post Office Protocol
POTS	plain old telephone service
PPM	periodic permanent magnet (focused)
PPM	pulse position modulation
PPS	precise positioning service (GPS)
PQFP	plastic quad flat pack
PR	pseudorange
PRBS	pseudorandom binary or bit sequence
PRF	pulse repetition frequency
PRN	pseudorandom noise
PROM	programmable read-only memory
PRT	planar resistor technology
PSA	polysilicon self-aligned (bipolar transistor)
PSD	power spectral density
PSK	phase-shift keying
PSMM	pilot strength measurement message
PSTN	public switched telephone network
PTFE	polytetrafluoroethylene
PTH	plated-through hole
PTO	public telecommunications operator
PTT	post, telephone and telegraph (Europe)
PWM	pulse width modulation
P1dB	power 1 dB compression point
QAM	quadrature (quaternary) amplitude modulation
QIFM	quadrature intermediate frequency mixer
QPSK	quadrature phase-shift keying
QRNS	quadratic residue number system
QSOP	quality small outline package
QWIP	quantum well infrared photodetector
QWR	quarter-wave rule
RACH	random access channel
RADAR	radio detection and ranging
RAIM	receiver autonomous integrity monitoring (GPS)
RAM	radar-absorbing material
RAM	random access memory
RAP	radar-absorbing paint
RAS	radio astronomy synthesis
RBC	radiation boundary conditions
RBER	residual bit error ratio
RBW	resolution bandwidth
RCS	radar cross section
RDS	radio data system
RELP	residually excited linear predictive coder
RF	radio frequency
RFID	radio frequency identification
RFMU	radio frequency monitoring unit
RFS	radio frequency simulator
RHCP	right-hand circular polarization
RIE	reactive ion etch
RIN	relative intensity noise
RISC	reduced instruction set computing
RL	rotating linear (antenna pattern)
RLL	radio local loop
RMS	root mean square
RNSS	radio navigation satellite service

[Continued on page 144]

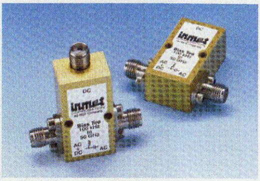


ROTHR relocatable over-the-horizon radar
RP range processor
RRC raised-root cosine
RRE radar range equation
RSSI received signal strength indicator
RSU roadside unit (auto toll collecting)
RTD resistance-temperature detector (probe)
RTD roundtrip delay
RwoH reliability without hermeticity
RWR radar warning receiver
RX receiver/receive
RZ return to zero
SA selective availability (GPS error introduction/correction)
SAR synthetic-aperture radar
SAR search and rescue
SAR specific absorption rate
SAT supervisory audio tone
SATCOM satellite communications (Satellite Communications Agency, Department of Defense)
SAW surface acoustic wave
SBAS satellite-based augmentation system
SBN single-sideband phase noise
SCFL source-coupled field effect transistor logic
SCPI Standard Commands for Programmable Instruments
SCR semiconductor-controlled rectifier
SCSI small computer standard/system interface
SDD symbolically defined device
SDH synchronous digital hierarchy (European telecommunication)
SDLA successive detection log amplifier
SDMA spatial division multiple access
SDR software-defined radio
SDRAM synchronous dynamic random access memory
SEAD suppression of enemy air defenses
SEM scanning electron microscope
SES severely errored seconds
SFDR spur-free dynamic range
SGLS space ground link system
SHF super high frequency
SI semi-insulating
SIC selectively implanted collector
SIG Special Interest Group
SIGINT signal intelligence
SIM subscriber identity module
SINAD signal-to-noise and distortion (ratio)
SIP single inline package
SIR stepped impedance resonator
SIS signal in space
SLE satellite link emulator
SLM spatial light modulator
SMI sample matrix inversion
SMP subminiature push-on (connector)
SMP surface-mount package
SMR specialized mobile radio
SMS short message service
SMT surface-mount technology
SNA scalar network analyzer
SNIR signal-to-signal plus interference ratio
SNR signal-to-noise ratio
SOI silicon on insulator
SOIC small outline integrated circuit
SOLR short-open-line-reciprocal (calibration)
SOLT short-open-load-thru (calibration)
SONET synchronous optical network (US telecommunications)
SOT small outline transistor
SP3 third-order suppression
SPC statistical process control
SPI serial peripheral interface
SPRE satellite position reporting equipment
SPS standard positioning service (GPS)
SPUDT single-phased unidirectional transducer
SRAM static random access memory
SS spread spectrum
SSB single sideband
SSBW surface-skimming bulk wave
SSD simultaneous signal detection
SSG small-signal gain

SSI small-scale integration
SSOP shrink small outline package
SSOT shrink small outline transistor
SSPA solid-state power amplifier
SSPE single solid-phase epitaxy
SSR surface search radar
STALO stable local oscillator
STM synchronous transport module (1 STM = 155 Mbps)
STOVL short takeoff, vertical landing (aircraft)
STW surface transverse wave
SWAP shared wireless access protocol
SWR standing wave ratio
TAB tape-augmented bonding
TACAN tactical air navigation system
TACS Total Access Communications System
TAG technical advisory group
TARD towed active radar device
TBCCO thallium barium calcium copper oxide
TCAS Traffic Alert and Collision Avoidance System
TCC temperature coefficient of capacitance
TCE thermal coefficient of expansion
TCH traffic channel
TCM trellis-coded modulation
TCR temperature coefficient of resistance
TCXO temperature-compensated crystal oscillator
TDD time division duplex
TDD time domain duplex
TDMA time division multiple access
TDMQPSK time division multiplex quadrature phase-shift keying
TDWR terminal Doppler weather radar
TE transverse electric
TEC thermal electric cooler
TEM transverse electromagnetic
TETRA trans-European trunked radio (old name)
TETRA terrestrial trunked radio (new name)
TFT thin-film transistor/technology
TFTS terrestrial flight telephone system
TLM transmission line matrix
TM transverse magnetic
TMA thermomechanical analysis
TMN telecommunication management network
TOI third-order intercept (point)
T/R transmit/receive
TRAC Technical Regulations Application Committee (of ETSI)
TRAM transimpedance amplifier
TRP Technology Reinvestment Program (NIST)
TRL thru-reflect-line (calibration)
TRX transceiver
TS timeslot
TSA tapered-slot antenna
TSOP thin small outline package
TSS tangential signal sensitivity
TTD true time delay
TTL transistor-transistor logic
TVRO television receive only
TWTA traveling-wave-tube amplifier

[Continued on page 147]

TX	transmit/transmitter
UAV	unmanned aerial vehicles
UFMOP	unintentional frequency modulation on pulse
UIM	uniform impedance resonator
UM	unintentional modulation
UMTS	Universal Mobile Telecommunications System (Europe)
U-NII	Unlicensed National Information Infrastructure
UPT	universal personal telecommunications
URE	user range error
USAT	ultra-small aperture terminals
UTC	Universal Time, Coordinated
UWB	ultrawideband
VANA	vector automatic network analyzer
VBW	video bandwidth
VCO	voltage-controlled oscillator
VDU	video display unit
VHDL	very high speed IC description language
VISA	virtual instrument software architecture
VLR	visitor location register
VLSI	very large scale integration
VMEbus	versa module Eurocard computer bus
VNA	vector network analyzer
VPN	virtual private networks
VSAT	very small aperture terminal
VSB	vestigial side band modulation
VSB	VMEbus subsystem bus
VSWR	voltage standing wave ratio
VVA	voltage-variable attenuator
VXIbus	VMEbus extension for instrumentation
WAAS	wide area augmentation system (GPS ground based)
WADSP	wideband acquisition/digital signal processing
WAN	wide area network
WAP	Wireless Application Protocol
WBMCS	wireless broadband multimedia communications systems
W-CDMA	wideband code division multiple access
WDM	wavelength division multiplexing
WDDM	wavelength division demultiplexing
WEP	wired equivalent privacy
WLAN	wireless local area network
WLL	wireless local loop
XFCB	extra-fast complementary bipolar
XPD	cross-polarization discrimination
XPIC	cross-polar interference canceller
XPOL	cross-polarization level
YAG	yttrium aluminum garnet
YBCO	yttrium barium copper oxide
YIG	yttrium iron garnet
YTO	YIG-tuned oscillator
3G	third generation
3GPP	Third-generation Partnership Project



A Broadband Bias Tee for Optical Networking Applications

The explosive growth of the Internet has created an insatiable demand for communications bandwidth by everyone, from the Web-browsing individual in the home office, to the multibillion-dollar corporation that is at a severe competitive disadvantage without it. Although several broadband access methods are now available, fiber optics is still the primary vehicle for broadband connectivity, particularly for communications traffic over long distances. Even with the large number of fiber-optic links already in place, over 90 percent of the commercial buildings in the US are still not served. This market represents an enormous opportunity for optical networking system, module and component manufacturers, and is the reason for the unprecedented growth rates that are expected in this market segment, some of which have already started to take shape.

Fiber-optic technology has made tremendous progress in recent years with respect to bandwidth and data capacity to support this demand. Optical carrier (OC) systems have quickly evolved from 2.5 Gbps (OC-48) to 5 Gbps (OC-96), and now 10 Gbps (OC-192) systems have reached mass production levels, which, not too long ago, were thought to be impossible. However, the demand continues to explode. Internet traffic is growing at a rate of 200 percent per year and now exceeds the amount of voice traffic. In order to support the necessary data applications, 40 Gbps (OC-768) systems are already being developed and prototyped for use in several long-haul and transoceanic communications links.

However, 40 Gbps systems present entirely new challenges because the overall speed and performance of the components used in these systems must be effectively increased four times over existing 10 Gbps systems. In addition to the challenges associated with the optical components (such as laser diodes and photodetectors), unique challenges also exist with the RF/microwave components that are required to support these functions. Due to the non-return-to-zero (NRZ) modulation methods used in these systems and the high frequency performance needed to support the desired data rates, RF/microwave components must operate over an extremely broad frequency range. Examples of passive components that face this challenge are DC blocks and bias tees that utilize frequency-dependent components, such as capacitors and inductors.

The model 8810EF bias tee has been introduced in response to the increasing market

[Continued on page 150]

INMET CORP.
Ann Arbor, MI

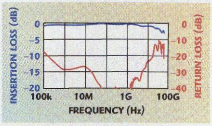


Fig. 1 Insertion loss and return loss vs. frequency on a standard log scale.

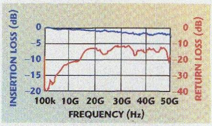


Fig. 2 Expanded high frequency detail.

demand for broadband RF/microwave components used in higher data rate optical networking applications. The 8810EF bias tee utilizes 2.4 mm connectors and is targeted to operate over the 100 kHz to 50 GHz frequency band. Since a low cost design approach was the focus from the beginning of product development, the 8810EF is priced very competitively and can consequently be used in the production of optical systems and modules, as well as for test and measurement applications.

TABLE I

BIAS TEE SPECIFICATIONS

Frequency	100 kHz to 50 GHz
Impedance (Ω)	50
Insertion loss (dB)	
100 kHz	0.5 (typ)
50 GHz	< 3.0
SWR	
f < 12 GHz	1.3 (max)
f > 12 GHz	1.8 (max)
DC voltage (V)	16 (max)
DC current (mA)	250 (max)
Isolation (dB)	
f ≤ 14 GHz	> 40
f > 14 GHz	> 30
RF power (W)	5 (max)
RF connectors	2.4 mm
Dimensions (")	0.63 × 1.20 × 0.50

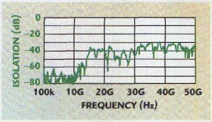


Fig. 3 DC-to-RF isolation performance.

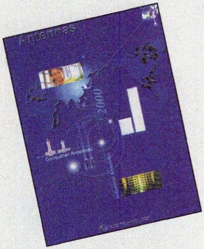
Typical insertion loss and return loss performance of the 8810EF bias tee is shown in ***Figure 1***, where the frequency is plotted on a log scale so that the low frequency performance is easier to distinguish. The graph shows that the insertion loss at 100 kHz is still less than 0.5 dB and the return loss is approximately 18 dB, equating to an SWR of 1.3. ***Figure 2*** shows the insertion loss and return loss vs. a linear frequency range from 10 to 50 GHz. The 8810EF was designed to handle 250 mA of DC current so that it can be used to bias higher current components (such as transimpedance amplifiers) in addition to lower current components (such as optical modulators). A summary of the product's specifications is listed in ***Table 1***.

Figure 3 shows the typical isolation performance of the bias tee between the DC and RF ports. The device typically exhibits better than 40 dB of isolation at the lower frequency range and equals or exceeds 30 dB over the entire 100 kHz to 50 GHz bandwidth.

Although the 8810EF bias tee consists of two female 2.4 mm connectors, other sex configurations are available (for example, male/female combinations). There are also plans to offer this bias tee with 2.9 mm connectors for 40 GHz applications, as well as with a variety of connectors used for injecting the DC bias. The model 8810EF uses an SMA connector for the DC bias; however, an SMC connector can also be provided in addition to the option of two terminals for voltage and ground. Additional information on broadband bias tees and other broadband components such as DC blocks, DC blocking terminations and attenuators can be obtained via e-mail from clindberg@inmetcorp.com.

Inmet Corp.,
Ann Arbor, MI (734) 426-5553.

Circle No. 302

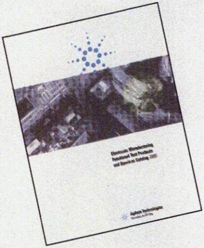


▲ Antenna Catalog

This 114-page catalog describes several antennas, including omnidirectional, sector, dual polarization, patch, parabola, Yagi, inverted, cellular phone, ceramic, retractable, dual-band, CT2 base station, half-wavelength sleeve dipole, dual-band magnetic and GPS. Product photographs, characteristics, and electrical and mechanical specifications are included. An environment test engineering report, glossary and company profile are also provided.

ACE Technology,
Chatsworth, CA (818) 718-1534.

Circle No. 310

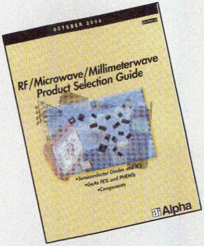


▲ Electronics Manufacturing Functional Test Products and Services Catalog

This 68-page catalog contains detailed information on the company's test system components, accessories and support services, which can help test engineers reduce the cost of building test systems. Product descriptions, specifications and photographs are included.

Agilent Technologies Inc.,
Palo Alto, CA (800) 452-4844, ext. 6494.

Circle No. 311

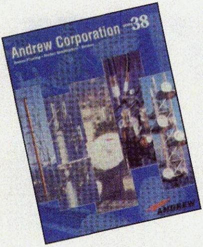


▲ RF/Microwave/Millimeter-wave Selection Guide

This brochure includes all of the company's products from DC to 40 GHz, including thousands of high performance, low cost RF, microwave and millimeter-wave products designed for telecommunications applications. The guide is designed so the customer can quickly find the right product for any requirement.

Alpha Industries,
Woburn, MA (781) 935-5150.

Circle No. 312

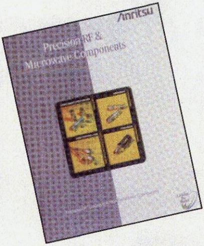


▲ Product Catalog

This 752-page catalog is a complete reference source for the company's products and services. Detailed product descriptions, specifications, planning guides, technical data and system planning software information are provided. New sections cover broadband antenna products, PerforMax™ base station antennas, ValuLine® antennas and ISM, MMDS and UNII band passive products.

Andrew Corp.,
Orland Park, IL (800) 255-1479.

Circle No. 313

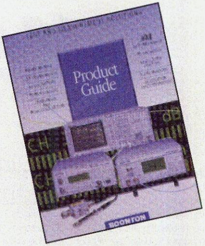


▲ Component Catalog

This 40-page catalog provides complete features, specifications and applications for the company's full line of adapters, attenuators, terminations and connectors. Components, including instrumentation-grade adapters, precision attenuators, high return loss connectors from DC to 65 GHz and precision terminations, as well as microwave detectors, power dividers, RF limiters and bias tees, are highlighted.

Anritsu Co.,
Microwave Measurements Division,
Morgan Hill, CA (800) 267-4878.

Circle No. 314



▲ Test and Measurement Solution Product Guide

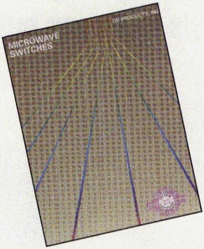
This full-length product guide details power meters, peak power meters, RF voltmeters, VXI products and power sensors that can be used in many commercial and military applications. Included are descriptions and specifications of the company's family of peak power meters/analyzers, including the model 4400A, model 4500A and 4530 series.

Boonton Electronics Corp.,
Parsippany, NJ (973) 386-9696.

Circle No. 315

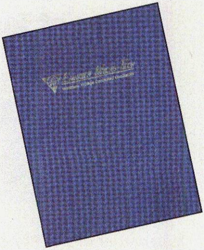
▲ Wireless and Microwave Filter Product Brochure

This eight-page brochure features transmit filters, receive filters, duplexers, 2.4/5.8 GHz radio products, delay filters, integrated assemblies, combline cavity filters, interdigital cavity filters and waveguide filter products. An overview of the company, product descriptions and photos, and ordering and shipping information are included.
ClearComm Technologies Inc.,
Salisbury, MD (410) 860-0500.
Circle No. 316



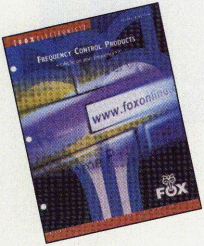
▲ Microwave Switch Catalog

This 16-page catalog features the company's various SMA, N and TNC connectorized switches. Specifications, available options, schematics, outline drawings and product photos are given for each component. General specifications, instructions on constructing a part number, definitions and notes are also provided.
DB Products Inc.,
Pasadena, CA (626) 449-3790.
Circle No. 317



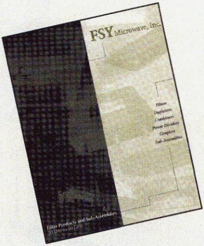
▲ Miniature Voltage-controlled Oscillator Catalog

This 32-page catalog describes various ELCO and EVCO series VCOs. Information on care, soldering techniques and assembly is included, as well as features, outline drawings and notes. Specifications, common questions, instructions on creating a model number, and quote and order information are also provided.
Emhiser Micro-Tech (EMT),
Verdi, NV (775) 345-0461.
Circle No. 318



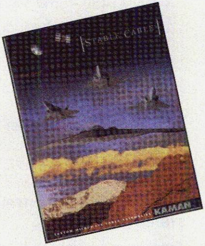
▲ Frequency Control Product Catalog

This 96-page catalog features detailed information on the company's recently expanded line of products. A complete listing of distributor stocking standards is provided, with a policy that none of the standards is noncancellable and nonreturnable (NCNR) to distributors or OEMs.
Fox Electronics,
Fort Myers, FL (888) 438-2369.
Circle No. 319



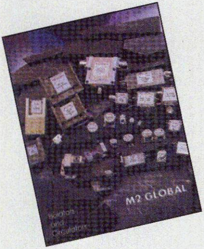
▲ Filter and Subsystem Catalog

This 96-page catalog features filters and subsystems from 30 kHz to 40 GHz. With a strong emphasis on the wireless market, the products include filters, duplexers, combiners, power dividers, couplers and subassemblies. Product photos, electrical and mechanical specifications, performance curves and an engineering reference section are included.
FSY Microwave Inc.
Columbia, MD (410) 381-5700.
Circle No. 320



▲ Custom Microwave Cable Assembly Catalog

This eight-page catalog features SMA-M, TNC-F bulkhead and SMA-M 90° cable assemblies. In-depth product descriptions, drawings, specifications, qualifications, performance characteristics, applications and "insertion loss vs. frequency" graphs are included. A company overview is also provided.
Kaman Aerospace Corp.,
Colorado Springs, CO (719) 635-6954.
Circle No. 321



▲ Isolator and Circulator Catalog

This 38-page catalog details a variety of isolators and circulators available in coaxial, waveguide, drop-in and surface-mount configurations covering the 300 MHz to 40 GHz frequency range. General information, electrical specifications, mechanical specifications and schematics are provided. A mail-back "request for quote" form is included.

M2 Global Technology Ltd.,
San Antonio, TX (210) 561-4800.

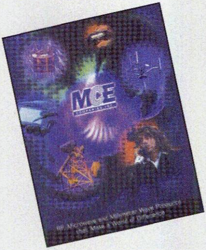
Circle No. 322

▲ Automated Tuner System Brochure

This 16-page brochure details the latest features, options and applications available with the company's automated tuner system. Features include Windows® 95/98/NT-compatible software, dynamic prematching, interpolated tuning and optimum parameter search. Also featured are the prematch and harmonic tuners, Signal Synthesis and post-analysis software, and the harmonic tuner controller.

Maury Microwave Corp.,
Ontario, CA (909) 987-4715.

Circle No. 323



▲ RF, Microwave and Millimeter-wave Product Brochure

This brochure features information on DML Microwave Ltd., Inmet, KDI/Triangle, Metelics and Weinschel. Product offerings and photos are included for each company. A corporate profile and description are also featured, as well as a worldwide design and manufacturing map.

MCE Companies Inc.,
Ann Arbor, MI (734) 426-1230.

Circle No. 324

▲ SiO_2 Cable System Brochure

This six-page brochure features RF coaxial and multiconductor transmission lines and SiO_2 cable and connector systems for nuclear applications and Si2400 fireproof cables. Product photos and graphs are provided, as well as features, specifications, applications and full descriptions. Installation and customer support information is also provided.

Meggitt Safety Systems Inc.,
Simi Valley, CA (805) 584-4100.

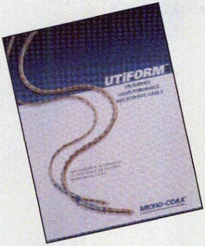
Circle No. 325

▲ Waveguide Subsystem and Component Catalog

This 45-page catalog features various waveguide subsystems and components, including flexible waveguide; E-plane bends; flange adapters; tapered transitions; bulkhead flanges; low, medium and high power terminations; E- and H-plane tees; hybrid tees; coaxial adapters; standard gain horns; shorting plates; pressure windows; waveguide flanges; and alloys.

Mesa Microwave Inc.,
San Diego, CA (800) 739-9173.

Circle No. 326

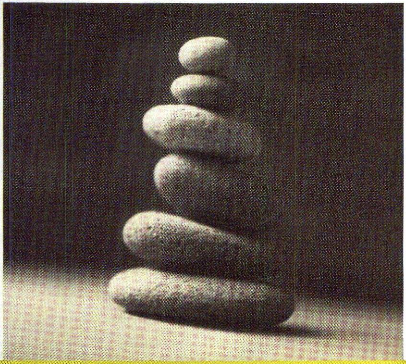


▲ Hand-formable Microwave Cable Brochure

This six-page brochure features the UTiFORM family of tin-dipped, hand-formable microwave cables, economical alternatives to semirigid and flexible cables. All mechanical and electrical characteristics of the cables are provided in easy-to-read charts. Graphs are also included to illustrate the cables' insertion loss, shielding effectiveness and power handling.

MICRO-COAX,
Collegeville, PA (800) 223-2629.

Circle No. 327



▲ Voltage-controlled Oscillator Short-form Catalog

This five-page catalog features a full voltage-controlled oscillator selection guide, which lists each product's full specifications by model number. Information on product applications, design and performance, assembly and testing is provided, as well as package outline drawings.

Modco Inc., Sparks, NV (800) 672-4552.

Circle No. 328

▲ Component, Network and Instrument Catalog

This 648-page catalog offers the latest in high performance components, networks and instruments. The company's complete product line appears in the catalog, and is presented in six primary categories: wireless products, electromechanical RF switches, passive components, active components, RF radiation safety products and power meters/monitors.

Narda–an L-3 Communications company, Hauppauge, NY (631) 231-1700.

Circle No. 329

▲ Buried Single-layer Capacitor Catalog

This six-page catalog features Buried Single Layer™ capacitors and provides general size information, capacitance ranges, available test methods and characteristic graphs. Product specifications, features, applications and a "how to order" chart are also provided.

Presidio Components Inc., San Diego, CA (858) 578-9390.

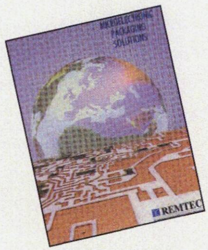
Circle No. 330

▲ Radar and RF Product Catalog

This 28-page catalog contains information on radar systems and RF products, including the AN/MPS-19 S-band mobile tracking system designed for precision instrumentation tracking and drone control. Also featured are many radar systems, RF packages and microwave tubes. Test and engineering capabilities are described. Product photos and specifications are provided.

Radio Research Co. Inc., Waterbury, CT (203) 753-5840.

Circle No. 331



▲ Microelectronic Packaging Solution Catalog

This catalog describes the company's Plated Copper on Thick Film (PCTF)™ proprietary manufacturing process, which combines patterned copper-plated images with air-fireable thick films on ceramics for the manufacture of metallized substrates, chip carriers and packages. Special features, compatible assembly methods and typical packaging solution examples are also described.

Remtec Inc., Norwood, MA (781) 762-9191.

Circle No. 332

▲ Coaxial Connector Catalog

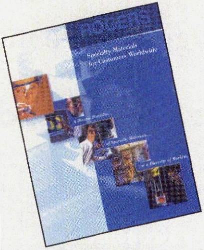
This 120-page catalog features a full range of standard and RF custom coaxial connectors, including 400 new items. More than 2000 coaxial products, including cable assemblies, connector kits, Unidapt® universal adapter products, cellular products and hand tools, are described. Product specifications and photographs are included.

RF Connectors, San Diego, CA (800) 233-1728 or(858) 549-6340.

Circle No. 333

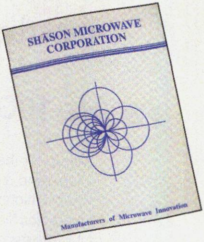
▲ Antenna Design and Development Catalog

This catalog presents hundreds of new antennas along with standard products that are available from stock or for near-term delivery. Sections feature antennas, antenna feeds, specialized microwave components, microwave subsystems and testing services.
Seavey Engineering Associates, Pembroke, MA (781) 829-4740.
Circle No. 334



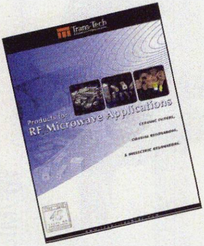
▲ Specialty Materials Catalog

This 16-page catalog details the company's line of specialty materials such as urethane foams, electroluminescent lamps and inverters, induflex laminates, PORON silicone materials, R/flex flexible circuit materials, RT/duriod and TMM high frequency circuit materials, RO4000 and RO3000 high frequency circuit materials, elastomer components and composite materials. Applications, markets, material details and key properties are listed for each product.
Rogers Corp., Rogers, CT (800) 774-9605.
Circle No. 335



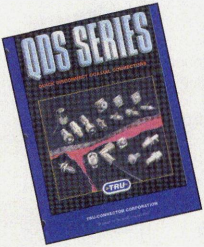
▲ Product Catalog

This catalog features solid-state amplifiers, frequency converters, power dividers and instrumentation systems. Specifications, electrical characteristics, product outlines, descriptions, photographs, applications and features are included. Corporate information and descriptions of the company facilities are also provided.
Shason Microwave Corp., Webster, TX (281) 526-0536.
Circle No. 336



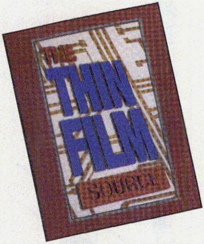
▲ RF/Microwave Component Catalog

This 90-page catalog features the company's complete line of RF/microwave components, including bandpass filters, diplexers, coaxial resonators and dielectric resonators. Product specifications, application notes and technical drawings are included.
Trans-Tech Inc., Adamstown, MD (301) 695-9400.
Circle No. 337



▲ Coaxial Connector Catalog

This catalog details a wide range of RF coaxial connectors and a line of adapters and custom-designed cable assemblies. It features quick-disconnect connectors that correspond to LC, C, SC, BNC and TNC types, super-quick designs for sputtering, wafer processing and high power applications, and quick-change types for use with wattmeters and other high power testing and monitoring equipment.
Tru-Connector Corp., Peabody, MA (800) 262-9878 or (978) 532-0775.
Circle No. 338



▲ Thin-film Circuit Device Catalog

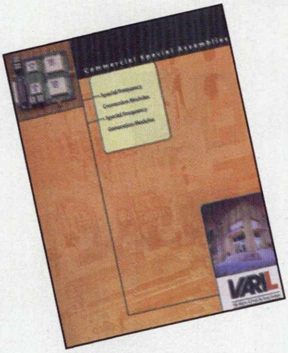
This 12-page catalog features thin-film circuit devices. Included in the catalog are substrate materials used for the devices, metallization schemes, sheet resistor designs, plated thru holes/slots, filled via products, layout and design guidelines, and a checklist. Product specifications, applications and outline drawings are included. A "request for quotation" form is also provided.
UltraSource Inc., Hollis, NH (603) 881-7799.
Circle No. 339

CATALOG UPDATE

▲ 2000 Product Catalog

This 16-page catalog features voltage-controlled oscillators, ceramic resonator oscillators, phase-locked loops, fixed-frequency oscillators and synthesizers. An engineer's notebook, applications notes, definitions, and tape-and-reel information are included. Complete product descriptions, specifications, applications, features and photographs are provided.
Universal Microwave Corp., Odessa, FL (877) 375-9332.

Circle No. 340



▲ Commercial Special Assembly Catalog

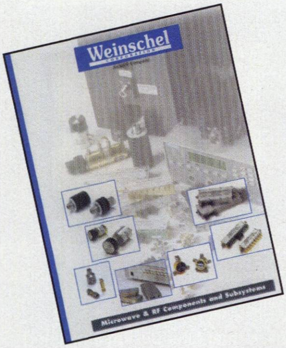
This 13-page catalog features special frequency conversion and frequency generation modules. Product photographs, diagrams, schematics, performance specifications, performance graphs, programming calculations and outline drawings are included. Packaging and installation information is also provided.
Vari-L, Denver, CO (303) 371-1560.

Circle No. 341

▲ 2000 Product Catalog

This 525-page catalog covers telecom and enterprise networks, multimedia and wireless. It describes test solutions for development, manufacture, installation, maintenance and repair of systems and networks for transmitting speech, data and images. A company overview as well as product photographs, specifications, applications and full descriptions are included.
Wavetek Wandel Goltermann, Eningen, Germany +49 7121 86 1616.

Circle No. 342



▲ Microwave and RF Component and Subsystem Catalog

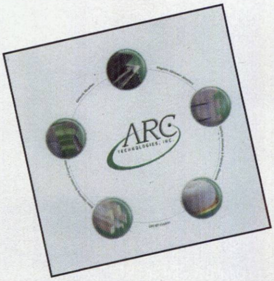
This 224-page catalog features microwave and RF components and subsystems, including coaxial fixed attenuators, terminations and loads, phase shifters, programmable attenuators, SmartStep components and subsystems, power splitters/dividers, directional couplers and coaxial adapters. Product descriptions, specifications and photographs are included.
Weinschel Corp., Frederick, MD (800) 638-2048 or (301) 846-9222.

Circle No. 343

▲ Microwave Product Catalog

This 12-page catalog features a company introduction, business focus description, technology overview and product descriptions, including comb generators, crystal stabilized sources, multi-channel sources, frequency multipliers, frequency synthesizers and converters, receivers and microwave subsystems. Product photographs, specifications and key features are also provided.
Zeta, San Jose, CA (408) 434-3600.

Circle No. 344

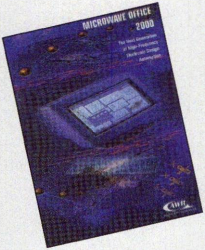


▲ Engineer's Survival Kit

This survival kit is intended for use with interference control and includes a variety of product samples such as foam absorbers, MAGRAM and new EMI materials, as well as a new capabilities brochure. These samples can be used in prototyping the user's next design.
ARC Technologies, Amesbury, MA (978) 388-2993.

Circle No. 345

CATALOG UPDATE

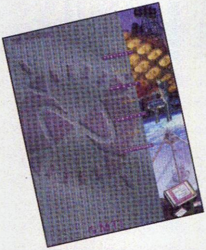


▲ High Frequency Electronic Design Automation Brochure

This 10-page brochure features Microwave Office 2000 design automation software, which combines an advanced IC layout editor with state-of-the-art simulation technology. Screen shots, features, capabilities, characteristics and ordering information are included.
Applied Wave Research Inc.,
El Segundo, CA (310) 726-3000.
Circle No. 346

▲ High Performance Synthesizer Datapack

This datapack contains information on several frequency synthesizers. The data sheets include performance specifications, and mechanical and block diagrams. Products covered include the STEL-2375 DDCS chirp synthesizer hybrid, the STEL-9953A DDS synthesizer with internal clock and the MS-2000 LMDS synthesizer.
ITT Industries,
Lowell, MA (978) 441-0200.
Circle No. 347



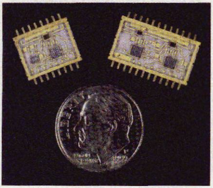
▲ High Performance Mini-OCXO Catalog

This 23-page catalog contains several innovative OCXO designs, including the 205 series, which is the most compact OCXO in the industry. The hermetic package measures 0.815" × 0.515" × 0.394". The 220 series performs to STRATUM III, IIIe standards and is ideal for applications requiring low power consumption.
MTI-Milliren,
Newburyport, MA (978) 465-6064
Circle No. 348

RF Digital Attenuators in Plastic MLP Packages

Broadband digital attenuators have been used to set power levels in RF and microwave circuits for many years. The concept is to electronically switch resistive T and Π networks to attenuate and control signals. In doing so, attenuators must have low insertion loss, generate accurate (flat with frequency) attenuation levels, maintain low input and output SWR for all attenuation levels, produce low spurious signals, consume low DC power and switch very quickly. Although the basic "switched pad" circuits are well known and very useful, recent developments in GaAs MMICs and plastic packaging technologies have expanded operating frequencies while reducing physical size and costs.

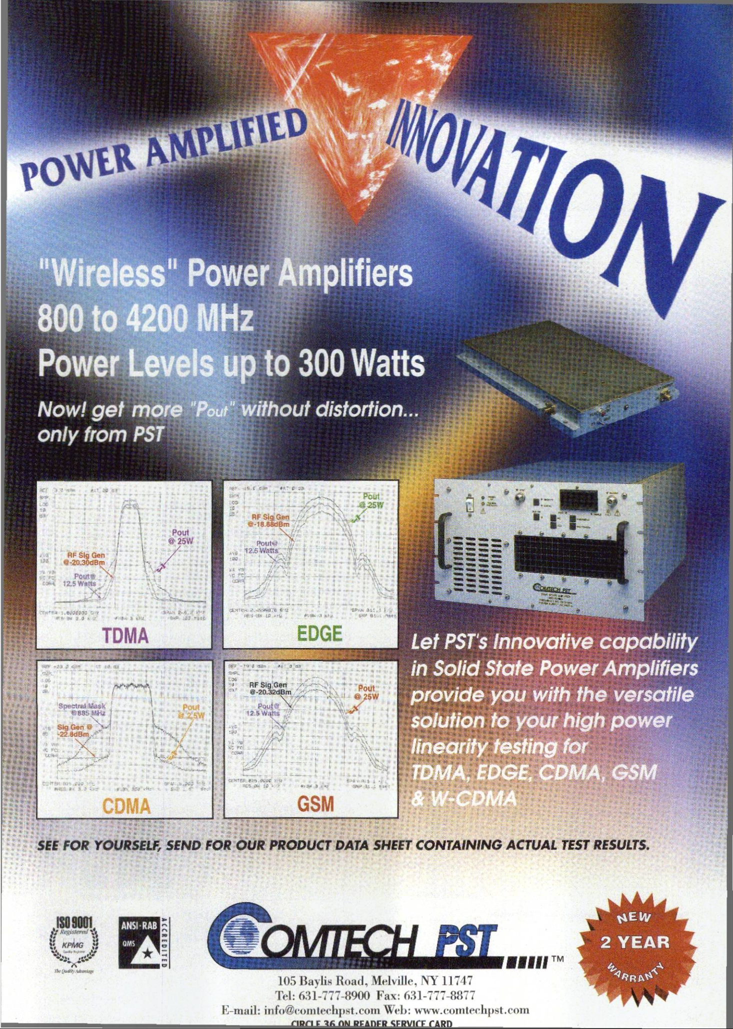
Fig. 1 Relative sizes of the five-bit and six-bit attenuators.

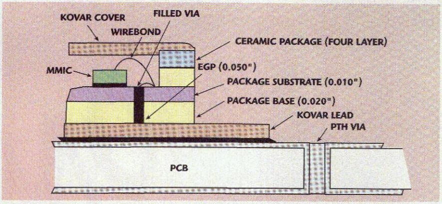


Using this GaAs MMIC base, a family of digital attenuators producing five- and six-bit formats with least significant bit (LSB) weights of 0.5 and 1 dB have been developed in various package platforms. Initially, the product line consisted of multichip GaAs MMICs and silicon-based CMOS application-specific IC (ASIC) drivers packaged in ceramic flatpacks. For example, the model AT-263 attenuator utilizes a five-bit, 1 dB LSB MMIC in the RF path and two quad drivers to perform the interface for the TTL control signals. Its sister component, the model AT-283, has the same structure except the MMIC has a 0.5 dB LSB. The six-bit attenuators (models AT-106 and AT-107) employ five-bit MMICs with an additional dual-bit 16 dB MMIC connected in series to create the sixth bit. The 16 dB MMIC can be wirebond configured to produce a most significant bit (MSB) of 16 or 32 dB as the application requires. ***Figure 1*** shows the interior views of five- and six-bit ceramic attenuators. For reference, the AT-106 attenuator with its four semiconductor chips occupies a total package area (body and leads) of 0.450" × 0.650" (11.4 × 16.5 mm).

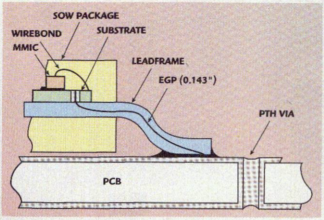
[Continued on page 168]

M/A-COM
Lowell, MA


POWER AMPLIFIED INNOVATION
"Wireless" Power Amplifiers
800 to 4200 MHz
Power Levels up to 300 Watts
Now! get more "Pout" without distortion...
only from PST
RF Sig Gen @-20.30dBm
Pout @ 12.5 Watts
Pout @ 25W
TDMA
RF Sig Gen @-18.88dBm
Pout@ 12.5 Watts
Pout @ 25W
EDGE
Spectral Mask @885 MHz
Sig Gen @ -22.8dBm
Pout @ 25W
CDMA
RF Sig Gen @-20.32dBm
Pout@ 12.5 Watts
Pout @ 25W
GSM
Let PST's Innovative capability in Solid State Power Amplifiers provide you with the versatile solution to your high power linearity testing for TDMA, EDGE, CDMA, GSM & W-CDMA
SEE FOR YOURSELF, SEND FOR OUR PRODUCT DATA SHEET CONTAINING ACTUAL TEST RESULTS.
ISO 9001 Registered KPMG
The Quality Advantage
ANSI-RAB QMS ACCREDITED
COMTECH PST ™
NEW 2 YEAR WARRANTY
105 Baylis Road, Melville, NY 11747
Tel: 631-777-8900 Fax: 631-777-8877
E-mail: info@comtechpst.com Web: www.comtechpst.com
CIRCLE 36 ON READER SERVICE CARD

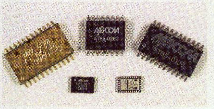


▲ *Fig. 2 Cross section of a ceramic package on a PCB.*



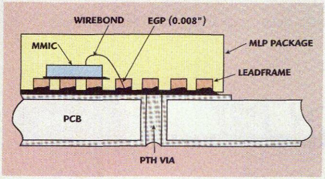
▲ *Fig. 3 Cross section of an SOW package on a PCB.*

Two important aspects for high frequency performance are maintaining the impedance match for series (I/O) ports and minimizing the shunt (GND) inductance. Unless the MMIC designer specifically knows the final package in which the MMIC will be placed, MMICs are designed as stand-alone components. That is, the I/O ports are designed to look into 50 Ω networks while the die's base and the substrate it sits on should be a low inductance to ground. For example, **Figure 2** shows the cross-sectional view of the effective ground path (EGP) for the MMIC in a ceramic package. This path effectively begins at the end wirebond and ends at the PCB ground. Ceramic packages, with their electrically grounded base and short EGP lengths, produce excellent RF performance up to 2.5 GHz. However, these packages have higher costs compared with plastic small outline integrated circuit (SOIC) devices, and that has resulted in limited demand in high volume, low cost applications.



▲ *Fig. 4 Sizes of the ceramic, SOW and MLP packages.*

▼ *Fig. 5 Cross section of an MLP package on a PCB.*



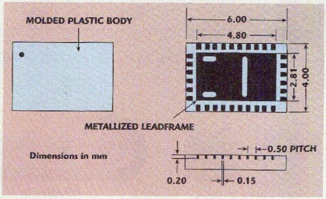
To pursue the low cost attenuator market, the family of attenuators was expanded to include SOW-16 and 24-lead plastic packages. The AT65 series attenuators have reduced costs compared to the ceramic attenuators. However, the downside of transitioning to plastic packages was an increase in insertion loss and SWR. The additional lead inductance reduced the upper frequency limit to 2 GHz. The 0.300"-wide SOW package has an EGP that is approximately three times that of the ceramic (0.143" vs. 0.500"), as shown in **Figure 3**. While the SOIC plastic packages are perfectly acceptable for today's GSM and PCS telecommunication systems, they cannot support tomorrow's higher frequency applications or denser packaging objectives.

PACKAGE SELECTION

To realize a low cost plastic attenuator for frequencies beyond 2 GHz, the miniature leadless package (MLP) offered by various package vendors was investigated. This package platform offers low inductance I/O pads on a 0.5-mm pitch. In addition, an exposed conductive center die paddle provides improved RF grounding, which permits operation at higher frequencies. Aside from the size reduction, the package's main feature is that its cost is only slightly higher than that of the plastic SOIC packages. **Figure 4** shows the ceramic, plastic SOW and MLP packages of the digital attenuator family.

The MLP package, with its ability to have the leadframe and paddle soldered directly to the PCB, can produce an EGP that is 82 percent shorter than that found in the referenced ceramic package. As shown in **Figure 5**, the EGP is limited to the thickness of the 0.008" copper leadframe. The outline for the 6.0 × 4.0 mm MLP package is shown in **Figure 6**.

▼ *Fig. 6 Outline of the MLP package.*



[Continued on page 170]

DIE DEVELOPMENT

Once the package format was selected, developing ASICs and MMICs to accommodate the MLP platform became the next step. With typical package footprints at 10 to 30 percent of the SOIC packages, a total die shrink for all internal components was in order. The two drivers had to be combined into a single hex driver, and the single six-bit MMICs had to be developed to replace the two MMICs in the six-bit attenuators. Because new MMICs were required, it was determined that they should be designed to support much higher frequencies than the previous devices. For this effort, the upper frequency goal was increased to 4 GHz. This range would produce a respectable margin to ensure that the MLP attenuators would operate to a minimum of 3 GHz.

ASIC DRIVER

The MLP design effort began with the development of the hex channel ASIC driver, which meant increasing the number of channels while reducing the die size. Adding two driver channels was not an issue; however, reducing the size of the die to the required area meant minimizing output drive capability. Specifications were reduced from ±25 mA to ±1 mA with the ability to drive 4 pF loads vs. the original specification of 25 pF. By using smaller output FET junctions, the hex driver was realized at a respectable die size of 2.33×1.22 mm.

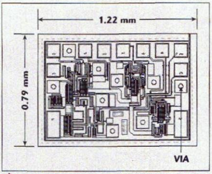
RF MMIC DEVELOPMENT

Four new MMICs were designed using patented compensation techniques.[1] Two five-bit, 1 dB LSB attenuators were designed — one used the standard 10-mil GaAs process, while a second device was designed with the advanced 4-mil GaAs via process. Two six-bit MMICs (0.5 and 1 dB) were also designed with the 10-mil process.

The main difference between the two GaAs processes is the method used to connect the MMIC with circuit ground. In the 4-mil via process, the ground returns are plated-through vias. This configuration allows the designer to use vias at specific ground points in the layout. In the standard 10-mil process ground points must be routed to I/O pads at the edge of the die and wirebonded to ground. The upside of the 4-mil process is the extension of the upper frequency limit. However, downsides include lower yields associated with thinner wafers and higher processing costs due to the vias and backside metallization process steps.

All of the GaAs MMICs were designed with the aide of HP EEsof Series IV software and the company's GaAs MMIC design manual. Extensive modeling was performed on all designs to minimize insertion loss and optimize the attenuation flatness of the individual bits and their summation. During this process it was determined that the physical order of the bits is very important to bit accuracy, and must be optimized to minimize sensitivity to external loading and bit errors. For example, the optimum

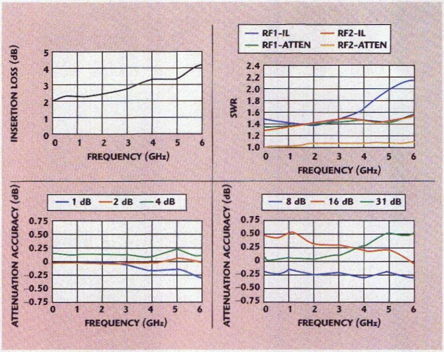
[Continued on page 172]



▲ *Fig. 7 The five-bit, 1 dB, 4-mil, GaAs MMIC layout.*

physical order for the bits in the 4-mil, five-bit attenuator is 16, 1, 2, 4 and 8 dB.

Another technique that lessened the interaction of the bits was to add 0.25 pF decoupling capacitors to the control lines on the larger bits. This addition minimizes coupling between the RF signals and control lines, which improves the accuracy of the bits. In addition, using the single standard series FET cell for the insertion loss path in the 16 dB bit limited the frequency performance. The isolation of the single FET is too close to the desired attenuation at high frequencies. While a very small FET could be used, its on resistance would significantly increase the insertion loss of the bit. To overcome this dilemma, a series/shunt/series configuration was implemented. This structure allows the insertion loss to remain low while, at the same time, increasing the isolation across the series-switching FET elements. The result is an extremely flat 16 dB bit.



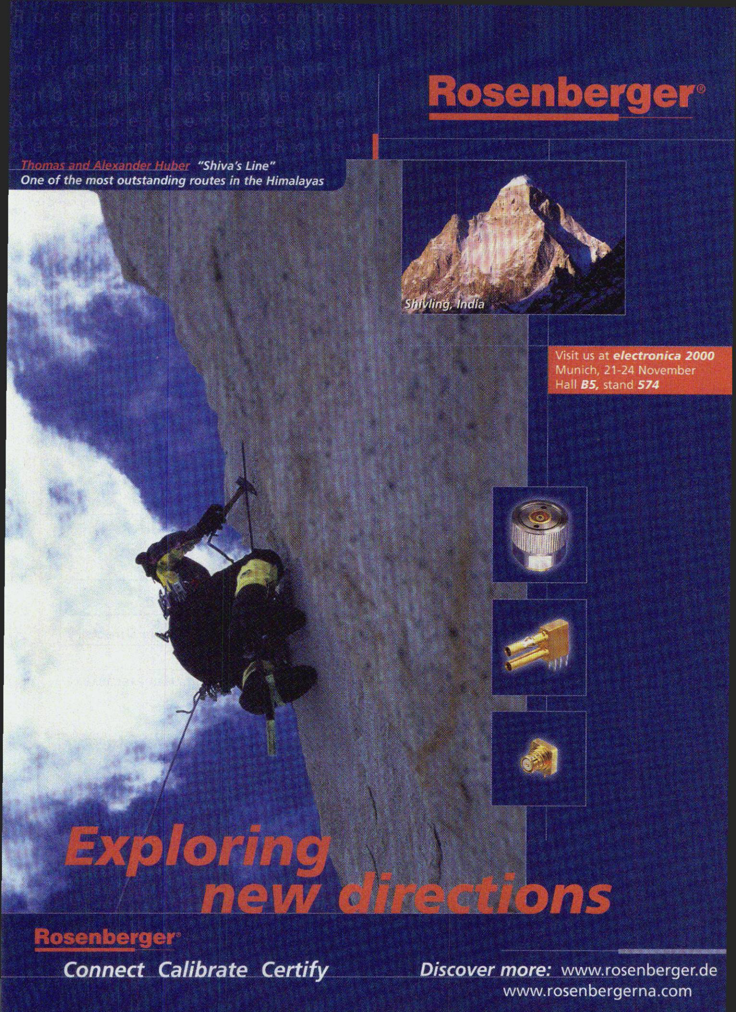
▲ *Fig. 8 Performance of the 31 dB five-bit, 4-mil, GaAs MMIC.*

In an effort to keep the die size as small as possible, the impedance of the internal transmission lines was increased to 70 Ω. This change allowed the width of RF lines to be reduced from 73 to 30 μm while the SWR remained less than 2 over most of the band. The resultant die size was essentially limited by the number and position of the I/O bond pads, and not the internal circuitry. ***Figure 7*** shows the die layout; ***Figure 8*** shows the measured results.

ASSEMBLY

Both the driver and MMIC dice are attached to the grounded paddle with epoxy. Unlike the ceramic and SOW plastic devices that contain internal circuitry, interconnections between ASIC and MMIC dies utilize direct die-to-die wirebonds. Extensive testing has shown that this method is an effective and reliable assembly technique for interconnecting die in small packages.

[Continued on page 174]



CIRCLE 156 ON READER SERVICE CARD

TABLE I

MLP ATTENUATORS

P/N	Max. Frequency (GHz)	Bits	Bit Size (dB)	Dynamic Range (dB)	Power Supplies (V)
AT90-0001	6	5	1.0	31.0	+5, –5
AT90-0106	3	6	1.0	50.0	+5, –5
AT90-0107	4	6	0.5	31.5	+5, –5
AT90-0263	4	5	1.0	31.0	+5, –5
AT90-0283	3	5	0.5	15.0	+5, –5
AT90-1106	3	6	1.0	50.0	+5
AT90-1107	4	6	0.5	31.5	+5
AT90-1263	4	5	1.0	31.0	+5
AT90-1283	3	5	0.5	15.0	+5

PRODUCT DESCRIPTION

Table 1 lists the characteristics of the AT90-XXXX attenuator family. The initial product operates with +5 and –5 V supplies at +6 and –1 mA (max), respectively. Logic inputs are TTL compatible. A logic 0 sets the bits to reference loss while a logic 1 selects the attenuation levels. Typical switching speed is 35 ns with rise and fall times of 5 ns.

The AT90-0001 attenuator containing the 4-mil via process die exceeded expectations and is specified to operate to 6 GHz. While DC blocks are not needed on the RF ports, 0.01 μF decoupling capacitors are required on each power supply line to ensure switching speed performance. The plastic MLP package measures 6.0 × 4.0 × 0.9 mm. Thirty-two 0.25 × 0.40 mm I/O pads are set at 10 per long side, six per short side on a 0.5 mm pitch. The 2.8 × 4.8 mm center die pad must be soldered to the PCB to ensure good RF performance.

To accommodate single power supply systems, four single-supply (+5 V at 10 mA) attenuators are presently in development. These devices will use an internal GaAs DC–DC converter to produce the required negative voltage. The two previously referenced decoupling capaci-

[Continued on page 176]

TABLE II

AT90-0001 PRELIMINARY SPECIFICATIONS

Parameter	Test Conditions	Frequency	Min.	Typ.	Max.
Insertion loss (dB)	All logic inputs at logic 0	DC to 1.0 GHz	–	2.4	2.9
		DC to 2.0 GHz	–	2.5	3.1
		DC to 4.0 GHz	–	3.3	3.8
		DC to 6.0 GHz	–	5.0	5.8
Attenuation accuracy (dB)	1 to 31 dB bits	DC to 3.0 GHz	–	–	±(0.3 + 3% of attenuation in dB)
	1 to 25 dB bits	DC to 6.0 GHz	–	–	±(0.3 + 3% of attenuation in dB)
	25 to 31 dB bits	DC to 6.0 GHz	–	–	±(0.3 + 5% of attenuation in dB)
SWR	full range	DC to 2.0 GHz	–	1.4	1.7
		DC to 6.0 GHz	–	1.7	2.4
1 dB compression (dBm)	–	50 MHz	–	22	–
	–	0.5 to 6.0 GHz	–	28	–
Input IP2 (dBm)	two tone inputs to +5 dBm	50 MHz	–	43	–
		0.5 to 6.0 GHz	–	60	–
Input IP3 (dBm)	two tone inputs to +5 dBm	50 MHz	–	37	–
		0.5 to 6.0 GHz	–	48	–
Vcc (V)	–	–	4.75	5.0	5.25
Vee (V)	–	–	–8.00	–5.0	–5.00
Switching speed (ns)	50% control to 90% RF	T_{on}	–	27	–
	50% control to 10% RF	T_{off}	–	16	–
	10% to 90% RF	T_{rise}	–	13	–
	90% to 10% RF	T_{fall}	–	3	–
Logic 0 (V)	control currents are 1 μA (max)	–	0.0	–	0.8
Logic 1 (V)		–	2.0	–	5.0
Icc (mA)	Vcc, Vee min to max	–	–	3	6
Iee (mA)	0 V • logic 0 • 0.8 V	–	–	0.01	1
	Vcc – 2.1 V • logic1 • Vcc				

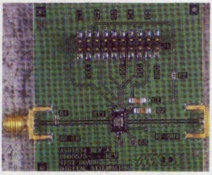


Fig. 9 A test board for the AT90-0001 attenuator.

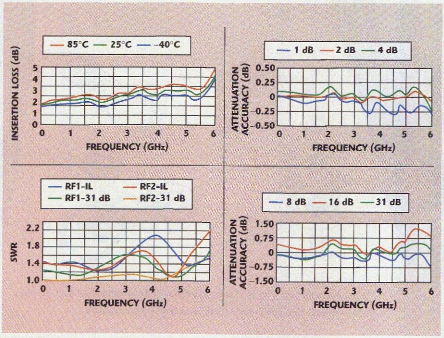


Fig. 10 The AT90-0001 attenuator's measured performance on a test board.

tors must be increased to 0.1 μF, and a third 0.01 μF coupling capacitor is required between pins 23 and 21.

Sample attenuators (AT90-XXXX) and/or test boards (AT90-XXXX-TB) are available upon request. ***Table 2*** lists the AT90-0001 31 dB, five-bit attenuator's preliminary specifications. A test board for the device is shown in ***Figure 9***. ***Figure 10*** shows measured results. Full data sheets containing suggested PCB layouts are available on the company's Web site at www.macom.com.

References

1. Shmuel Ravid, Alan R. Olsen and Gary E. St. Onge, "Electronic Attenuator," US Patent 5,281,928.

M/A-COM,
Lowell, MA (800) 366-2266.

Circle No. 305

HIGH EFFICIENCY L- AND S-BAND TRANSMITTERS

A new line of miniature airborne telemetry transmitters has been introduced that uses a proprietary approach to amplifier design and features previously unattainable DC-to-RF efficiencies. The breakthrough design utilizes GaAs FETs in a configuration that eliminates the usual transmitter design trade-off of a linear regulator (very poor efficiency) vs. a switching regulator (electromagnetic/RF interference problems).

In many telemetry applications, the transmitter represents the major portion of the current draw and becomes the determining factor in flight time, range, battery size/weight, heat dissipation and other flight parameters. By dramatically lowering the current draw requirement, the new transmitter completely resets this trade-off equation.

Another common situation requiring design compromises is an existing system's increased data rate specification. For example, a requirement to double the data rate of an existing system requires the pre-detect bandwidth of the receiver to double. A 3 dB gain in received power is needed for the link to maintain the original range and bit error rate.

Since lowering the low noise amplifier (LNA) noise figure by 3 dB is probably impossible, the system designer is usually left with the choices of increasing the gain of the transmit and/or receive antenna(s) or increasing the transmitter power. Assuming the existing telemetry pack system represented an optimal design prior to the introduction of this series of transmitters, the designer's choices are narrowed even further to increasing the transmit antenna gain (difficult due to flight constraints) or increasing the receive antenna gain (usually very expensive).

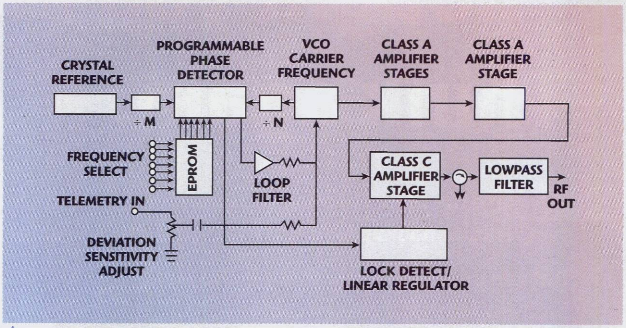
The new line of ultra-high efficiency (UHE) transmitters effectively solves this system design dilemma. For example, doubling the transmit power from 5 W (conventional design) to 10 W (UHE) actually lowers the current draw requirement and heat dissipation. Other link elements, including the transmit antenna, receive antenna and LNA, as well as system elements, such as battery size and heat radiators, remain unchanged.

Yet another situation posing a design dilemma is one where higher RF power is not needed, but more current is required for additional processing circuitry and, of course, no additional supply current is available. In this case, changing from a conventional 5 W transmitter to a new UHE model frees up nearly 1 A of supply current.

[Continued on page 180]

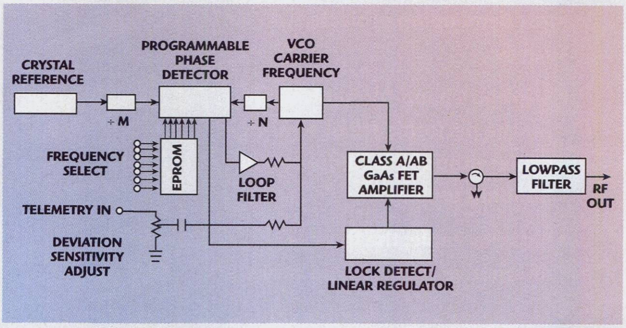
EMHISER RESEARCH INC.
Verdi, NV

PRODUCT FEATURE



▲ *Fig. 1 Block diagram of a conventional L-/S-band transmitter.*

▼ *Fig. 2 Block diagram of the UHE L-/S-band transmitter.*



PERFORMANCE COMPARISON

Most conventional telemetry transmitters are configured similar to the block diagram shown in ***Figure 1***. A phase-locked exciter generates the RF carrier and determines the modulation characteristics. This exciter drives several cascaded linear (class A) amplifier stages, which, in turn, drive the power stage(s) operating in class C. The power stage(s) is typically a silicon bipolar transistor.

In contrast to high power bipolar transistors, high power GaAs FETs are optimized for class A or AB rather than class C operation. While a class C stage is more efficient than a class A or AB stage in terms of DC-to-RF power conversion, the situation reverses when taking into account the much higher gain S_{21} of GaAs FETs.[1] Typical L- and S-band GaAs FET gains are 16 to18 dB, as opposed to approximately 8 dB for silicon bipolar transistors. Therefore, the power-added efficiency (PAE) of GaAs FETs far exceeds the efficiency of a class C silicon bipolar device.

A block diagram of the new UHE transmitter is shown in ***Figure 2***. The multiple class A bipolar driver stages (two stages minimally, three typically) and class C power stage are entirely replaced by the new GaAs FET amplifier. The high gain of the GaAs FETs permits the removal of several amplifier stages and their attendant DC power losses.

The elimination of amplifier stages, the increased GaAs FET RF power out/DC power in efficiency (up to 70 percent) over silicon bipolar transistors and the GaAs FET amplifier configuration significantly reduce the total current draw. In addition, the overall transmitter efficiency increases as the RF power output of the transmitter increases since the overhead current of the exciter represents a smaller percentage of the total current draw.

Performance comparisons between the UHE line of telemetry transmitters and conventional designs dramatically demonstrate the advantages of the new

[Continued on page 182]

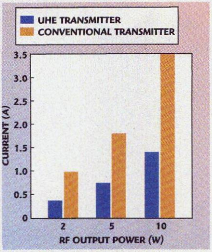


Fig. 3 Transmitter current comparison.

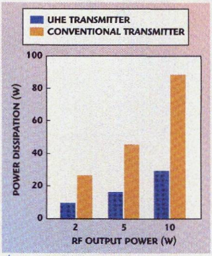


Fig. 4 Transmitter power dissipation comparison.

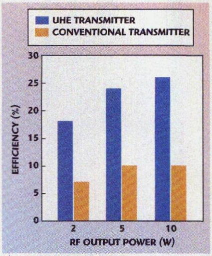


Fig. 5 Transmitter efficiency comparison.

transmitters. ***Figures 3*** and ***4*** show the decreased current draw and power dissipation, respectively, while ***Figure 5*** shows the increased transmitter efficiency. Using these figures, the following examples evaluate the replacement of conventional telemetry transmitters with the company's new UHE line.

A change from a 10 W conventional transmitter to a 10 W UHE series transmitter with the same data rate results in no reduction in range, a 60 percent reduction in current and 67 percent less power dissipation. Changing from a 5 W conventional transmitter to a 10 W UHE series transmitter with the same data rate provides 41 percent additional range with a 22 percent reduction in current draw and a 35 percent reduction in power dissipation. A similar change from a 5 W conventional transmitter to a 10 W UHE series transmitter with double the data rate produces no range change but a 22 percent reduction in current draw and 35 percent less power dissipation. A final example is a change from a 2 W conventional transmitter to a 5 W UHE series transmitter with the same data rate. This replacement results in a 58 percent increase in range, a 25 percent reduction in current draw and a 38 percent reduction in power dissipation.

With standard input voltage levels of +28 V ±4 V, the frequency-agile UHE 2 W design draws 400 mA (max), the 5 W draws 750 mA (max) and the 10 W draws 1.4 A (max). Conventional frequency-agile telemetry transmitters draw 1.0, 1.8 and 3.5 A for 2, 5 and 10 W, respectively.

CONCLUSION

A new line of UHE telemetry transmitters offers designers new choices for system optimization. The transmitters are available in 2, 5 or 10 W RF power levels in the standard nine- or 11-cubic-inch packages (2.5" × 3.5" × 1" or 2.5" × 3.5" × 1.3"), and in 2 and 5 W RF power levels in the five- or six-cubic-inch packages (2" × 3" × 0.8" or 2" × 3" × 1").

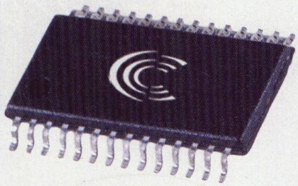
Reference

1. Tim Bambridge, "High Efficiency 5 W S-band Telemetry Transmitter Using Gallium Arsenide Field Effect Transistors," *Proceedings of the 1995 International Telemetering Conference*, Volume XXXI, Las Vegas, Nevada, 30 Oct. 1995 to 02 Nov. 1995.

Emhiser Research Inc.,
Verdi, NV (775) 345-2705.

Circle No. 300

A 6 GHz Dual Fractional-N Frequency Synthesizer



Today's high performance radio systems require low power and fine step sizes as well as the usual low phase noise, fast switching and small size that have become prevalent in modern portable communications equipment. The model CX72302 direct digital modulation fractional-N frequency synthesizer has been designed to provide all of these characteristics while featuring ultra-fine frequency resolution and an on-chip crystal oscillator. The new frequency synthesizer IC features a 6 GHz (max) operating frequency, –80 dBc/Hz phase noise floor and 400 Hz or less step size, making it ideal for very narrowband wireless applications. This performance is a direct result of the on-chip low noise dividers and low divide ratios provided by the IC's high fractionality.

The IC's ultra-fine step size is capable of compensating for crystal oscillator drift or IF filter drift using the proper temperature sensing. As a result, a simple crystal oscillator may be used as a reference as opposed to the bulkier and more costly temperature-compensated or oven-controlled crystal oscillators, thus reducing parts count, size and associated component costs. The IC's fine step size can also be used for Doppler shift corrections.

The crystal frequency is divided down by one to 32 independent programmable dividers for the main and auxiliary synthesizers. As a result, reference crystals or oscillators up to 50 MHz may be used with the CX72302 synthesizer.

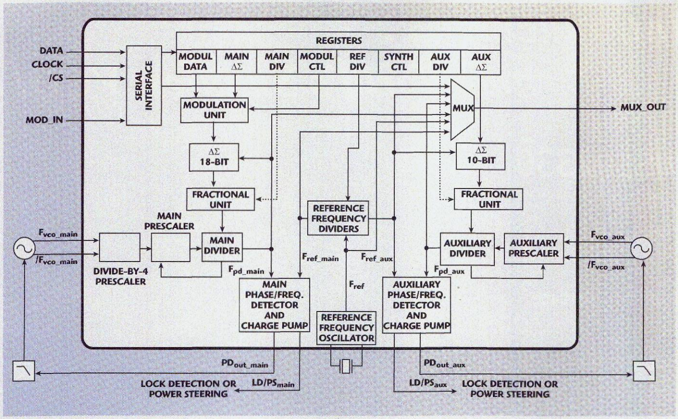
The phase detectors operate at a maximum speed of 25 MHz, thus permitting better phase noise due to the lower division value. In addition, with the high reference frequency, the loop bandwidth also is increased, resulting in improved settling time and reduced in-band phase noise. The lower in-band phase noise permits the use of lower cost VCOs in the system.

The CX72302 synthesizer features a patent-pending Frequency Power Steering™ circuit that assists the loop filter in steering the VCO when the frequency is too fast or too slow. In this configuration, acquisition times up to five times faster than conventional phase/frequency detectors can be achieved. Typical switching times of less than 100 μs are possible with a 10 MHz reference.

A combination of wide bandwidth, fine frequency resolution and a three-wire, high speed serial interface permits direct phase and frequency modulation of the VCO. This capability supports any constant envelope or continuous phase modulation, meaning any analog FM or digital FM, and can eliminate the

[Continued on page 186]

Conexant Systems Inc.
Nepean, Ontario, Canada



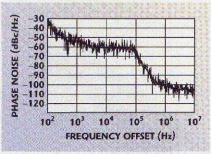
▲ *Fig. 1 The CX72302 block diagram.*

need for in-phase and quadrature digital-to-analog converters, quadrature upconverters and IF filters from the transmitter portion of the system. ***Figure 1*** shows the CX72302 IC's block diagram.

PERFORMANCE SPECIFICATIONS

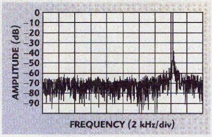
The CX72302 synthesizer is designed to operate over a –40° to +85°C temperature range from a 3 V DC supply and consumes 51 mW (typ). Under power down operation the device draws typically 10 μA of current. The main VCO output frequency range is from 800 MHz to 6 GHz, while the auxiliary VCO output has a range of 400 to 1100 MHz. The reference oscillator's frequency can be up to 50 MHz. The main fractional-N tuning step size is $F_{ref\_main}/2^{16}$ or $F_{ref\_main}/2^{8}$ (Hz), while the auxiliary step size is $F_{ref\_aux}/2^{10}$ (Hz). Both the main and auxiliary phase detectors have a maximum operating frequency of 25 MHz. The charge pump output source current is in the range of 125 to 1000 μA, and the sink current is –125 to –1000 μA. The synthesizer's phase noise within the loop bandwidth is –128 + 20log(N)

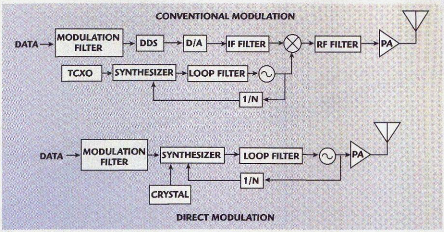
[Continued on page 188]



▲ *Fig. 2 The synthesizer's typical phase noise characteristics.*

Fig. 3 The synthesizer's spectral purity at 5.185 GHz. ▼





▲ *Fig. 4 Direct modulation vs. conventional modulation.*

(dBc/Hz), while the total spurious power is –70 dBc. ***Figures 2*** and ***3*** show the device's typical phase noise and close-in spectral purity, respectively. The CX72302 synthesizer is supplied in a 28-pin EP-TSSOP plastic package that measures 9.7 × 6.4 × 1.1 mm high and is designed for surface mounting to a PCB.

APPLICATIONS

The CX72302 dual fractional-N frequency synthesizer is part of a family of similar devices that includes the CX72300 (2.1 GHz) and CX72301 (1.1 GHz) synthesizers. The CX72302 device is targeted for wireless local loop (WLL) and wireless local area network applications, as well as local multipoint distribution system, multichannel multipoint distribution system and microwave radio applications. Its features are particularly useful in providing direct digital modulation that significantly simplifies a communications transmitter by eliminating D/A converters, RF and IF filters, mixers, buffer amplifiers and costly temperature-controlled crystal oscillators. ***Figure 4*** shows an example of a simplified transmitter block diagram utilizing the CX72300-series synthesizer as a direct digital modulator. The other two models in the family are targeted toward two-way radios and pagers (CX72301) and multimode cellular phone satellite handsets, tuners, receivers and 3G/cellular/PCS base station applications (CX72300).

CONCLUSION

A 6 GHz dual fractional-N frequency synthesizer IC is now available that features ultra-fine step sizes, a high reference frequency, low phase noise, and fast switching and settling times. The new device can greatly simplify a digitally modulated transmitter by implementing direct digital modulation, and its use of an on-chip crystal oscillator significantly reduces component cost and system complexity. Additional information on this device and others in the synthesizer family may be obtained from the company's Web site at www.conexant.com.

Conexant Systems Inc.,
Nepean, Ontario, Canada
(613) 274-0922.

Circle No. 303

Multistage Depressed Collector Klystrons

Finding ways to operate satellite communications (SATCOM) high power klystrons more efficiently has a double-edged benefit. The SATCOM transmitter uses less prime power, saving uninterruptible power supply capacity, and the klystron runs cooler, significantly improving its reliability. The multistage depressed collector (MSDC) high power klystron has been specifically designed for SATCOM uplink applications and features a collector efficiency of 60 percent or greater. This improved efficiency permits a prime power savings of two to three kilowatts when operating at full power. For low operating powers under clear-sky conditions, the prime power savings could amount to five to six kilowatts.

Fig. 1 MSDC prime power savings.

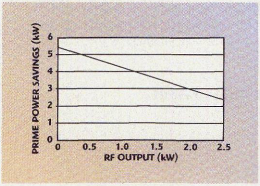


Figure 1 shows the prime power savings vs. RF output power of the MSDC klystron compared to a standard klystron design. Since most klystrons operate at low RF operating powers for intermodulation consideration, the MSDC has the capability to provide maximum savings at the most likely set of operating conditions. Thus, the MSDC tube runs cooler with the potential of a longer lifetime than its standard klystron cousins.

MSDC klystrons have been developed for both C- and Ku-band commercial satellite service and feature a small, compact design and a four-stage depressed collector configuration specifically intended for satellite earth station use. Utilizing collector depression the collector heat dissipation is much reduced, thus lowering the required air flow for cooling. This reduced air flow permits the use of smaller AC power systems, especially in hot, humid environments. Lower collector temperatures are key to enhancing the klystron's lifetime.

[Continued on page 192]

COMMUNICATIONS & POWER INDUSTRIES CANADA INC.
(CPI CANADA)
Georgetown, Ontario, Canada

TABLE I

MSDC KLYSTRON TYPICAL CHARACTERISTICS

Model	VKC2503B	VKC2500B	VKU2501B	VKU2502A
Frequency range (GHz)	5.850 to 6.425	5.725 to 6.725	13.75 to 14.50	12.75 to 13.25
Instantaneous bandwidth (MHz)	45	45	85	85
Output power (W)	3350	3350	2500	2500
Gain (dB)	41	41	49	49
Beam voltage (kV)	8.7	8.7	8.6	8.6
Beam current (A)	1.09	1.09	1.06	1.06
Body current (mA)	5	5	7	7
Heater current (A)	6.1	6.1	4.2	4.2
Heater voltage (V)	6.0	6.0	6.5	6.5

Table 1 lists the various MSDC klystron models and their typical operating characteristics. Both the C- and Ku-band klystrons are mounted with the collector up and use permanent magnet focusing. The C-band klystrons' RF input connector mates with a type-N plug, YG-21 D/U or equivalent, and the RF output connector is a CPR 137 waveguide flange. The Ku-band units' RF input and output ports mate with UG-419/U waveguide flanges. All models require external air flow cooling.

Communications & Power Industries Canada Inc. (CPI Canada), Georgetown, Ontario, Canada (905) 877-0161.

Circle No. 301

A High Power LDMOS Transistor for Broadcast Transmitter Applications

Digitization in the broadcast world is paving the way for major new markets, such as high speed Internet access and mobile multimedia in-car entertainment, as well as high definition TV and a huge expansion in program choice. With standards now in place, as well as an increasing number of commercial services and rapidly maturing technology, broadcasters and service providers are keen to push forward the move to digital transmission. A unique ultra-high frequency (UHF) power lateral double-diffused metal-oxide semiconductor (LDMOS) transistor has been developed that cuts the cost of upgrading terrestrial transmitters for digital operation.

Digital technology enables terrestrial broadcasters to simultaneously increase revenues and reduce costs; however, transmitter equipment first must be adapted. The key requirement is sufficient RF power — a need addressed directly by the model BLF861 power LDMOS transistor. Designed specifically for terrestrial transmitters, this new device offers greatly improved output power and gain over existing bipolar technology, dramatically reducing the number of amplifiers required and significantly reducing the cost per watt of output power for transmitter manufacturers.

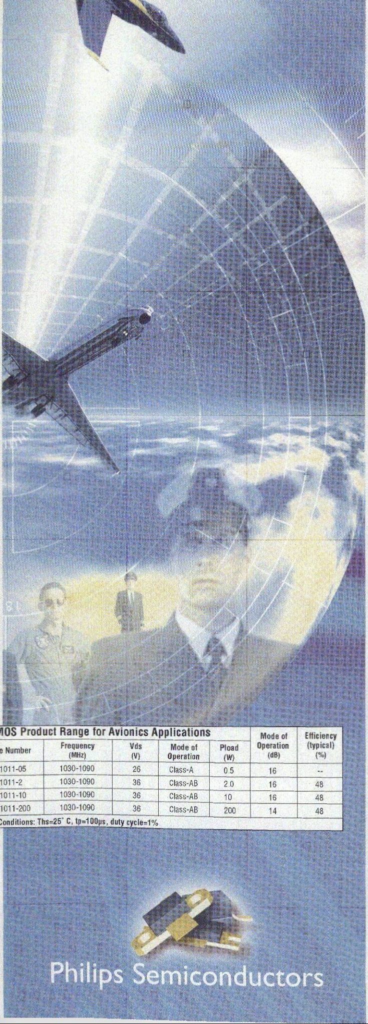
The BLF861 transistor also provides excellent ruggedness and linearity. In addition, unlike competing devices the unit covers the entire spectrum of bands IV/V, which are used for TV transmission worldwide (470 to 860 MHz). This unique feature allows transmitter manufacturers to offer maximum flexibility for service providers, with transmission capability for all broadcast channels. Overall, the BLF861 transistor's many advantages meet all transmitter manufacturers' needs for reliable, cost-effective solutions. Currently, the BLF861 is in volume production and is being used by major broadcast transmitter manufacturers.

PRODUCT PERFORMANCE

The BLF861 device uses the company's LDMOST technology, which utilizes gold metallization for reliable performance. Due to the nature of LDMOST, no insulator is required; therefore, toxic materials (such as BeO) are not used.

[Continued on page 201]

Philips Semiconductors
Eindhoven, The Netherlands



LDMOS Product Range for Avionics Applications

Type Number	Frequency (MHz)	Vds (V)	Mode of Operation	Pload (W)	Mode of Operation (dB)	Efficiency (typical) (%)
BLA1011-05	1030-1090	26	Class-A	0.5	16	--
BLA1011-2	1030-1090	36	Class-AB	2.0	16	48
BLA1011-10	1030-1090	36	Class-AB	10	16	48
BLA1011-200	1030-1090	36	Class-AB	200	14	48

Test Conditions: Ths=25° C, tp=100μs, duty cycle=1%

Golden Innovations in LDMOS Transistors for Avionics

Philips Semiconductors, one of the world's leading manufacturers of LDMOS transistors, offers the world's first complete line up of LDMOS parts designed and tested for **Avionics** applications.

The use of Philips Semiconductors LDMOS transistors in **Avionics** amplifiers improves design architecture by reducing the number of transistors and surrounding circuitry, which leads to overall cost savings.

PHILIPS

Philips LDMOS transistors show an excellent thermal behavior, and an all-gold metallization system ensures superb reliability. LDMOS transistors from Philips Semiconductors also ensure device consistency in large volume production by using automated die attach and wire bonding equipment.

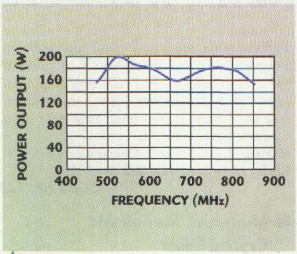
Plus, with a dedicated RF/microwave business group, local market resources, and the largest RF inventory in the world, Avnet Electronics Marketing is uniquely positioned to be your source for LDMOS transistors.

Call Avnet Electronics Marketing to learn more about using Philips Semiconductors LDMOS transistors in pulsed **Avionics** applications, **1-800-332-8638.** Or visit the Avnet Electronics Marketing gateway page at **www.em.avnet.com/rfm/avionics.html**.

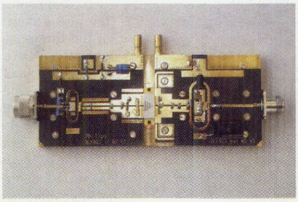
AVNET® electronics marketing

MORE POWER TO YOU

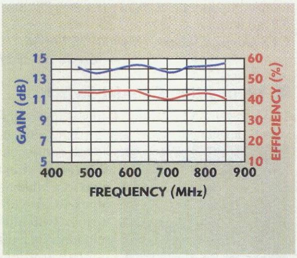
CIRCLE 143 ON READER SERVICE CARD



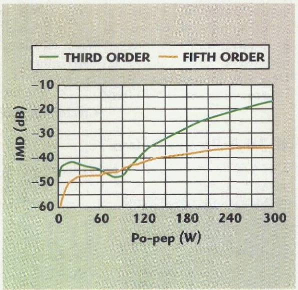
▲ *Fig. 1 Output power over the UHF band.*



▲ *Fig. 2 The broadband test circuit.*



▲ *Fig. 3 Gain and efficiency over the UHF band.*



▲ *Fig. 4 IMD performance at 860 MHz.*

The BLF861 transistor was designed specifically for band IV/V UHF transmitter applications, thus placing severe pressure on the transistor design to achieve real broadband performance. By applying internal input and output matching, the broadband performance is realized. Furthermore, the target was to achieve an output power of at least 150 W in CW operation. ***Figure 1*** shows the unit's output power over the entire UHF band. ***Figure 2*** shows the broadband circuit used with the BLF861 device to achieve the described performance. Apart from output power, other important requirements for an RF power transistor for TV transmitters are efficiency, gain (shown in ***Figure 3***) and intermodulation distortion (IMD) (shown in ***Figure 4***).

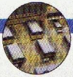
THE NEXT STEP

The BLF861 transistor demonstrates exceptional performance for UHF transmitters. However, another RF power LDMOS transistor, the model BLF861A, is being introduced for two compelling reasons. First, LDMOST technology development is an ongoing process that leads to significant improvements. One of these major improvements is the I_{dq} drift reduction — a well-known phenomenon related to LDMOST devices. New process improvements have significantly reduced this I_{dq} drift. Second, the device's ruggedness was able to be further improved. The existing BLF861 is able to withstand mismatch conditions of an SWR of 10. However, there may be failure situations in a transmitter where abrupt source/load mismatch conditions occur (for example, a disconnected antenna). The new BLF861A device can withstand these source/load failures under full power conditions for a short period of time with no thermal damage. This feature has been implemented using an extra process change.

From an applications point of view, the differences between the BLF861 and BLF861A are minimal. This means that the BLF861A transistor can be substituted in a BLF861 application with only minor changes. The company is now in the process of industrializing the BLF861A device and plans to start volume production in December.

Philips Semiconductors,
Eindhoven, The Netherlands
(800) 234-7381 (US)
or +31 40 27 82785.

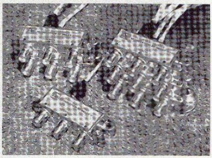
Circle No. 304



NEW PRODUCTS

COMPONENTS

SPDT RF Relay



The model RF 2X1 SPDT RF relay is designed for remote switching of VHF signals. The unit provides high isolation and low loss in the frequency range from DC to 900 MHz, and isolation is approximately 60 dB with an insertion loss of approximately 0.5 dB. The switch is ideal for broadband or IF control switching in cable and wireless systems. Three F connector ports are mounted on one side for ease of connection and placement. Eight-foot leads are provided for control voltage, and the power requirement is 30 mA at 12 V DC (approximately 300 mW).

Alaun Electronics,
La Canda, CA (888) 810-0333.

Circle No. 216

SP6T Radial Solid-state Switch

The model SWN-1140-6DR-DEC-SP reflective SP6T radial solid-state switch works from

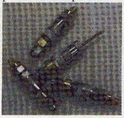
0.5 to 18.0 GHz with an insertion loss of < 1.0 dB (typ) at 0.5 GHz and < 2.45 dB at 18.0 GHz. Video transient is < 320 mV at 300 MHz bandwidth and < 100 mV at 20 MHz bandwidth. SWR is better than 2, and isolation is ≥ 90 dB at 0.5 GHz and ≥ 40 dB at 18 GHz. Switching speed is < 60 ns delay ON and < 40 ns delay OFF. Supply voltages for the switch are +5 V at 31.3 mA and –12 V at 44 mA. Weight: 2.0 oz. (typ). Size: 1.25" × 1.25" × 0.4".

American Microwave Corp. (AMC),
Frederick, MD (301) 662-4700.

Circle No. 217

SMA Phase-adjustable Adapters and Connectors

The Coaxicom 3993 phase adjusters offer a precise and simple means of phase adjustment

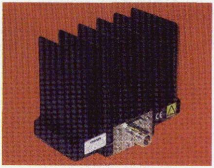


over frequency ranges up to 18 GHz. A phase adjustment nut that is locked into place after setting provides the user with incremental changes in electrical length at 10°/GHz. The series is offered as an in-line adapter or as a direct solder SMA plug for semirigid cable. All models can also be specified for 4.0, 8.0 or 12.4 GHz operation. The units eliminate cable trimming and allow phase matching to be done at the final production stages. The 3993-1 adapter operates to 18 GHz, with an adjustment range of 180° (min) and a maximum SWR and insertion loss of 1.30 and 0.42 dB, respectively. The 3993A adapter operates at 4 GHz with an SWR of 1.10 (max) and an insertion loss of 0.2 dB. The 3993-2 and 3993-3 phase-adjustable connectors have SMA plugs for 0.141" and 0.086" semirigid cables, respectively. Their performance is essentially the same as the adapters.

Coaxial Components Corp.,
Islandia, NY (800) 583-9954
or (631) 234-4447.

Circle No. 220

High Power Termination

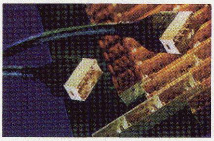


The model 150-WT-FN high power termination was designed utilizing thermal imaging photography to ensure even heat distribution. It offers a power rating of 150 W (avg) at 25°C and an impedance of 50 Ω (nom). The frequency range and SWR are DC to 1 GHz at 1.10 (max) and 1 GHz to 2.4 GHz at 1.25. N female connectors are included, and the operating position is horizontal or vertical. Size: 4.850" × 5.400" × 4.30". Weight: 2.5 lb.

BCP (Bird Component Products),
Largo, FL (727) 547-8826.

Circle No. 219

Mini Coax Connector System



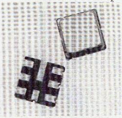
The har-pak® mini coax connector system is a high contact density modular connection system using cutting-edge back plane wiring techniques. Excellent crosstalk characteristics make the connectors ideal for many applications in the wireless telecom market. Noted for its rugged, compact board-to-board interconnections, the system is flexible and can accommodate a wide variety of cable assemblies, such as SMA, SMB and N-type. The modules are available in various sizes, offering two to 10 coax lines per module. Both the straight and angled connectors feature blind mating board-to-backplane RF connection and are press-fitted with flat rock tooling. The system also features board-to-cable RF interconnection and float plate solutions for blind mating of heavy subassemblies. Price: $28 (100).

Harting Inc. of North America,
Elgin, IL (877) 741-1500.

Circle No. 223

Miniature Monolithic Crystal Filter

The model ATFN6024A monolithic crystal filter offers a miniaturized package size that does



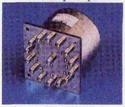
not compromise the performance of the three-pole crystal filter housed within. It is specifically designed for use in multimode phone, digital TDMA, two-way radio and telecommunications infrastructure applications. In addition, the filter offers increased functionality and operates in the 73 to 135 MHz frequency range. It can be customized to operate at higher frequencies. Size: 3.8 × 3.8 mm.

CTS Corp., Elkhart, IN (800) 757-6686.

Circle No. 221

14-position Coaxial Switch

The model 5E1J-5808 14-position coaxial switch developed specifically for the automat-



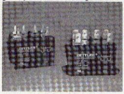
ed test equipment market is best used as a building block to provide various switching solutions. Its most typical applications are switch matrices and switchable filter banks. The SP14T switch is normally open and has an operating voltage of 24 V DC over the DC to 13 GHz (upgradable to 18 GHz) frequency range. SWR is 1.6, insertion loss is 1.6 and isolation is 50 dB (min).

Dow-Key Microwave Corp.,
Ventura, CA (805) 650-0260.

Circle No. 222

30 A Power Relays

The AZ2700 series power relays have the capacity to handle up to 8310 VA plus 4 kV di-



electric, making them ideal for a wide variety of applications from HVAC to UPS systems to microwave ovens. Mounting options include PCB, E bracket, screw and panel mount. Connections are PCB or 0.250" quick-connect. Price: $3.79 (1000).

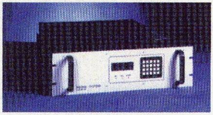
American Zettler Inc.,
Aliso Viejo, CA (949) 831-5000.

Circle No. 218

[Continued on page 204]

NEW PRODUCTS

Solid-state Matrix Switch



The model 12321 32 × 32 output solid-state matrix switch features a DC to 24 MHz frequency bandpass, crosspoint verfication, and RS 232C and IEEE-488 interfaces. Typical applications of the non-blocking full fanout switch include routing NTSC video, HF antenna switching and automatic testing. Size: 5.25" × 19.00" × 25.00".

Matrix Systems Corp.,
Calabasas, CA (818) 222-2301.

Circle No. 226

Low Cost Coaxial Power Interconnect

The PowerDirect™ low cost coaxial power interconnect delivers high currents as close to the integrated circuit as possible. The new power distribution architecture provides an extremely low inductance and resistance path from the power source to its destination. The current carrying capacity is 50 A, providing transients (slew rates) as high as 400 A/µs with a minimal required board area of only 0.11 square inches. PowerDirect technology combines a high performance coaxial interconnect with an optimal PCB layout pattern to provide a cost-effective solution for power delivery directly to high performance semiconductor devices. Benefits include low PCB surface and interplane area and improved PCB routability. There are several interconnect methods for the PowerDirect including plate-through-hole screw and surface-mount technology.

INCEP Technologies Inc.,
San Diego, CA (858) 547-9925.

Circle No. 224

50 and 75 Ω Rotary Step Attenuators

The models MDC2017 (50 Ω) and MDC2717 (75 Ω) rotary step attenuators offer the user a selection of frequency coverage, step size and dynamic range. Dual concentric attenuators are also available, where the outer control knob steps in either 0.1 or 1.0 dB steps, depending on the model. All units are available for panel mounting, or two or more units can be supplied cascaded for bench-top operation. Connector options include SMA, N, BNC, TNC and F (75 Ω units only).

MIDISCO,
Islandia, NY (800) 637-4353.

Circle No. 228

Japanese Band CDMA Duplexer

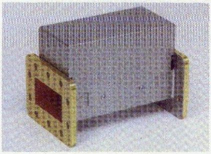
The model WSD-00179 high performance Japanese band CDMA duplexer offers low insertion loss and excellent selectivity in a small size. It is configured with a transmit passband of 832 to 870 MHz and a receive passband of 887 to 925 MHz, and features 1.5 dB (max) insertion loss and 15 dB (min) return loss within each passband. The unit offers channel-to-channel isolation of 70 dB (min), with transmit-to-antenna rejection of 20 dB (min) from

[Continued on page 206]

NEW PRODUCTS

DC to 810 MHz, 70 dB (min) from 887 to 925 MHz and 50 dB (min) from 925 to 2775 MHz. Antenna-to-receive rejection is 70 dB (min) from DC to 870 MHz and 50 dB (min) from 1000 to 2775 MHz. Applications include filtering for pico, micro and macrocell base station installations, and general-purpose handset or equipment test systems. Size: 4.65" × 4.20" × 2.75", excluding type N-F connectors.
K&L Microwave Inc.,
Salisbury, MD (410) 749-2424.
Circle No. 225

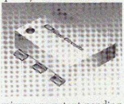
International C-band Bandpass Filter



The model 11383 international C-band waveguide bandpass filter is installed between a television receive-only feedhorn and the low noise amplifier or low noise block to suppress strong out-of-band interference caused by marine or airport radar systems. The filter has an insertion loss of 0.5 dB (typ) at the center frequency and 1.25 dB (max) (1.0 dB typ) at 3.6 and 4.2 GHz. Suppression is 25 dB (min) at 3.55 and 4.25 GHz. The flanges are rectangular CPR229G (grooved) and CPR-229F (flat). The unit measures 5.375 inches long (flange to flange) and is also available in lightweight aluminum construction (model 11383AL).
Microwave Filter Co. (MFC),
East Syracuse, NY (800) 448-1666
or (315) 438-4700.
Circle No. 227

Ultra-thin Frequency Mixers

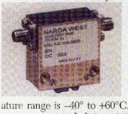
The model ADE-1MH ultra-thin 0.108" frequency mixers cover the 2 to 500 MHz frequency band. At midband, the mixers have low 5.2 dB conversion loss (typ) and good 50 dB L-R, 45 dB L-I isolation (typ). The mixers are patent-pending and level 13 (LO). Price: $5.95 each (10–49).



Mini-Circuits,
Brooklyn, NY (718) 934-4500.
Circle No. 229

Low Intermodulation Isolator

The model INA-0808 isolator operates over the 869 to 894 MHz frequency range with an insertion loss of 0.2 dB (max), isolation of 25 dB (min) and SWR of 1.2 (max). Intermodulation is < –110 dBc and the operating temperature range is –40° to +60°C. SMA female connectors are provided. Size: 1.50" × 1.50" × 0.75".



Narda–an L-3 Communications company,
Folsom, CA (916) 351-4550.
Circle No. 231

Miniature Transformers

This new family of miniature RF transformers is available in a variety of impedance ratios and operates over wide frequency bandwidths from 500 kHz to 1.5 GHz while maintaining a flat frequency response. These small, surface-mount transformers are used to match impedances, step-up/step-down voltages and create DC isolation, as well as convert the circuit from balanced to single ended. The miniature package makes these transformers ideal for space-constrained RF applications, including cable modems, set-top boxes, wireless and cable network infrastructure equipment, and other high frequency communication systems and Internet devices. The transformers are available with and without centertaps in both DC-isolating and non-DC-isolating configurations. Size: 0.15" × 0.15" (3.81 × 3.81 mm). Price: 99¢ (10,000).

Pulse, San Diego, CA (858) 674-8100.
Circle No. 232

[Continued on page 208]

NEW PRODUCTS

IMD-free Diplexer

The model W1840D diplexer was designed free of intermodulation distortion (IMD). Standard dual +43 dBm input signals produce less than –140 dBc of IMD. The unit covers full PCS bands with < 1.2 dB insertion loss. Band centers RX/TX isolation is > 90 dB. Return loss on the W1840D is > –16 dB and power capability is > 50 W. SMA or type-N connectors are available. Size: 2.0" × 2.0" × 9.0".

Wireless Technologies Corp., Springdale, AR (501) 750-1046.

Circle No. 239

Single Junction Isolators

These isolators are designed for high performance, AMP, GSM, DCS 1800 and PCS 1900 frequency bands, and provide better than 25 dB isolation, < 0.25 dB insertion loss and 25 dB (min) return loss over the –10° to +85°C temperature range. The units are ideal for use in base station combiners, amplifiers and other filter subsystems, and can handle up to 70 W reverse power. They are designed using strip line technology and have a solid body with a screwed-in lid. Designs are free of NdFeB magnets. Large quantities are available on short notice and at competitive prices.

SDP Components Inc., Pointe-Claire, Quebec, Canada (514) 428-8749.

Circle No. 233

Bulk Cable Products

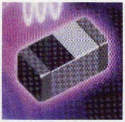
The Vital Links™ series flexible cables offer a wide range of options specifically designed to provide extra performance margins for applications with demanding specifications. The DB and SI series are an economical performance upgrade over standard RG178, RG316 and RG142 cables. The SW series is a cost-effective, microporous PTFE cable group offering much better flexibility and performance than solid TPFE cables. The KW series is a flexible, high power and ultra-low loss cable group. KW800 has a loss factor of only 2.2 dB/100 feet at 1 GHz and can be formed by hand into a four-inch-diameter loop without using special mandrels or bending apparatus. The HP series offers excellent SWR performance and low loss for applications up to 50 GHz.

Semflex Inc., Mesa, AZ (800) 778-4401.

Circle No. 235

Multilayer Chip Inductors

The HK series high Q-value multilayer chip inductors reduce EMI, increase battery life and improve overall efficiency in cell phones, pagers, notebook PCs and other products employing high frequency circuits. The inductors also feature 100 percent silver internal conductors, advanced dielectric ceramics and unique fabrication techniques to achieve superior price/performance characteristics in small case sizes. They offer extremely low DC resistance values, from 0.04 to 1.10 Ω (typ). The series is surface mountable and available on tape and reel for high speed manufacturing. Price: 3¢ to 8¢ per piece (depending on part) in OEM quantities.

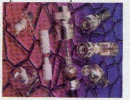


Taiyo Yuden (USA) Inc., Schaumburg, IL (847) 925-0888.

Circle No. 238

RF Coaxial Connectors

This line of C-series coaxial connectors handles up to 3000 V peak and is designed for high voltage semiconductor, wafer processing, sputtering and research applications. The connectors feature overlapping Teflon dielectrics to provide a longer electrical leakage path,



[Continued on page 210]

which allows them to handle up to 3000 V peak. Male and female designs for both semi-rigid and flexible cables are available in straight, right-angle and bulkhead configurations. Manufactured in accordance with MIL-STD-348 and MIL-C-39012 specifications, the connectors can be made with TruLustre, silver- or nickel-plated brass or aluminum shells, and silver- or gold-plated brass, phosphor bronze or beryllium-copper center conductors. Price: $19.95 each, depending upon configuration and quantity.

Tru-Connector Corp., Peabody, MA (800) 262-9878 or (978) 532-0775.

Circle No. 237

■ High Power Stripline Mountable Circulators

These high power, low loss tab-mount circulators and isolators designed to protect solid-

state circuits are available over a 10 percent minimum bandwidth in the 1 to 3 GHz frequency range. Various models cover IFF, PCS and radar bands. The units are rated at 300 W CW and 3 kW peak power, and typically provide greater than 20 dB isolation, 0.2 dB loss and 1.25 SWR. SMA connectors are an option. Size: 1.25" × 1.33" × 0.75".

UTE Microwave Inc., Asbury Park, NJ (732) 922-1009.

Circle No. 266

■ High Frequency Coaxial EMI Filters

The dual-polar series solder-in style high frequency coaxial EMI filters are available in C-

and L-sections and offer EMI suppression from 1 MHz to 10 GHz. They are ideal for the satellite construction market, for high volume usage in test and measurement equipment and for microwave repeater applications. The dual C- and L-section filters replace two individual filters, decreasing the size and weight of the systems in which they are used, thereby reducing overall costs. The series meets MIL-PRF-28861 standards and is offered with a working voltage of either 50, 100 or 200 V DC and a minimum capacitance of 10,000; 2700 and 5000; or 100, 500 and 1000 pF, respectively. Price: $3 to $5 (1000).

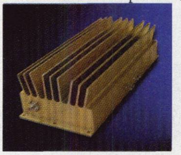
Sierra-KD Components, Carson City, NV (775) 887-5700.

Circle No. 236

AMPLIFIERS

■ S-band, Solid-state RF Amplifier

The model SSPA 2227-80 high power, S-band, solid-state RF amplifier (SSPA) covers in



excess of 500 MHz of bandwidth from 2.2 to 2.7 GHz. This class AB SSPA offers greater than 30 dB of gain and a minimum of 70 W across the band. Typical output power from 2.3 to 2.7 GHz is greater than 100 W. The amplifier offers 35 percent efficiency (typ) across the band with a noise figure of < 5.0 dB. Input/output SWR is better than 2.0, and the unit operates from+12 V DC over a –40° to +85°C temperature range. Size: 4.00" × 8.25" × 2.50".

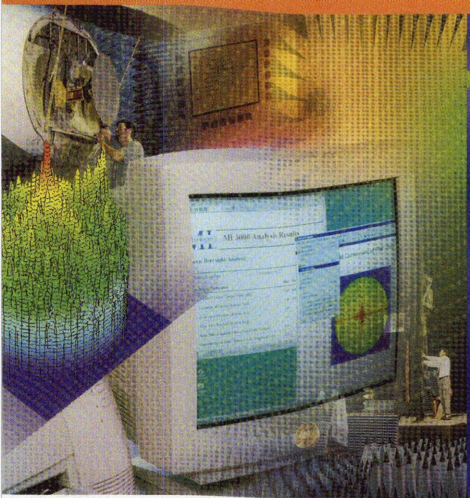
Aethercomm Inc., San Marcos, CA (760) 598-4340.

Circle No. 240

■ 3 V GaAs PA Driver Amplifier

The model RF2367 low noise CDMA/TDMA/GSM PA driver amplifier has a frequency range of 150 to 2500 MHz and is optimized for operation in the DCS and PCS bands for applications where low transmit noise power is of concern. In addition to its use as a DCS/PCS driver amplifier, the new IC can also be used for a variety of applications including WLAN or other wireless systems in the

[Continued on page 212]



NEW PRODUCTS

2.4 GHz ISM band. Operating from a single 3 V power supply, the RF2367 features adjustable bias current, a high intercept point and power down control. The device's performance at 1880 MHz includes 21.5 dB gain, +24 dBm ouput IP3 and 2.2 dB noise figure.
RF Micro Devices, Greensboro, NC (336) 664-1233.

Circle No. 241

ANTENNAS

■ Indoor/Outdoor Antenna

The model DB794CM5N-KU indoor/outdoor ceiling-mount, single-monopole, corner reflector antenna features high directional gain with reliable coverage of up to three bands, including GSO1800, PCS1900 and UMTS frequencies in the 1710 to 2200 MHz range. The antenna was specifically designed for high capacity pedestrian venues that require reliable mass voice and/or data communications. Typical applications include walkways, concert halls and convention centers. Its light weight and compact size allow the DB794CM5N-KU to be inconspicuously situated indoors with minimal disruption to its surroundings. Weight: 0.5 lb. Size: 5.0" × 5.0" × 5.0".
Decibel Products, Dallas, TX (214) 631-0310.

Circle No. 242

■ High Gain Directional Panel Antenna

The model PCW24-01518-BFL 18 dBi panel antenna covers the 2.4 to 2.5 GHz frequencies and provides 15° of horizontal and vertical beamwidth. Size: 15.75" × 15.75" × 4.00".
HD Communications Corp.,
Systems Group, Ronkonkoma, NY (631) 588-9661.

Circle No. 265

■ Microwave Heater Horn

The model 0023-800 high power horn for use in industrial microwave process heating operates at 2450 MHz and features a special throat

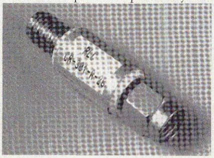
geometry that creates waveguide modes for very uniform near-field power density. In use, materials to be heated or dried are placed a short distance from the horn aperture and heating occurs much more uniformly than with a standard horn, eliminating hot spots and optimizing process control. The 0023-800 is designed for sample dimensions up to 12" square, though other sample dimensions can be accommodated on order. SWR is 1.08 (max).
Seavey Engineering Associates Inc.,
Pembroke, MA (781) 829-4740.

Circle No. 234

DEVICES

■ Miniature Ultra-flat Schottky Detectors

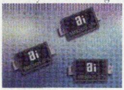
These miniature ultra-flat detectors utilize a zero-bias Schottky design. The microwave power is coupled directly to the extremely small compo-



nents, reducing package parasitics and transition mismatches. The design results in a very low SWR and a flat, smooth output over a wide bandwidth. Options available include negative or positive output, choice of three output connectors and operation to 26.5 GHz. The detectors operate over a 0.01 to 18.5 GHz frequency range with 100 mW input power

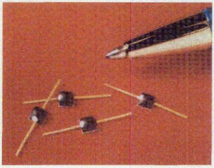
(max). The operating temperature range is –55° to +100°C with video resistance of 5000 Ω (nominal).
RLC Electronics Inc.,
Mt. Kisco, NY (914) 241-1334.
Circle No. 244

■ Low Capacitance, High Voltage Schottky Diode



The model SMS3925-079 40 V, 0.6 pF RF Schottky diode is designed for use as a level detector in wireless handsets and for general-purpose switching applications. It is packaged in the surface-mount miniature SC-79 package, and is designed for low cost, high volume applications. Price: 17¢ (100,000).
Alpha Industries,
Woburn, MA (781) 935-5150.
Circle No. 243

■ Detector



The model STZ500 detector for telecommunications and wireless applications operates over the 0.01 to 18.0 GHz frequency range. It has a positive output polarity and a video load of ≥ 1 MΩ. In addition, the STZ500 handles an input range of 0 to 20 dBm over a temperature range of –55° to +125°C.
Signal Technology California Operation,
Sunnyvale, CA (408) 773-3744.
Circle No. 245

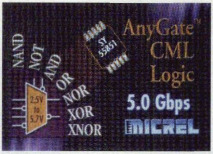
HARDWARE

■ Crimp Tools

The models CT-400/300 and CT-240/200/100 crimp tools are designed to work with LMR® cables size 400 and smaller. The CT-400/300 works with all LMR-400 and LMR-300 cables and crimp-style connectors while the CT-240/200/100 is compatible with all LMR-240, LMR-200 and LMR-100 cables and crimp-style connectors. Crimp dies are integral with both tools. LMR cables are flexible, non-kinking low loss RF transmission line cables that utilize easy-to-install connectors and are suitable for use as antenna feeders, system jumpers and interconnects.
Times Microwave Systems,
Wallingford, CT (203) 949-8424.
Circle No. 246

INTEGRATED CIRCUIT

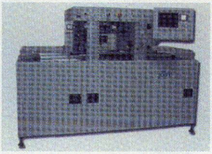
■ Common Mode Logic IC



The model SY5581 AnyGate™ Common Mode Logic (CML) IC can be configured as any of the nine most common two-input logic functions, providing unparalleled flexibility for designers of ultra-high speed systems. It is capable of being configured as either AND, NAND, OR, NOR, XOR, XNOR, DELAY, NEGATION or 2 MUX. Operating from a wide voltage range of 2.3 to 5.7 V, the outputs are guaranteed to toggle to at least 2.5 GHz. The part uses CML logic levels for all I/Os and is compatible with legacy PECL and LVDS interfaces. Price: $10.80 (1000+). Delivery: stock to eight weeks (ARO).
Micrel Inc., San Jose, CA (408) 944-0800.
Circle No. 247

PROCESSING EQUIPMENT

■ Integrated Assembly and Manufacturing System



The model 7323 integrated assembly system provides a comprehensive all-in-one solution for the precision manufacturing of microdisplays and liquid-crystal displays (LCD). With LCD dimensions as large as 2" square, it is well suited to the manufacturing of personal and projection microdisplays and LCDs for personal electronics displays, wearable computers, head-mounted displays and mobile phones. By performing parallel operations, the system produces throughputs as high as 250 units per hour (material presentation and process dependent). The 7323 tightly integrates tacking, alignment, bonding and unloading operations. Designed for use as either a complete standalone production cell or as part of an overall automated production environment, the system uses a flexible Windows NT®-based programming and control environment.
MicroJoin, Poway, CA (858) 877-2100.
Circle No. 249

[Continued on page 214]

NEW PRODUCTS

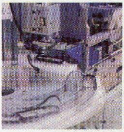
■ Solder Stencil Capability for PCB Production

A solder stencil capability has been added to the company's environmentally friendly systems for the production of prototype circuit boards. Stencils ensure the application of precisely defined amounts of solder paste to PC boards for optimum SMD connections, replacing compressed air techniques that often result in bubbles and bridges. A typical stencil can be produced in less than 10 minutes, which allows it to be used for short run prototyping work in design labs. Stencils accommodate pads as small as 10 mils in diameter with a minimum pitch of 20 mils between pad centers. Stencil thickness can be selected in the range from 3 to 5 mil. To complete the assembly, a ZelFlex stretching frame is included to mount the stencil for precise positioning. A low cost pick-and-place system is also available to automate component assembly.

LPKF Laser & Electronics,
Wilsonville, OR (800) 345-5753.

Circle No. 248

■ Automated Installation System



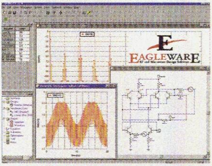
The CRESCENDO™ installation system is designed for automatic, rapid and accurate installation of CORE-SHIELD® EMI gaskets. It is intended for high volume application of EMI shielding gaskets, protective acoustic covers and thermal interface products used in hand-held portable devices. The system is the fastest technique available for EMI gasket application, with installation rates of up to 12 cycles per minute. With a compact design, it can be integrated with automated assembly lines to minimize or eliminate labor content.

W.L. Gore Associates,
Newark, DE (302) 738-7880.

Circle No. 258

SOFTWARE

■ Harmonic Balance Simulator



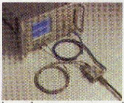
The HARBEC harmonic balance nonlinear simulator allows the designer to specify any number of fundamental tones for analysis and to co-simulate EM, linear and nonlinear circuits. The engine also uses artificial intelligence techniques to find and incorporate the best convergence strategy. In the GENESYS design environment, EM, linear and nonlinear circuit co-simulation is nearly transparent. Behind the scenes, GENESYS automatically recognizes the lumped components, removes them, adds internal ports and runs the EM simulation. The multiport data are transparently included in a circuit theory simulation. Once the initial design is complete, the lumped components can be interactively tuned or automatically optimized at high speed. This capability brings the accuracy of EM simulation to the design of nonlinear circuits. Price: $4990.

Eagleware, Norcross, GA (678) 291-0995.

Circle No. 250

■ Guided Scalar Measurement Software

This guided scalar measurement software allows the 6800 series scalar and system microwave analyzers to be configured so that unskilled operators can simply and precisely perform complex or repetitive measurements. It allows the instruments to be customized for short-run production measurements on components, assemblies and subsystems, for cable and waveguide installation measurements in aircraft and ships and for radio link feeder test-



ing. The software also allows for sensitive measurement parameters, such as frequency, to be suppressed. Once set up, the software uses a series of screens to guide the operator in: selecting the pre-defined measurement or test such as insertion loss, return loss or fault location; setting the relevant measurement options for accessories; calibrating the instrument; connecting the device under test; and carrying out the desired measurement. Price: $990.
IFR Systems Inc.,
Wichita, KS (800) 835-2352
or (316) 522-4981.

Circle No. 251

■ RF Analysis Software

SpurFinder 2.02 helps a designer to evaluate various frequency conversion schemes and provides a quick idea of the pre-selection and post-selection filter rejection requirements for the conversion scheme. It also draws a mixer spur chart showing the output frequencies of all mixer spurious products for a given range of frequencies. The latest version includes many improvements, such as the new Slider Bar, which lets the user slide a cursor across the input frequency range, and a table displays the output mixer spurious products and their frequencies in real time. The designer can also use this program to pick the conversion scheme with the best spurious performance. Price: $129 or $29 for an upgrade to Version 2.
R.A. Wood Associates,
Utica, NY (315) 735-4217.

Circle No. 252

SOURCES

■ Miniature OCXOs

The 270 double oven controlled crystal oscillator (OCXO) series rivals rubidium clock performance and drops into a standard European CO-08 footprint.

Available with an output frequency between 4.8 and 90 MHz and utilizing a full-size TO-8 quartz resonator, the oscillator performs to the stability required for Stratum II and IIe, GPS and TDMA PCS applications. The device operates over a –30° to +70°C temperature range with steady-state power consumption of 5.5 W (typ). Typical RF output is +9 dBm ±2 dB sinewave (into a 50 Ω load) with < –30 dBc harmonics and –80 dBc spurious levels. The 270 series is also ideal for phase noise related issues, delivering –100 dBc/Hz at a 1 Hz offset and –155 dBc/Hz at a 10 kHz offset for a 5 MHz unit. Size: 1.423" × 1.071" × 0.765".
MTI-Milliren Technologies Inc.,
Newburyport, MA (978) 465-6064.

Circle No. 253

■ Surface-mount DTCXO

The QED 110-AH/BH digital compensation temperature-controlled crystal oscillator (DTCXO) achieves a stability of ±0.4 PPM over the operating temperature range of –40° to +85°C. Designed for use in test

equipment and man-pack and handset military radios, the unit operates with a supply voltage of 3.3 V DC (5 V upon request). It is available in a frequency range from 1.25 to 110 MHz, and current compensation is as low as 4 mA for the 3.3 V models, depending on frequency. The phase noise floor is –150 dBc/Hz and the overall phase noise performance is matched to the frequency stability achieved. The QED 110-AH/BH has a low aging rate, which in the first year is < ±1 PPM (typ) and ±4 PPM (typ) total aging in 10 years. Size: 0.79" × 0.51" × 0.39".
TEMEX Components,
Phoenix, AZ (623) 780-1995.

Circle No. 254

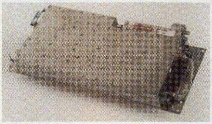
SUBSYSTEMS

■ I-Q Vector Modulator

The model 7328H I-Q vector modulator operates over a frequency range of 6 to 18 GHz and includes an enhanced modulation rate of > 50 MHz via 12-bit ECL control inputs for both I and Q channels. In addition, its high performance characteristics include an attenuation range exceeding 60 dB, with variation of amplitude vs. temperature of 0.04 dB/°C (max). Operating over a temperature range of –40° to +70°C, the unit provides a full 360° of phase shift, absolute insertion phase accuracy vs. frequency of ±15° and a variation of phase vs. temperature ±2°C (max). Size: 6.00" × 3.12" × 0.50".
General Microwave Corp.,
Farmingdale, NY (631) 630-2000.

Circle No. 255

■ Low Cost, High Performance Synthesizers



The CFS HP series synthesizers feature phase noise of –100 dBc/Hz at 10 kHz offset at C band, as well as a tunable C band or Ku band and a fixed L band. The units are built with a low profile construction and can be fitted with a parallel or serial interface. Applications include use in dual-conversion up- and down-converters.
Miteq Inc.,
Hauppauge, NY (631) 436-7400.

Circle No. 256

[Continued on page 216]

NEW PRODUCTS

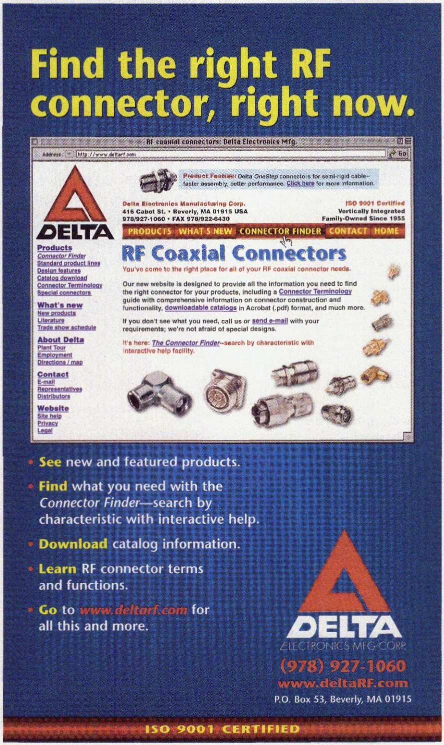
SYSTEM

Digital Microwave Radio

The 3000 series SONET/SDH digital microwave radio features the XPIC (cross-polarization interference cancellor) technology that allows transmission on both the horizontal and vertical polarity of any given frequency pair, making it possible to transmit up to 16 155 MB OC-3s in the 6 GHz band. This makes the radio one of the highest capacity long-haul microwave products on the market and offers network operators a complete solution by accommodating OC-3 needs with the flexibility to transport up to 48 DS3s or 1344 DS1s. The radio also features a modular design, various systems applications, excellent threshold/interference ratio and standard automatic transmitter control, synchronization flexibility, advanced operation, administration, maintenance and provisioning, as well as low power consumption and convection cooling.

NEC America Inc.,
Irving, TX (888) 632-9283.

Circle No. 257



TEST EQUIPMENT

RF Vector Network Analyzers

The PNA series RF vector network analyzers combines fast measurement speed, low noise, dynamic range and comprehensive automation and connectivity. It is an entirely new family of instruments designed to exploit state-of-the-art technologies and incorporate the Windows® 2000 Professional operating system, which links the measurement environment with the PC environment. The instruments combine fast sweep speeds, wide dynamic range, low trace noise, four measurement receivers with direct access and 9 GHz frequency coverage. The Windows operating system provides the full power of network connectivity and allows designers to use a variety of tools for automated test, such as COM/DCOM and programming languages, as well as Microsoft® applications for the post-processing of measurement data.

Agilent Technologies,
Palo Alto, CA (800) 452-4822, ext. 7127.

Circle No. 259

Direct Receiver Access Models

The models MS4622C and MS4623C direct receiver access (DRA) models are members of the company's Scorpion® family of vector network measurement systems (VNMS). Both allow increased flexibility in testing amplifiers not conveniently handled by other models and can use

[Continued on page 218]

NEW PRODUCTS

an external test set selected by the user. In addition, they have the ability to measure nonlinear effects in mixers, enhanced antenna measurements over the GPIB and high power amplifiers, making them both complete high performance measurement solutions. The MS4622C provides measurement capabilities from 10 MHz to 3 GHz and the MS4623C provides the same measurement capabilities from 10 MHz to 6 GHz. Both can include a second synthesizer for ease in intermodulation distortion and multiple test port measurements. Price: $28,500 for the MS4622C and $33,500 for the MS423C. Delivery: six to eight weeks (ARO).

Anritsu Co.,
Microwave Measurement Division,
Richardson, TX (800) 267-4878.

Circle No. 260

Handheld Microwave Oven Leakage Meter

The model HI-1801 microwave oven survey meter provides an easy and inexpensive way for public health agencies and services technicians to check for microwave leakage. Durable, compact and portable, the instrument is not susceptible to damage caused by excessive fields. The HI-1801 provides 2450 MHz frequency response with 0 to 10 mW/cm^2 and ±1 dB accuracy. Response time is 2 to 3 seconds and maximum power density 2 W/cm$_2$ continuous. Size: 2.87" × 4.2" × 2.2".

Holaday Industries Inc.,
Eden Prairie, MN (877) 465-2329.

Circle No. 271

Photodiode Meter

The model 2500 photodiode meter is designed for testing of laser diode modules (LDM), and has the capability for very fast low level current measurement, optical power measurement and extended voltage output. It also provides more targeted functionality for testing and controlling LDM than any comparable instrument. The model 2500 has a space-saving footprint and has been fine-tuned to provide the essential features, high speed and repeatable performance needed for efficient production testing in the rapidly growing LDM industry. The built-in picoammeter can resolve currents as low as 10 femtoamps, which supports more precise dark current measurement. The architecture of the model also supports greater measurement flexibility and includes a built-in ±10 V/±100 V voltage source that offers the extended range needed to power a variety of user-selected photodetectors, including large-area and avalanche types. Software drivers for LabVIEW™ and LabWindows™CVI are available with the model 2500 for easier development of test programs and test software packages. Price: $7995. Delivery: four to six weeks.

Keithley Instruments Inc.,
Cleveland, OH (888) 534-8453.

Circle No. 261

Power Meter

The model 9000B low cost, high performance CW power meter uses a diode-based power sensor and can measure power levels from –39 to +20 dBm and cover frequencies from 100 kHz to 40 GHz. The power meter is completely portable and can be used for swept measurement. It is designed to offer excellent measurement speed at all power levels, auto zero and dB relative mode, and operation on internal rechargeable batteries that offer greater than 12 hours of operation, and includes an internal fast battery charger. The 9000B has a built-in 50 MHz, 0 dBm reference oscillator and V/dB output port for swept scalar measurement system and auxiliary display and bus reading when used with a DVM.

Krytar,
Sunnyvale, CA (408) 734-5999.

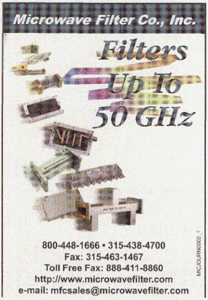
Circle No. 262

[Continued on page 222]

CIRCLE 171

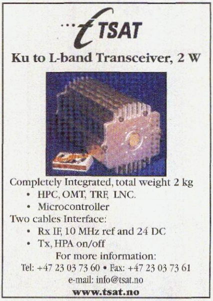
CIRCLE 33

CIRCLE 158

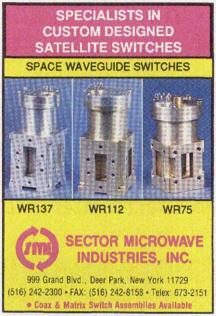


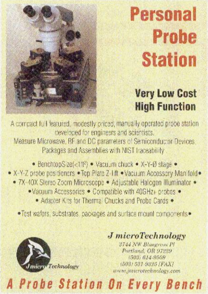
CIRCLE 96

CIRCLE 2



CIRCLE 188





CIRCLE 71


A Perfect Fit!

NEW PRODUCTS

Cellular Phone Production Test System

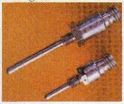
The TS7100 cellular phone production test system is a ready-to-go solution for the mass production of mobile phones to both present and upcoming standards. The integrated open system platform TSVP has 31 slots for test cards based on CompactPCI and PXI industry standards. The software library with GSM, CDMA and AMPS sequences covers all common mobile radio production tests. The TS7100 is compact and easily integrated into existing production lines.

Rohde & Schwarz GmbH and Co.,
Munich, Germany
+49 89 4129-13779.

Circle No. 263

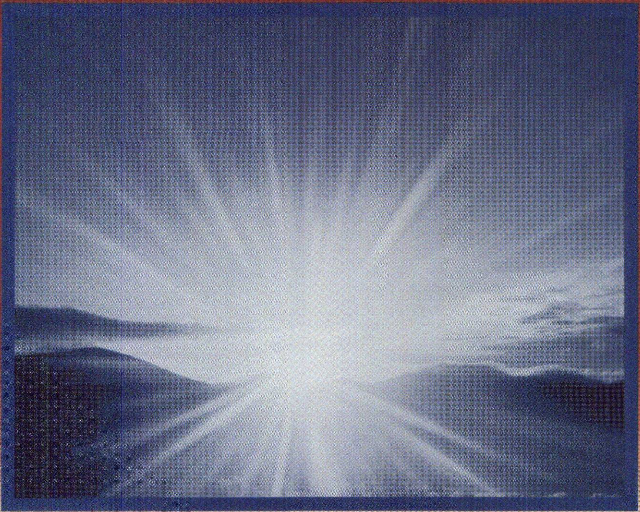
Rugged Temperature Probe

This rugged temperature probe provides high accuracy temperature sensing under the harshest conditions. The integrated stainless-steel sensor well/hermetically sealed connector is resistant to moisture, vibration, mechanical shock, temperature shock and corrosive environments. It is available in both thermistor and Pt RTD element versions; several options are available for connector type and probe style.



Sensor Scientific Inc.,
Fairfield, NJ (973) 227-7790.

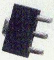
Circle No. 264



More power equals more freedom.

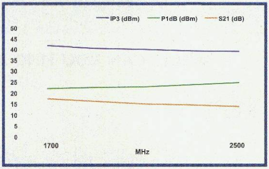
Introducing the SXT-289. A new wideband GaAsHBT power amplifier.

Stanford Microdevices introduces the SXT-289 — the perfect driver amplifier for today's and tomorrow's advanced communication infrastructure equipment.



With power to spare, giving you freedom from design constraints, this amplifier was designed and manufactured using state-of-the-art Gallium Arsenide heterojunction bipolar transistor (GaAs HBT) process technology. These devices are ideal for use as a driver stage for power amplifiers installed in cellular PCS infrastructure equipment and conform to TDMA, CDMA and PCS 1900 modulation standards. The SXT-289 operates from a single 5VDC supply and offers exceptional linearity performance in a small form-factor plastic SOT-89 with backside ground.

For more information on the SXT-289 or any of our other products, visit our website today and experience RF Innovation from Stanford Microdevices.



Typical device performance. Bias =5V @ 110mA typ.

STANFORD MICRODEVICES

www.stanfordmicro.com • 800-764-6642

CIRCLE 170 ON READER SERVICE CARD

ERRATA

In "The Design of Intermediate Linear Phase Bandpass Crystal Filters in Semilattice Form," a technical feature by Mark Mell that appeared in the August issue of *Microwave Journal*, Tables 2 and 3 contained several errors. The corrected tables appear below. In addition, in Appendix C a j term was missing in the first Ya(s) equation. It should read

$$\mathrm{Ya}(s) = \frac{1.730769s^2 + 0.4267183 - j0.8875740s}{s^3 + 1.331361s - j0.5769231s^2 - j0.4267183}$$

In the same issue in the article "A Simplified Approach to Determining AM/PM Conversion Coefficient in Microwave Low Noise Amplifiers and Systems" by Maurice Toolin, the definitions for S_1 and S_2 on page 82 should read

S_1 = voltage amplitude of $P_2\mathrm{out}\Delta$ normalized to $P\Delta$
S_2 = voltage amplitude of $P_3\mathrm{im}\Delta$ normalized to $P\Delta$

Also, $P_2\mathrm{out}\Delta(P_1\mathrm{out} - P_2\mathrm{out})$ is recorded as 30.5 dB. On page 90 in Appendix A, the final equation should read

$$K_p(°/\mathrm{dB}) = 13.2 \log^{-1}\left(\frac{P_j\mathrm{in} + G - \mathrm{Pint}}{10}\right)$$

TABLE II

IMPLEMENTATION OF THE PARTIAL SYNTHESIS PROCEDURE

Pole Locations	Selected Pole Locations
–0.335733689 + j0.90131941	–0.335733689 + j0.90131941
–0.335733689 – j0.90131941	–0.646039867 – j0.49841682
–0.646039867 + j0.49841682	–0.748995671 + j0.174020484
–0.646039867 – j0.49841682	
–0.748995671 + j0.174020484	
–0.748995671 – j0.174020484	

$$U(s) = (s + 0.335733689 - j0.90131941)\,(s + 0.646039867 + j0.49841682)\,(s + 0.748995671 - j0.174020484)$$

$$U(s) = s^3 + (1.730769 - j0.57692311)\,s^2 + (1.331361 - j0.88757401)\,s + 0.4267183 - j0.42671831$$

$$\mathrm{Ya} = \frac{M + jN}{N + jM}$$

where N denotes all odd real terms, jN all odd imaginary terms, M all even real terms and jM all even imaginary terms

$$M = 1.730769s^2 + 0.426718 \quad jN = -j0.8875740s$$
$$N = s^3 + 1.331361s \quad jM = -j0.57692311s^2 - j0.4267182$$

$$\mathrm{Ya}(s) = \frac{1.730769s^2 + 0.4267183 - j0.8875740s}{s^3 + 1.331361s - j0.5769231s^2 - j0.4267183}$$

$$\mathrm{Ya}(s) = \frac{0.59518825}{(s - j1.33483227)} + \frac{0.75378601}{(s + j1.05960567)} + \frac{0.38179497}{(s - j0.30169648)}$$

$$\mathrm{La} = \frac{1}{0.5951882} \qquad \mathrm{Xa} = \frac{-j1.3348322}{0.59518825}$$
$$\mathrm{Lb} = \frac{1}{0.7537860} \qquad \mathrm{Xb} = \frac{j1.0596056}{0.75378601}$$
$$\mathrm{Lc} = \frac{1}{0.3817949} \qquad \mathrm{Xc} = \frac{-j0.30169648}{0.38179497}$$

TABLE III

CALCULATIONS TO DETERMINE Ya(s) CRYSTAL FREQUENCIES AND MOTIONAL INDUCTANCE

Given:

	Low-pass Values from Table 2	
$f_0 = 21.4$ MHz	La = 1.680141	Xa = –j2.242706
BW = 100 kHz	Lb = 1.326637	Xb = j1.4057114
R = 2000 Ω	Lc = 2.619207	Xc = –j0.7902054

Then:

$$\mathrm{Lta} = \frac{\mathrm{RLa}}{\pi \mathrm{BW}} \qquad \mathrm{fa} = f_0 - \frac{\mathrm{BW}}{2}\frac{\mathrm{Xa}}{j\mathrm{La}}$$

$$\mathrm{Lta} = \frac{(2000)\bullet(1.680141)}{\pi 100\bullet 10^3} \qquad \mathrm{fa} = 21.4\bullet 10^6 - \frac{100\bullet 10^3}{2}\bullet\frac{-j2.242706}{j1.680141}$$

$$\mathrm{Lta} = 0.010696 \qquad \mathrm{fa} = 21.46674\bullet 10^6$$

Substituting Lb/Lc for La and Xb/Xc for Xa yields

Ltb = 0.0084456 $\qquad$ fb = $21.34702 \bullet 10^6$

Ltc = 0.016674 $\qquad$ fc = $21.41585 \bullet 10^6$

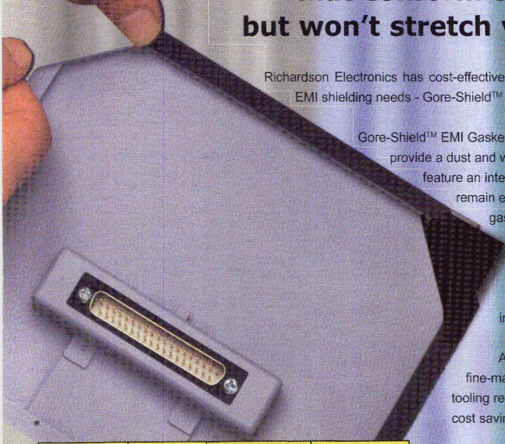
Finally, Cta, Ctb and Ctc are determined as

$$\mathrm{Cta} = \frac{1}{\left[4\left[\mathrm{Lta}\left(\mathrm{fa}^2\pi^2\right)\right]\right]}$$

$$\mathrm{Cta} = \frac{1}{\left[4\left[(0.010696)\left[\left(21.46674\bullet 10^6\right)^2\pi^2\right]\right]\right]}$$

$$\mathrm{Cta} = 5.139 \bullet 10^{-15} \qquad \mathrm{Ctb} = 6.582 \bullet 10^{-15} \qquad \mathrm{Ctc} = 3.312 \bullet 10^{-15}$$

Looking for EMI gaskets that conform to your needs but won't stretch your budget?



Richardson Electronics has cost-effective, off-the-shelf solutions for your EMI shielding needs - Gore-Shield™ EMI gaskets.

Gore-Shield™ EMI Gaskets are soft, conformable, and provide a dust and water tight seal. These gaskets feature an integral conductive adhesive, but remain easy to apply. Gore-Shield™ gaskets are field repairable, cannot be damaged by over compression and offer reliable/consistent performance with no change in shielding over time.

Additionally, there is no need for fine-machined surfaces and no tooling required, which adds up to further cost savings.

Thickness mm (inch)	Width mm (inch)	Gore Part Number	Richardson Part #
0.25 (0.010)	3.20 (0.125)	EDR-05-010-0125-SC	C010-0125-SC-50
0.5 (0.020)	3.20 (0.125)	EDR-05-020-0125-SC	C020-0125-SC-50
	6.35 (0.250)	EDR-05-020-0250-SC	C020-0250-SC-50
	9.50 (0.375)	EDR-05-020-0375-SC	C020-0375-SC-50
	12.70 (0.500)	EDR-05-020-0500-SC	C020-0500-SC-50
1.0 (0.040)	3.20 (0.125)	EDR-05-040-0125-SC	C040-0125-SC-50
	6.35 (0.250)	EDR-05-040-0250-SC	C040-0250-SC-50
	9.50 (0.375)	EDR-05-040-0375-SC	C040-0375-SC-50
	12.70 (0.500)	EDR-05-040-0500-SC	C040-0500-SC-50
1.5 (0.060)	3.20 (0.125)	EDR-05-060-0125-SC	C060-0125-SC-50
	6.35 (0.250)	EDR-05-060-0250-SC	C060-0250-SC-50
	9.50 (0.375)	EDR-05-060-0375-SC	C060-0375-SC-50
	12.70 (0.500)	EDR-05-060-0500-SC	C060-0500-SC-50
2.0 (0.080)	3.20 (0.125)	EDR-05-080-0125-SC	C080-0125-SC-50
2.5 (0.100)	6.35 (0.250)	EDR-05-125-0250-SC	C125-0250-SC-50

For the most cost-effective EMI gasket solution and worldwide support, call your local Richardson Electronics office today.

Richardson Electronics and W.L. Gore & Associates - Driving the Cost Out of EMI Shielding

GORE

Richardson Electronics

Engineered Solutions

RELL Online catalog.rell.com Catalog

Visit Richardson's online catalog at *catalog.rell.com*

More than 60 locations worldwide to serve you. E-mail: ssc@rell.com, **Internet:** www.rfpowernet.com/wlgore.asp, **Toll Free:** 800-RF Power or 800-737-6937 (U.S. & Canada), **Australia:** Castle Hill, ACN 069 808 108, +61 (2) 9894-7288, Bayswater, ACN 069 808 108, +61 (3) 9738-0733, **Brazil:** São Paulo, +55 (11) 3845-6199, **China:** Shanghai, +86 (21) 6440-0807, **Colombia:** Sante Fe de Bogota, DC, (57-1) 636-1028, **France:** Colombes Cedex, +33 (1) 55.66.00.30, **Germany:** Puchheim, +49 (89) 890 214-0, Hamburg, +49 (40) 555 88 410, **Italy:** Sesto Fiorentino (FI), +39 (055) 420831, Agrate Brianza (MI), +39 (039) 653145, Roma, +39 (06) 41.73.37.51, **Japan:** Osaka, +81 (6) 6314-5557, Tokyo, +81 (3) 5215-1577, **Korea:** Seoul, +82 (2) 539-4731, **Mexico:** Mexico City, +52 (5) 674-2228, Guadalajara, +52 (3) 645-4641, **Netherlands:** Amsterdam, +31 (20) 446 7070, **Philippines:** Pasig City, +63 (2) 636-8891, **Singapore:** +65 487-5995, **Spain:** Madrid, +34 (91) 528 3700, Barcelona, +34 (93) 415 8303, **Sweden:** Stockholm, +46 8 564 705 90, **Taiwan:** Taipei, +886 (2) 86915238, **Thailand:** Bangkok, +66 (2) 749-4402, **Turkey:** Içlevent Istanbul, +90 212 264 3721, **United Kingdom:** Lincoln, +44 (1522) 542631, Slough, +44 (1753) 733010, **Vietnam:** Ho Chi Minh City, +84 8.811.1919. For other international inquiries call **Corporate Headquarters:** LaFox, IL (630) 208-2200, Fax (630) 208-2550. MK0254 ©2000 Richardson Electronics, Ltd.

1-800-RF-POWER • www.rfpowernet.com/wlgore.asp • ssc@rell.com

CIRCLE 152 ON READER SERVICE CARD

NEW LITERATURE

PRODUCT BROCHURE

This six-page brochure features EMI shielding products, such as EMI gaskets, conductive silicones, conductive yarn over elastomer gaskets, wire mesh gaskets, elastomer gaskets, combination gaskets, EMI shielding tape, shielded windows, air vent panels and metallized fabrics. Product photographs, descriptions and contact information are included.
Advanced Performance Materials (APM),
St. Louis, MO (800) 843-4556
or (314) 344-9300.

Circle No. 200

MICROMACHINED INTEGRATION TECHNOLOGY BROCHURE

This brochure on µmIntegration™ (micromachined integration) technology shows the benefits and applications of the latest technology and products being released. It includes information on the µmIsolation™ (micromachined isolation) IC-based approach to digital isolation, as well as the µmRelay™ (micromachined relay) technology.
Analog Devices Inc.,
Wilmington, MA (800) 262-5643.

Circle No. 201

RF DESIGN MODULE BROCHURE

This four-page brochure describes the company's RF design module, which extends modeling capabilities to high frequency analysis. Screen shots, characteristics, features and a list of supported operating systems are included.
APLAC Solutions Corp.,
Helsinki, Finland +358 9 5404 5000.

Circle No. 202

ELECTRONIC COMPONENT SUPPLIER BROCHURE

This brochure features the company's new logo and contains a list of its product line, suppliers, MIL specs and clients. A company profile, catalog request form, contact information and a distributor update are also included.
BTC Electronic Components,
Raleigh, NC (800) 526-2828.

Circle No. 203

COMPANY BROCHURE

This four-page brochure provides an overview of the newly formed company and its products. Focused on providing various semiconductor system solutions for communications electronics, the company offers wireless communications solutions, network access solutions, digital infotainment solutions, personal imaging solutions and personal computing solutions. Contact information is included.
Conexant Systems Inc.,
Newport Beach, CA (800) 854-8099.

Circle No. 204

PRODUCT DATA SHEET

This two-page data sheet describes a variety of procurement products for distribution, purchasing, outsourcing, supply management and kitting. Product photographs and overviews and a listing of the company's product line are included.
Delaire USA,
Manasquan, NJ (732) 528-4520.

Circle No. 205

CRYSTAL OSCILLATOR DATA SHEET

This two-page data sheet features the model FE-101A OCXO subminiature oven-controlled commercial quartz crystal oscillator. The unit warms up to stabilized frequency in less than two minutes with temperature stability of 5×10^{-8} at 50°C. Full specifications, technical highlights, available options and an outline drawing are included.
Frequency Electronics Inc.,
Mitchel Field, NY (516) 794-4500.

Circle No. 206

SEMICONDUCTOR DATA SHEET

This data sheet provides information on the company's S- and L-band radar products as well as its avionics and MOSFET products. Part number, frequency band, ouput power, voltage and pulse width/duty factor are listed. The sheet also includes the company's mission statement and quality policy.
Integra Technologies Inc.,
El Segundo, CA (310) 606-0855.

Circle No. 207

REFERENCE GUIDE

This 12-page reference guide (*Connecting Multiple Converters*, PowerPage™ 44) describes how to connect multiple DC-to-DC converters to make complete power supply systems. The guide also details some cautionary areas such as switching frequency synchronization and controlling multiple power systems with a single switch.
Powercube,
Chatsworth, CA (800) 866-3590.

Circle No. 208

PRODUCT BROCHURE

This four-page brochure features dielectric resonators, ferrite materials and dielectric substrates. Product photographs, descriptions, and a company and facilities overview are included. Product applications and contact information are also listed.
TRAK Ceramics Inc. (TCI),
Hagerstown, MD (301) 766-0560.

Circle No. 209

RF CONNECTOR CATALOG

This 12-page catalog features the company's full line of QDS series quick-disconnect RF connectors for use with telecommunications, semiconductor and test equipment. The product line combines the performance of type-N connectors with a fast on/off capability that mates securely without bayonets or threaded nuts. Technical drawings, product descriptions and specifications are included.
Tru-Connector Corp.,
Peabody, MA (800) 262-9878
or (978) 532-0775.

Circle No. 210

PRODUCT BROCHURE

This six-page brochure features devices, building blocks, jammer amplifiers, command transmit systems, communications products, replacement amplifiers and special applications. Product photographs, descriptions and specifications are included, as well as a company overview.
Zeta, a division of Sierra Networks Inc.,
San Jose, CA (408) 434-3600.

Circle No. 211

U-NII Solutions

Over 150,000 Shipped

Cost Competitive

100% RF Tested

Thermal Performance

High Linearity

In Stock Now

Model Number	Frequency (GHz)	Gain (dB)	P-1dB (dBm)	IP3 (dBm)	Vd (Volts)	Id (mA)
6001	5.25 – 5.35	23	23	34	4.75	600
6002	5.25 – 5.35	20	20	30	4.75	600
6003	5.725 – 5.825	22	28.5	43	7.00	600
6004	5.725 – 5.825	22	27	41	7.00	600
6006	5.725 – 5.825	22	23	37	7.00	600
6007	5.25 – 5.35	18	20	30	4.75	600
	5.725 – 5.825	21	25	38		

Don't be fooled by others. Teledyne has MMICs for U-NII in STOCK!

Teledyne has been manufacturing **GaAs MMIC** power amplifiers for **over 2 decades**. These U-NII and Hiperlan amplifiers have been in **production for several years** and **over 150,000** have already been **shipped**. We offer **competitive prices, immediate delivery** from stock and **outstanding service.**

If this is the kind of **value you've been looking for** contact Teledyne today via our Web site, e-mail or telephone. Find out how **we can provide the solutions** you need.

Teledyne Wireless, 1274 Terra Bella Avenue, Mountain View, CA 94043, Phone: 800.832.6869, Fax: 650.962.6845.

TELEDYNE
WIRELESS
A Teledyne Technologies Company

TELEDYNE DELIVERS VALUE-ADDED SOLUTIONS

www.teledynewireless.com

For Faster Information e-mail: amplifiers@teledyne.com

CIRCLE 179 ON READER SERVICE CARD

THE BOOK END

Handbook of CDMA System Design, Engineering and Optimization

Kyoung Il Kim
Prentice Hall PTR

252 pages plus CD ROM; $80
ISBN: 0-13-017572-2

Code division multiple access (CDMA) has become a preferred choice of the wireless telecommunications industry. This book is the result of recent efforts by many members of the technical staff of Bell Labs at Lucent Technologies Inc. to study CDMA technology as it applies to cellular or PCS. The text summarizes the work that has been developed and applied to the design and deployment of IS-95 CDMA systems, and provides an in-depth discussion of various engineering guidelines for a multitude of real-world issues involved in the design, deployment and optimization of IS-95 CDMA systems and networks. The goal is to aid the reader in understanding the types of issues involved in engineering successful CDMA mobile communication systems and the guidelines required to deal with those issues.

> ***"[The book provides] practical guidelines for individuals interested or engaged in the engineering and optimization of CDMA networks."***

To make the book more useful for those readers interested in cell planning, a demonstration version of Cellular Engineering 4 (CE4), a CDMA coverage prediction software tool developed at Bell Labs, has been included. Using this software, readers can obtain hands-on experience in CDMA cellular engineering techniques as well as in the design and analysis of CDMA networks. The North American PCS CDMA system operating at 1800 MHz is the example used for the discussions. However, almost all of the discussions are equally applicable to both 1.8 GHz and 850 MHz systems if appropriate modifications for frequency-related values are made.

The book begins with a CDMA overview and a summary of CDMA concepts and operations, then covers spectrum coordination, pilot assignment, mobile station access and paging, and handoff issues. It continues with discussions of link budgets, capacity, coverage, traffic engineering and antennas. The appendices provide a sample RF design process, an outline of RF optimization procedures and RF coverage predictions using CE4.

The book is easily understood, with clear, helpful graphics and minimal complex math. It provides practical guidelines for individuals interested or engaged in the engineering and optimization of CDMA networks.

To order this book, contact: Prentice Hall, PO Box 11073, Des Moines, IA 50336 (800) 947-7700.

Advanced Techniques for Digital Receivers

Phillip E. Pace
Artech House Inc.

430 pages plus software; $119, £82
ISBN: 1-58053-053-2

This book presents new electronic, electro-optic and superconductor digitization methods and emphasizes high resolution, symmetrical number system (SNS) techniques that can be applied to a variety of receiver components, architectures and receiver subsystems. The book is appropriate for senior undergraduate and first-year graduate students, and contains a disk with MATLAB/SIMULINK programs that may be used for problem exercises that appear at the end of each chapter.

Chapter 1 presents the concepts of time domain and frequency domain signals and systems. Linear time-invariant systems are discussed and filtering concepts are introduced. Chapter 2 presents a brief overview of analog receiver architectures. New digital receiver techniques are investigated, and radar, infrared, satellite ground station, Global Positioning System and electronic warfare receivers are described. Chapter 3 explains the signal conversion process. Both electronic and optical circuits are emphasized, as well as the concept of coherent sampling. Chapter 4 describes the parameters used to measure the dynamic performance of the signal conversion process. Transfer functions of the digital-to-analog and analog-to-digital converters (ADC) are presented.

> ***"This book presents new electronic, electro-optic and superconductor digitization methods..."***

Chapter 5 provides a detailed overview of high performance signal conversion architectures, including full-flash, two-step and folding ADCs, electro-optical digital antennas, time interleaved digitizers and pipelined ADC architectures. Chapter 6 discusses oversampling theory and sigma-delta modulation, and describes first- and second-order modulators. Chapter 7 presents the theory of digital RF memories; Chapter 8 covers the application of superconductor technology to amplitude-analyzing and sigma-delta ADCs.

Chapter 9 offers a complete discussion of SNS theory, and Chapter 10 discusses SNS undersampling discrete Fourier transform receivers and their advantages. The final chapter presents phase-sample, direction-finding antenna theory. A two-channel example is shown and experimental results are demonstrated.

To order this book, contact: Artech House Inc., 685 Canton St., Norwood, MA 02062 (781) 769-9750, ext. 4002; or 46 Gillingham St., London SW1V 1HH, UK +44 (0) 20 7596-8750.

Frank Bashore

Frank Bashore is a member of the Microwave Journal *staff.*

ADVERTISING INDEX

Circle No.	Advertiser	Page No.	Phone	Fax	Web/E-Mail Address
1	Advantest Corporation	55	+81-3-3342-7500		www.advantest.co.jp/index-e.html
2	Aerocomm Satellite Technology	220	+662-693-8300	+662-693-8304	www.aerocommthailand.com
3,4,	Agilent Technologies	COV 2, 81,	800-452-4844	415-857-5518	www.agilent.com
5,6,		133,			
7,8,		157,			
9		193			
11	Alpha Industries	69	781-935-5150	781-935-2359	www.alphaind.com
12	Amcom Communications Inc.	128	301-353-8400	301-353-8401	www.amcomusa.com
13	American Technical Ceramics	20–21	631-622-4700	631-622-4748	www.atceramics.com
14	Amplidyne Inc.	153	908-253-6870	908-253-6875	www.amplidyneinc.com
15	Amplifier Research	91	215-723-8181	215-723-5688	www.amplifiers.com/@/mj-shoulders
16	Anaren Microwave	52	800-544-2414	315-432-9121	www.anaren.com
17	Anritsu Company	143	800-ANRITSU	972-671-1877	www.us.anritsu.com
18,19,20	Ansoft Corporation	19,107,175	412-261-3200	412-471-9427	www.ansoft.com
21	Antenna Research Associates	58	301-937-8888	301-937-2796	www.ara-inc.com
22	Aplac	74	972-719-2562		www.aplac.com
23	Applied Wave Research	196	310-726-3000	310-726-3005	www.mwoffice.com
24	ARC Technologies Inc.	35	978-388-2993	978-388-6866	www.arc-tech.com
25,26,	Artech House	146	800-225-9977	781-769-6334	www.artechhouse.com
29,30	Cascade Microtech	COV 4	503-601-1000	503-601-1002	www.cascademicrotech.com
31	Celeritek	213,215	408-986-5060	408-986-5095	www.celeritek.com
32	Chin Nan	88	+886-6-2678303	+886-6-268337	www.chinnan.com
33	Citel Inc.	220	305-621-0022	305-621-0766	www.citelprotection.com
34	Communication Techniques	163	973-884-2580	973-887-6245	www.cti-inc.com
35	Compac Enclosures	186	631-585-3400	631-585-3534	www.compac-rf.com
36	Comtech PST	167	631-777-8900	631-777-8877	www.comtechpst.com
37	Condor Systems Inc.	24	408-879-2236	408-377-6892	www.condorsys.com
38	CTT Inc.	150	408-988-8521	408-986-9097	www.cttinc.com
39	Daico Industries	COV 3	310-507-3242	310-507-5701	www.daico.com
401	Delta Electronics	216	978-927-1060	978-922-6430	www.deltarf.com
134	Dept26.com	205			www.dept26.com
40	Dielectric Laboratories	62	315-655-8710	315-655-8179	www.dilabs.com
41	Dow-Key Microwave Corp.	165	805-650-0260	805-650-1734	www.dowkey.com
42	Dupont	101	800-284-3382	919-248-5770	www.dupont.com/mcm/
43	Dynamic Research Corporation	218	978-658-6100	978-657-7765	www.drc.com
44	Dynawave	14	978-469-0555	978-521-4589	www.dynawave.com
45,46	Eagleware Corporation	26–27,161	678-291-0995	678-291-0971	www.eagleware.com
	Edith Roman Associates	122	914-620-9000	914-620-9035	www.edithroman.com
47	EMC Technology	115	856-429-7800	856-429-6814	www.emct.com
48	Ericsson RF Power Products	119	1-877-GOLDMOS		www.ericsson.com/rfpower
49	Filtel Microwave Inc.	220	450-455-6082	450-424-5819	
50	Florida RF Labs	15	800-544-5594	888-544-5594	www.rflabs.com
51	Focus Microwaves Inc.	203	514-335-6227	514-335-6287	www.focus-microwaves.com
52	FSY Microwave Inc.	75	410-381-5700	410-381-0140	www.fsymicrowave.com
53	Fujitsu Compound Semiconductor Inc.	117	408-232-9500	408-428-9111	www.fcsi.fujitsu.com
54	Future Electronics	37	888-306-5347	514-428-7518	www.futureelectronics.ca/rf/philips
55	G.T. Microwave	102	973-361-5700	973-361-5722	www.gtmicrowave.com
56	General Microwave Corporation	214	631-630-2000	631-630-2066	www.generalmicrowave.com
57	GGB Industries Inc.	3	941-643-4400	941-643-4403	www.picoprobe.com
58	H.D. Communications	113	888-588-3800	631-588-3879	www.hdcomm.com
59	Haverhill Cable	204	978-372-6386	978-373-8024	www.haverhillcable.com
60	Hirose Electric USA	172	805-522-7958	805-522-3217	www.hirose.com
61	Hittite Microwave	61	978-250-3343	978-250-3373	www.hittite.com
	IEEE MTT-S	138	800-225-9977	781-769-5037	kdednah@mwjournal.com
	IEEE-APS Conference	142	781-890-5290	781-890-5294	www.eece.unm.edu/apwc2000
62	IMI	128	978-373-9190	978-521-1846	www.imipcb.com
63	Inmet Corporation	104	888-244-6638	734-426-5557	www.inmetcorp.com
64	Intersil	155	+44-1344-488405		www.intersil.com/commlink/quad
65,66,	ITT Industries, Microwave Systems	135,137,	978-441-0200		www.ittmicrowave.com
67,68		139,141			
69	JCA Technology	31	805-445-9888	805-987-6990	www.jcatech.com
70	JFW Industries Inc.	8	317-887-1340	317-881-6790	www.jfwindustries.com
71	Jmicro Technology	220	503-614-9509	503-531-9325	www.jmicrotechnology.com
72	Johanson Technology	82	805-389-1166		www.johansontechnology.com
73	JSM Electronics Inc.	98	888-FONEJSM	407-831-0087	
74	K&L Microwave Inc.	6	410-749-2424	410-749-2788	www.klmicrowave.com
75,76,77	KMW	29,59,219	562-926-2033	562-926-6133	www.kmwinc.com
78	Kospace Co. Ltd.	212	+82-31-637-8395	+82-31-637-7792	www.kospace.com
79	L3 Communications/Celerity	189	888-274-5604	408-873-1397	www.csidaq.com
80	Labtech Ltd.	54	+44-1544-260093	+44-1544-260310	www.labtechcircuits.com
81,82	M/A-Com	39,207	800-366-2266	800-618-8883	www.macom.com
83	Marconi Applied Technologies	140	914-592-6050	914-592-5148	www.marconitech.com
84	Maury Microwave Corporation	9	909-987-4715	909-987-1112	www.maurymw.com
85	MECA Electronics Inc.	118	973-625-0661	973-625-1258	www.e-meca.com

Circle No.	Advertiser	Page No.	Phone	Fax	Web/E-Mail Address
86	Merrimac Industries	209	888-434-MMFM	973-882-5990	www.multi-mix.com
	Micro Comm	222	978-683-2272	978-794-5627	www.micsearch.com
87	MicroMetrics Inc.	201	603-641-3800	603-641-3500	www.micrometrics.com
88	Microsemi	159			www.microsemi.com
89	Microwave & Video Systems Inc.	94–95	203-792-7474	203-792-7475	e-mail: mvsmicro@worldnet.att.net
90	Microwave Comm. Laboratories Inc. (MCLI)	18	800-333-6254	727-381-6116	www.mcli.com
91	Microwave Communications & Components	66	+82-2-3424-0800	+82-2-3424-0808	www.mcck.com
92	Microwave Development Company, Inc.	17	603-870-6280	603-870-6210	www.mdc-inc.net
93	Microwave Development Labs	121	800-383-4189	781-453-8629	www.micro-dev-labs.com
94	Microwave Devices	38	317-736-8833	317-736-8382	www.mwdevices.com
95,96	Microwave Filter Company	126,220	800-448-1666	315-463-1467	www.microwavefiter.com
97	Microwave Instrumentation Technologies	211	800-848-7921	678-475-8391	www.mi-technologics.com
	Microwave Journal	174,192,224	800-225-9977	781-769-5037	www.mwjournal.com
98	Microwave Specialty Corporation	114	760-744-1544	760-744-1565	www.microwavespecialty.com
99,100,	Mini Circuits Laboratory	4–5,	718-934-4500	718-332-4661	www.minicircuits.com
101,102,		7,			
103,104,		11,			
105,106,		41,			
107,108,		44,			
109,110,		48,			
111,112,		73,			
113,114,		83,			
115,116,		93,			
117,118,		151,			
119,120,		177,			
121,122,		181,			
123,124,		187,			
125,126		217			
127,128,	MITEQ Inc.	43,105,	631-436-7400	631-439-9540	www.miteq.com
129,130		171,229			
131	Modular Components National Inc.	28	410-879-6553	410-838-7629	www.mcn-mmpc.com
132,133,	Narda Microwave-East, an L3 Communications Co.	51,70–71	631-231-1700	631-231-1711	www.nardamicrowave.com
135	Nexyn	180	408-732-0793	408-730-0378	www.nexyn.com
	Noisecom	99–100	201-261-8797	201-261-8339	www.noisecom.com
136	NTK Technical Ceramics	50	408-727-5180	408-727-5076	www.ntktech.com
137	Oscilloquartz SA	110	+41-32-722-5555	+41-32-722-5556	www.oscilloquartz.com
138	Palomar Technologies	130	760-931-3600	760-931-5191	www.bonders.com
139	Paratek Microwave Inc.	67	877-377-0336	443-259-0140	www.paratek.com
140	PCB Engineering	126	800-368-4PCB	408-946-2246	www.pcbengineering.com
141	Peregrine Semiconductor	208	858-455-0660	858-455-0770	www.peregrine-semi.com
143	Philips Semiconductor	125	800-332-8638		www.em.avnet.com/rfm/avionics.html
142	Phoenix Microwave Corp.	25	215-723-6011	215-723-6015	www.stellexms.com
144	Picosecond Pulse Labs Inc.	188	303-443-1249	303-447-2236	www.picosecond.com
145	Presidio Components	54	858-578-9390	800-538-3880	www.presidiocomponents.com
146	Programmed Test Sources Inc.	120	978-486-3400	978-486-4495	www.programmedtest.com
147	Radio Research Instrument Co., Inc.	216	203-753-5840	203-754-2567	www.techexpo.com/www/radiores
148	Reactel	34	301-519-3660	301-519-2447	www.reactel.com
	RF & Hyper Europe	134	+33-1-53-17-11-40	+33-1-53-17-11-45	www.birp.com/hyper
149	RF Globalnet	183			www.rf.rfglobalnet.com/library/
150	RF Micro Devices	32–33	336-664-1233	336-931-7454	www.rfmd.com
151,152,190	Richardson Electronics	111,127,225	1-800-RFPOWER	630-208-2550	www.rfpowernet.com
153	RLC Electronics Inc.	23	914-241-1334	914-241-1753	www.rlcelectronics.com
154	Rogers Corporation	97	480-961-1382	480-961-4533	www.rogers-corp.com/mwu/info.htm
155	Rohde & Schwarz GmbH	103	+49-89-41293115	+49-89-41293115	www.fsp.rsd.de
156	Rosenberger	173	717-290-8000	717-399-9885	www.rosenbergerna.com
157	Sage Laboratories	13	508-653-0844	508-653-5671	www.sagelabs.com
158	Salisbury Engineering Inc.	220	800-989-2141	302-846-3888	www.salisbury-engineering.com
159	Sarnoff Corporation	191	609-734-2507	609-734-2443	www.sarnoff.com/ad/wireless
160	Sawtek Inc.	87	407-886-8860	407-886-7061	www.sawtek.com/mj
161	SDP Components	182	514-428-8749	514-428-8757	www.sdp.ca
162	Seavey Engineering Associates Inc.	144	781-829-4740	781-829-4590	www.seaveyantenna.com
163	Sector Microwave Industries Inc.	220	516-242-2300	516-242-8158	e-mail: sales@sectormicrowave.com
164	Spectrum	138-I*	+49-89-354-804-0	+49-89-354-804-90	www.spectrum-et.com
165	Spinner North America	206	770-263-6326	770-263-6329	www.spinnerna.com
166	Sprague-Goodman	92	516-334-8700	516-334-8771	www.spraguegoodman.com
167	SSI Cable Corporation	30	360-426-5719	360-426-5912	www.ssicable.com
168	SSPA Microwave	210	905-565-0558	905-565-0588	www.sspamicrowave.com
169,170	Stanford Microdevices	79,223	800-764-6642		www.stanfordmicro.com

ADVERTISING INDEX

Circle No.	Advertiser	Page No.	Phone	Fax	Web/E-Mail Address
171	Stealth Microwave	220	609-538-8586	609-538-8587	www.ssbtech.com
172,173	SV Microwave	109,221	727-541-5800	727-541-5869	www.svmicrowave.com
174,175,176	Synergy Microwave Corp.	57,131,195	973-881-8800	973-881-8361	www.synergymwave.com
177	Tektronix	169	800-426-2200		www.tektronik.com
178,179	Teledyne Wireless	65,227	650-962-6720	650-962-6845	www.teledynewireless.com
180	Temex	46	623-780-1995	623-780-9622	www.temex.ch
181	Temex Components	89	623-780-1995	+33-1-48-581046	www.temex-components.com
182	TestMart	16	888-665-2765	650-624-0535	www.testmart.com
183	Thermax/CDT	179	888-761-7800	718-746-4190	www.thermaxcdt.com
184	Thomson Microsonics	164	+33 04 92 96 40 00	+33 04 92 96 30 25	www.microsonics.thomson-csf.com
185,186	TRAK Communications	145,147	813-901-7450	813-901-7454	www.trak.com
187	Tru-Connector	129	978-532-0775	978-531-6993	www.tru-con.com
188	TSAT AS	220	+47-2303-73-60	+47-2303-73-61	www.tsat.no
189	Tusonix	63	520-744-0400	520-744-6155	www.tusonix.com
190	United Monolithic Semiconductor	127	+33-(0)-1-69330308	+33-(0)-1-69330309	www.ums-gaas.com
191	Vari-L Company Inc.	123	303-371-1560	303-371-0845	www.vari-l.com
199	Vectron International	136	1-88-VECTRON1	888-FAX-VECTRON	www.vectron.com
192	W.L. Gore & Associates	85	800-445-4673	302-738-5993	www.gore.com
193	Watkins Johnson Co.	77	800-951-4401	650-813-2447	www.wj.com
194	Weinschel Corporation	170	301-846-9222	301-846-9116	www.weinschel.com
195	Werlatone	47	845-279-6187	845-279-7404	www.werlatone.com
	Xemod	222	800-790-8710	602-955-96 39	www.aztechjobs.com
196,197	Z-Communications	149,185	858-621-2700	858-621-2722	www.zcomm.com

*Euro-Global only

SALES REPRESENTATIVES

the microwave journal

Harlan Howe, Jr., Publisher

Eastern and Central Time Zones
Carl Sheffres
National Sales Mgr.
685 Canton Street
Norwood, MA 02062
Tel: (781) 769-9750
FAX: (781) 769-5037
e-mail:
csheffres@mwjournal.com

Tim O'Callaghan
Eastern Reg. Sales Mgr.
685 Canton Street
Norwood, MA 02062
Tel: (781) 769-9750
FAX: (781) 769-5037
e-mail: tocallaghan
@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

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
e-mail:
wynncook@ix.netcom.com

Ed Johnson, Associate Publisher

International Sales
Sam Baird
Manager – Europe
Michel Zoghob
Gareth Watson
46 Gillingham Street
London SW1V 1HH,
England
Tel: +44 20 7596 8740
FAX: +44 20 7596 8749

Australia
James Tonkin
Tonkin Media Pty. Ltd.
300 Scenic Highway
Terrigal NSW 2260, Australia
Tel: +61 43 85 1746
FAX: +61 43 85 2017

Germany, Austria, and Switzerland (German-speaking)
Juergen Wissling
Wissling Marketing Services
Riedstrasse 5
72813 St. Johann-
Wuertingen
Germany
Tel: +49 7122 829310
FAX: +49 7122 829330

Michelle Carletti, Traffic Administrator

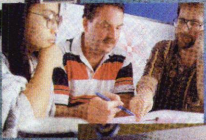
Japan
Kenichi Takefusa
Appeal Inc.
Arpus Hiroo, 2F, 5-17-11
Hiroo, Shibuya-ku,
Tokyo 150, Japan
Tel: +81 3 3443 0895
FAX: +81 3 3443 0871

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

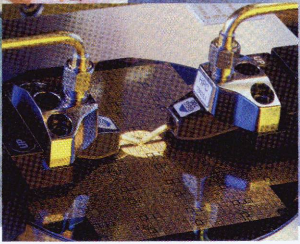
Taiwan
Laura Chen
Arco Publications
4 F, No. 5, Sec. 1,
Pa-Te Road
Taipei, Taiwan ROC
Tel: +886-2 396 5128
FAX: +886-2 396 4511

Israel
Oreet Ben Yaacov
Oreet International Media
15 Kineret Street
51201 Bene-Berak, Israel
Tel: +972 3 570 6527
FAX: +972 3 570 6526

RF and Microwave Probes



We stand behind our solutions.



On-wafer measurements demand the best performance from a probe. Unlike general-purpose probes that tradeoff electrical performance for production ruggedness, Cascade Microtech probes deliver metrology grade measurement accuracy combined with precise probe mechanics.

So nothing will stand between you and your measurements.

The probe you buy is only as reliable as the company that stands behind it.

Cascade Microtech is not just the world's largest manufacturer of probes; we also produce probe stations, probe cards, accessories, and software used in analytical testing and R&D characterization of semiconductor devices on-wafer.

All of our probes have one thing in common, our no-compromise Air Coplanar™ probe technology. This innovation plus our years of extensive probing experience and superior manufacturing techniques, guarantees you accurate measurements...the first time...every time. What's more, our probes are available in the industry's most comprehensive range of tip configurations and mounting styles to fit your needs.

Most important, when you need answers, Cascade Microtech is there for you with leading-edge solutions to your tough probing challenges and the superior application support you just can't get from a probes-only discounter.

Find out more at www.cascademicrotech.com.

Or call 503-601-1000 or 1-800-550-3279 (USA & Canada).

Japan: 03-5478-6100. Europe: +44 1295-812828.

Agilent Technologies
Innovating the HP Way

Channel Partner

CASCADE® MICROTECH

Innovating Test Technologies

CIRCLE 29: HAVE A SALES ENGINEER CONTACT ME
CIRCLE 30: SEND INFORMATION ON ACP PROBES