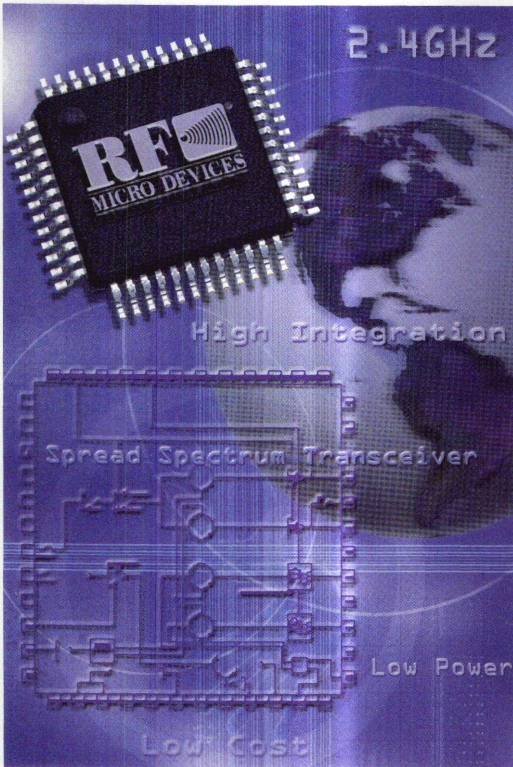




microwave
JOURNAL
EURO-GLOBAL EDITION

OCTOBER 1999
VOL. 42, NO. 10



**COMMUNICATIONS
AND PCNs**

▼
**UNDERSTANDING
OFFSET 8-PSK
MODULATION
FOR GSM EDGE**

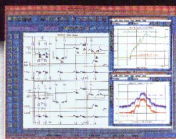
▼
**DIGITAL
PREDISTORTION
TECHNIQUES FOR RF
POWER AMPLIFIERS
WITH CDMA
APPLICATIONS**

▼
**VECTOR SIGNAL
MEASUREMENT FOR
38 GHz DIGITAL
RADIO APPLICATIONS**

CONTENTS, p. 10

horizon house
®

**YOU'VE WAITED 8 WEEKS
FOR YOUR RFIC PROTOTYPE.
YOU CAN *HOPE* IT WILL WORK,**



OR YOU CAN *KNOW* IT WILL WORK.

Goodbye heart palpitations. Goodbye queasy feelings. Goodbye guesswork and failed prototypes. Hello HP RFIC Designer—the only RFIC design software that offers a complete range of high-performance simulation technologies for communication product design. This powerful software expands existing SPICE technology to include four more simulation technologies: S-parameters, Convolution, Circuit Envelope, and new Harmonic Balance. These advanced capabilities help ensure your designs will meet stringent digital wireless standards, like ACPR for CDMA. Use HP RFIC Designer with HP DSP Designer to uniquely co-simulate RF and DSP interactions and avoid potential integration problems. And HP RFIC Designer links into major EDA frameworks from Cadence and Mentor,* so it fits into your existing design process. This unsurpassed range of capabilities gives your designers the freedom to create their best RFIC design ever.

HP RFIC Designer is just one of the many EDA solutions from HP EEs of for your communications product design. To learn more about HP RFIC Designer, or the rest of HP EEs of's product family, call your local sales office at one of the numbers listed below.

www.hp.com/info/rfic

Available for PC and UNIX systems.

ANOTHER WAY HP EESOF HELPS BRING YOUR BEST IDEAS INTO REALITY.

Enabling you to build
competitive RFICs,
HP RFIC Designer
is powered by
the innovative
HP Advanced Design
System software
technology from
HP EEs of.

EDA WINNER



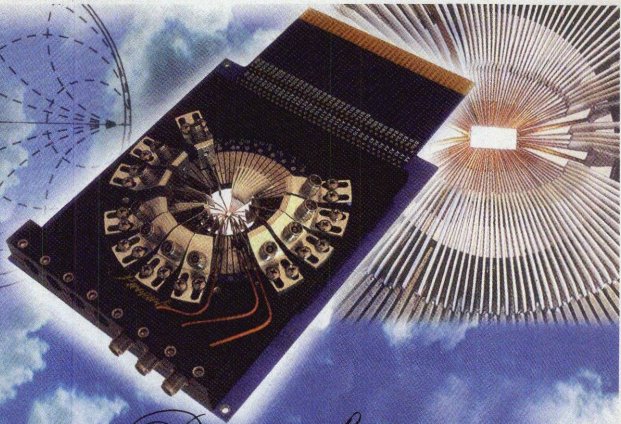
Circuit Envelope Simulator

©1997 Hewlett-Packard Co. TMFGS6403.3/INTL. Monitor Graphics is a registered trademark of Mentor Graphics Corp. Cadence is a trademark of Cadence Design Systems, Inc.

Australia 1800 628 481 • Austria 6600 8003 • Belgium (02) 778-3417 • Brazil (04-01) 726 8155 • Canada (800) 387-3124 •
China (96 10) 6596-0149 • Denmark (45) 96 15 15 • Finland (09) 8572-2348 • France (01) 69 36 41 14 • Germany (0 70 31) 14 61 93 •
Greece 04 736 40 36 • Hong Kong (852) 2509-7777 • Hungary 36 02 311 232 • Ireland (01) 615 8222 • Israel (03 53 89 107) •
Italy (02) 92 122 341 • Japan (81) 426-56-7832 • Korea (02-2) 7620-0900 • Malaysia (60-3) 291-0211 34400-8840 •
Mexico (05 5328) 4390 • Netherlands (020) 147 6222 • New Zealand (0849) 738-375 • Norway 20 73 5250 • Poland 48 22 390672 •
Singapore 1 800 352-8100 • South Africa 011 806 1100 • Spain (91) 631 1703 • Sweden (08) 444 22 77 • Switzerland (01) 735 72 00 •
(022) 780 41 80 • Taiwan 080 212 535 • United Kingdom 01344 369666



**HEWLETT®
PACKARD**



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.

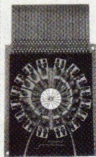


Not only do you get all the attractive features mentioned, but you get personal, professional service, rapid response, and continuous product support--all at an affordable price so your project can be completed on time and within budget.

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

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

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



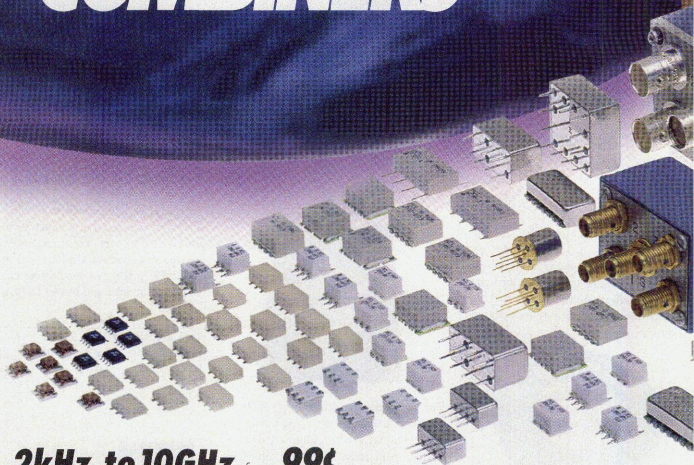
For technical assistance, custom product designs, or off-the-shelf delivery, call GGB Industries, Inc., at (941) 643-4400.

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

THE WORLD'S LARGEST SELECTION

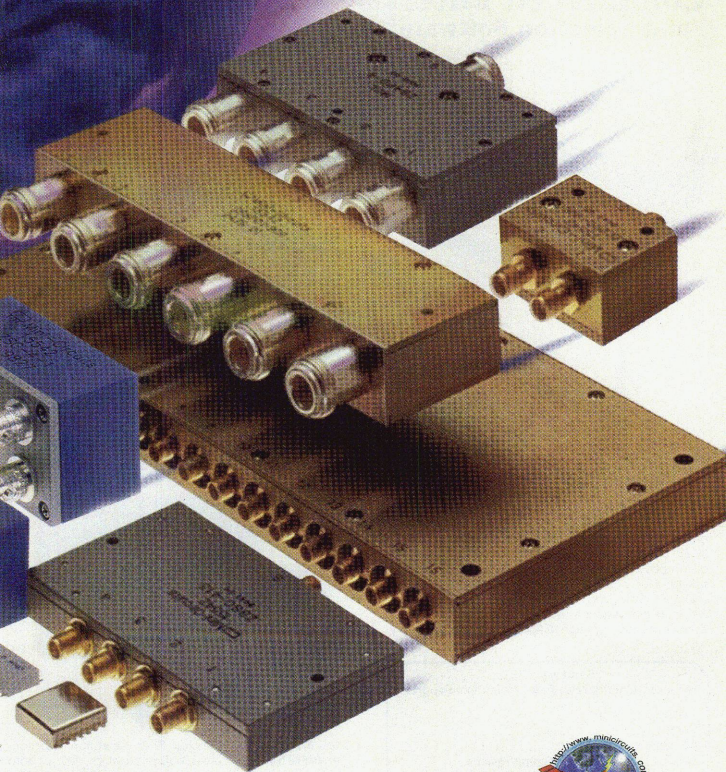
POWER SPLITTERS/ COMBINERS



2kHz to 10GHz from 99¢

Choose from over 550 standard off-the-shelf models from 2way and 3way to 48way; 0°, 90°, and 180°; 50 and 75 ohms covering 2kHz to 10GHz. Mini-Circuits will also supply your special needs and custom designs such as wider bandwidths, higher isolation, lower insertion loss and phase matched ports...all at catalog prices with rapid turnaround time. Case styles include surface mount, plug-in, flat pack, and coaxial connectorized... and custom case styles are no problem! Super-miniature and ultra-low profile surface mount units provide excellent solutions in cellular communications, cable systems, and countless wireless applications. And all units come with a 1 year guarantee and skinny 4.5 sigma performance repeatability unit-to-unit and production run to production run. Add fast delivery, unsurpassed applications support and value pricing, and the decision is easy. Call Mini-Circuits today!

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



see us on the web
<http://www.minicircuits.com>



 **Mini-Circuits®**

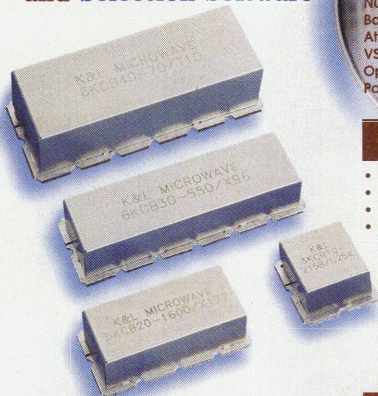
US 98 INTL 99
 CIRCLE READER SERVICE CARD

P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661 INTERNET <http://www.minicircuits.com>
 For detailed specs on all Mini-Circuits products refer to • 760- pg. HANDBOOK • INTERNET • THOMAS REGISTER • MICROWAVE PRODUCT DATA DIRECTORY • EEM

ISO 9001 CERTIFIED

F 194 Rev B

New **K^EL-com** Commercial Filters and Selection Software



K&L Microwave, the manufacturer that brought you **K^EL-flt**, now introduces its latest cost-effective filter product line and selection software... **K^EL-com**. When size, cost, performance and delivery are at a premium (when aren't they?), **K^EL-com** commercial filters are the answer. A cavity, lumped element or ceramic filter is not always practical due to size and/or cost. **K^EL-com** products provide filter solutions with small size, low-cost and excellent electrical performance. **Need it fast?** The **K^EL-com** line is standardized for high volume and short delivery.

K^EL-com Commercial Filters

Center Frequency
Filter Type
Number of Sections
Bandwidth
Attenuation
VSWR
Operating Temp.
Package Style

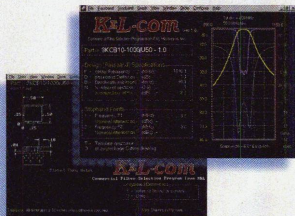
- 10 to 3000MHz
- Chebyshev Bandpass
- 2 to 6
- 5 to 20%
- -60dBc
- 1.5:1 typical
- -40 to +85°C
- Open Frame Leadless Surface Mount

Features

- High Volume
- Quick Turnaround
- Standardized Surface Mount Packaging
- Commercial Grade Components



K^EL-com Selection Software



The **K^EL-com** Commercial Filter Selection Program generates response curves, outline drawings, tabular data and part numbers based on user-defined filter parameters. Request your free copy of the **K^EL-com** Commercial Filter Selection Program on CD-ROM for Windows® 95/98 & NT, or download the program from K&L's website @: www.klmicrowave.com/keicom.html.

Send my **FREE**

K^EL-com Commercial Filter Selection Program

Name _____
Company _____
Address _____
City _____ State/Province _____
Country _____
Zip/Country Code _____
Phone () _____
FAX () _____
Email _____

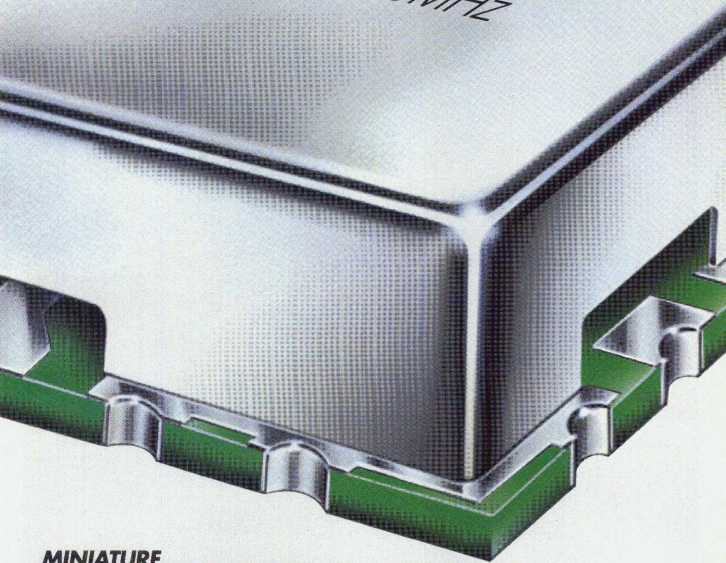
ISO 9001 Registered Quality Management System • www.klmicrowave.com

USA
Phone: 410-749-2424
FAX: 410-749-5725
Email: klsales@klmicrowave.com

EUROPE
Phone: 44-(0)-1262 605500
FAX: 44-(0)-1262 605504
Email: kleurope@kandal.demon.co.uk



ROS
50MHz to 1600MHz



MINIATURE SURFACE MOUNT VCO's \$12.95 from 101

The big news is Mini-Circuits miniature family of **50 to 1600MHz** ROS voltage controlled oscillators! Each unit is housed in a shielded 0.5"x0.5"x0.18" non-hermetic industry standard package for highly efficient wash-thru capability, reliability, and cost effectiveness. Models with "PV" suffix typically operate from a 5 volt power supply and require 5V tuning voltage to cover the frequency range. This makes them ideal for integration with monolithic PLL chips and commercial synthesizers working within the 245 to 1600MHz band. The series also features wide band 12V models optimized for 50 to 1410MHz linear tuning, up to one octave band widths, and low phase noise. Support your customers demands for smaller size and better performance, switch to ROS VCO's today!



ACTUAL SIZE

ROS SPECIFICATIONS:

Model	Freq. Range (MHz)	V _{tune} (V) Max.	Phase Noise* Typ.	Harmonics** (dBc)	Voltage (V)	Current (mA) Max.	Price \$ea. (5-40)
ROS-285PV	245-285	5	-100	-20	5	20	17.95
ROS-900PV	810-900	5	-102	-25	4.5	12	19.95
ROS-960PV	890-960	5	-102	-27	5	12	19.95
ROS-1000PV	900-1000	5	-104	-33	5	22	19.95
ROS-1600PV	1520-1600	5	-100	-26	5	25	18.95
ROS-100	50-100	17	-105	-30	12	20	12.95
ROS-150	75-150	18	-103	-23	12	20	12.95
ROS-200	100-200	17	-105	-30	12	20	12.95
ROS-300	150-280	16	-102	-28	12	20	14.95
ROS-400	200-380	17	-100	-24	12	20	14.95
ROS-535	300-525	17	-98	-20	12	20	14.95
ROS-765	485-765	16	-95	-27	12	22	15.95
ROS-1410	850-1410	11	-99	-8	12	25	19.95

*Phase Noise: SSB at 10kHz offset, dBc/Hz. **Specified to fourth.

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

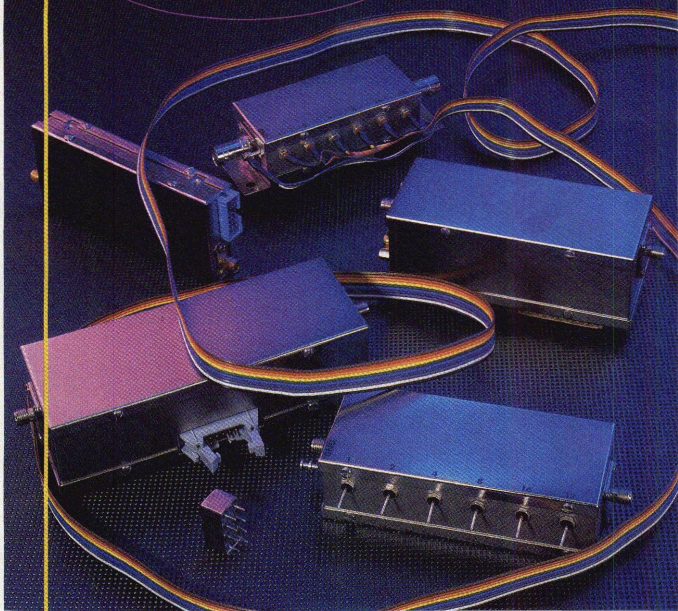
Mini-Circuits®

US 100 INTL 101
CIRCLE READER SERVICE CARD

P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661 INTERNET <http://www.minicircuits.com>

For quick access to product information see MINI-CIRCUITS CATALOG & WEB SITE • EEM • MICROWAVE PRODUCT DATA DIRECTORY • WWW.REGLOBAL.NET •

EXCELLENCE



Innovation

JFW has designed and manufactures over 1200 different programmable attenuators. Features include wide attenuation ranges, optional step sizes, various package styles and connector options to provide system designers the flexibility required in today's global market.

- New DC-2500 MHz Low Cost/High Performance series
- Solid-State, wide band models
- Models with frequency ranges up to 5Ghz
- GPIB controlled models available
- 50 and 75 ohm impedances available

JFW Industries, Inc.

5134 Commerce Square Drive • Indianapolis, Indiana 46237
Tele. (317) 887-1340 Fax (317) 881-6790

Internet— <http://www.jfwindustries.com>

E-mail— sales@jfwindustries.com

ISO 9001 Certified

Calibrate Your Vector Network Analyzer **ACCURATELY!**

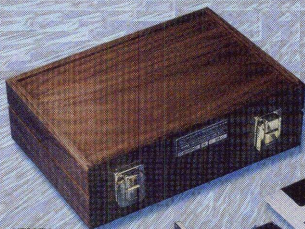
PROPERLY CALIBRATED vector network analyzers (VNAs) are essential for accurately determining the one- and two-port network characteristics of RF and microwave devices. TRL/LRL calibration is one of the most accurate VNA calibration methods available.

MAURY MICROWAVE's comprehensive line of coaxial and waveguide TRL/LRL VNA calibration kits provide accurate, stable and precise calibration standards that ensure accurate evaluation of VNA performance.

TRI-KITS – MAURY offers a variety of coaxial "TRI-KITS" that are ideal for performing TRL/LRL, short-open-load-thru (SOLT), and one-port calibrations for gated measurement. Available connector types are:

- 2.92mm (K)
- 3.5mm (also used for SMA testing)
- Type N
- 7-16
- 14mm (formerly GR900)
- 7mm (APC7)

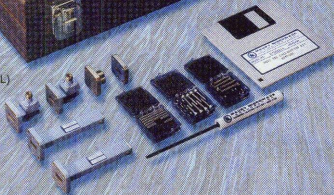
WAVEGUIDE TRL kits are available in all common, standard rectangular sizes from WR430 (1.7 to 2.6 GHz) through WR22 (33 to 50 GHz). If you require a specially configured calibration kit, please contact our Sales Department.



8860G14
(Type N TRL)



K7007H
(WR42 TRL)



For more information about these and other fine Maury products, contact our **SALES DEPARTMENT** at the numbers below.



**MAURY MICROWAVE
CORPORATION**

Visit us on the World Wide Web at
<http://www.maurymw.com>

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



microwave JOURNAL®

OCTOBER 1999 • VOL. 42, NO. 10

FEATURES

TECHNICAL FEATURES

22 Digital Predistortion Techniques for RF Power Amplifiers with CDMA Applications

Frank Zavosh, Mike Thomas, Chris Thron, Tracy Hall, Daniel Artusi, David Anderson, David Ngo and David Runton, Motorola Semiconductor Product Sector, Networking and Computing Systems Group

The application of digital predistortion to both GaAs and laterally diffused metal oxide semiconductor amplifiers with narrowband and wideband input signals

78 Understanding Offset 8-PSK Modulation for GSM EDGE

Ashkan Mashhour, Nokia Telecommunications

Eight-phase-shift keying (8-PSK) modulation and its derivation toward the form it takes in GSM enhanced data rates for GSM evolution (EDGE)

94 Vector Signal Measurement for 38 GHz Digital Radio Applications

G. Samuel Dow, Jeff Yang and Kuo-Hsiung Yen, TRW, Electronics Technology Division; and Robert Matreci, Eric Spotted-Elk, Stephen Pettis and Long Trinh, Hewlett-Packard, Santa Rosa Systems Division

A 38 GHz vector signal measurement test set and its application for performing vector signal analysis of a 37 to 40 GHz power amplifier module

108 High Efficiency Power Amplifier Design Using GaAs Heterostructure Field Effect Transistors

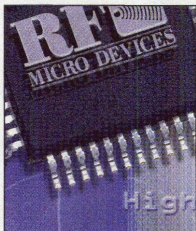
A.S. Virdee, Filtronic Components Ltd.; and B.S. Virdee, University of North London, School of Communications Technology and Mathematical Sciences

The computer-aided design and performance of high efficiency amplifiers operating in class AB/F at X-band

126 Impedance Measurements for High Power RF Transistors Using the TRL Method

Jean-Jacques Bouny, Motorola Semiconducteurs S.A.

Use of the thru-reflect-line (TRL) calibration technique to obtain precise characterization of high power RF transistors, including impedances and board measurements for de-embedding



ON THE COVER

A transceiver chipset for 2.4 GHz direct sequence spread spectrum applications is featured on this month's cover

Cover art courtesy of
RF Micro Devices

154

Microwave Journal (USPS 366-230) (ISSN 0192-6225, International Edition: ISSN 0192-6217, Euro-Global Edition) is published monthly by Horizon House Publications Inc., 695 Canton St., Norwood, MA 02062. Periodicals postage paid at Norwood, MA 02062 and additional mailing offices.

Photocopy Rights: Permission to photocopy for internal or personal use, or the internal or personal use of specific clients, is granted by *Microwave Journal* for users through Copyright Clearance Center provided that the base fee of \$5.00 per copy of the article, plus 8¢ per page, is paid directly to the Copyright Clearance Center, 222 Rosewood Drive, Danvers, MA 01923 USA (978) 750-8400. For government and/or educational classroom use, the Copyright Clearance Center should be contacted. The rate for this use is 0.05 cents per page. Please specify ISSN 0192-6225 *Microwave Journal* International or ISSN 0192-6217 *Microwave Journal* Euro-Global. *Microwave Journal* can also be purchased as 35 mm film from University Microfilms, Periodic Entry Department, 300 N. Zeeb Rd., Ann Arbor, MI 48106 (313) 761-4700. Reprints: For requests of 100 or more reprints, contact Kristen Dednah at (781) 769-9750.

POSTMASTER: Send address corrections to *Microwave Journal*, PO Box 3256, Northbrook, IL 60063-3256. 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, \$100.00 per year; two-year subscriptions, \$150.00; foreign, \$165.00 per year; two-year subscriptions, \$310.00; back issues (if available) and single copies, \$10.00 domestic and \$20.00 foreign.

©1999 by Horizon House Publications, Inc.



Horizon House also publishes
Telecommunications
and
Journal of Electronic Defense

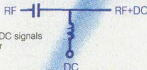
[Continued on page 12]

Printed under Canadian international publications mail agreement #0738954



BIAS TEES

From **\$25⁹⁵**



Easily combines RF+DC signals for your modulation or test requirements.

Now up to 500mA DC current 100kHz-6GHz

With Mini-Circuits Bias-Tees, you can DC connect to the RF port of an active device without effecting its RF properties...modulate a laser, apply DC to an amplifier output, and more! Using statistical process control plus combining magnetics and microstrip, large DC currents may pass through the Bias-Tee without saturation and degradation of performance. At 1/3 to 1/4 the price of competitive units, these new Bias-Tees are available in surface mount, pin, and connectorized models. So why wait, solve your connection problems with Mini-Circuits Bias-Tees.



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

Model	Freq (MHz) F ₁ -F ₂	Insertion Loss (dB Typ.)			Isolation (dB Typ.)			VSWR (Typ.)	Price \$ ea 1-9 qty.
		L	M	U	L	M	U		
▲ZFBT-4R2G	0-4200	0.15	0.6	0.6	32	40	50	1.1:1	63.95
▲ZFBT-4G	0-6000	0.15	0.6	1.0	32	40	50	1.1:1	79.95
▲ZFBT-4R2GW	0.1-4200	0.15	0.6	0.6	25	40	50	1.1:1	79.95
▲ZFBT-4GW	0.1-6000	0.15	0.6	1.0	25	40	50	1.1:1	99.95
▲ZFBT-4R2G-FT	0-4200	0.15	0.6	0.6	N/A	N/A	N/A	1.1:1	59.95
▲ZFBT-4G-FT	0-6000	0.15	0.6	1.0	N/A	N/A	N/A	1.1:1	79.95
▲ZFBT-4R2GW-FT	0.1-4200	0.15	0.6	0.6	N/A	N/A	N/A	1.1:1	79.95
▲ZFBT-4GW-FT	0.1-6000	0.15	0.6	1.0	N/A	N/A	N/A	1.1:1	99.95
▲ZFBT-6G-1W	2-6000	0.2	0.6	1.6	75	45	35	1.25:1	92.95
■PBTC-1G	0-1000	0.15	0.2	0.3	27	33	30	1.1:1	25.95
■PBTC-3G	0-3000	0.15	0.3	1.0	27	33	35	1.6:1	35.95
■PBTC-1GW	0.1-1000	0.15	0.3	0.3	25	33	30	1.1:1	35.95
■PBTC-3GW	0.1-3000	0.15	0.3	1.0	25	33	35	1.6:1	46.95
■JEBT-4R2G	0-4200	0.15	0.6	0.6	32	40	40	-	39.95
■JEBT-4G	0-6000	0.15	0.7	1.3	32	40	40	-	59.95
■JEBT-4R2GW	0.1-4200	0.15	0.6	0.6	25	40	40	-	59.95
■JEBT-6GW	0.1-6000	0.15	0.7	1.3	25	40	30	-	89.95

NOTE: Isolation dB applies to DC to RF and DC to RF+DC ports.

▲ SMA Models, FT Models Have Feedthrough Terminals #Type N, BNC Female or DC

■ Pin Models ■ Surface Mount Models

Mini-Circuits®

US 102 INTL 103
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 164 Rev B



microwave JOURNAL®

FEATURES

TUTORIAL

136 Adaptive Feedforward Linearization for RF Power Amplifiers

Shawn P. Stapleton, Simon Fraser University, School of Engineering Science

An optimized approach to solving the problem of intermodulation distortion in multichannel, wideband applications

TECHNICAL FEATURE

146 Microwave MCM-C Utilizing Low Loss LTCC and Photo-patterning Processes

Peter Barnwell, Michael O'Neill and Charles Sabo, Heraeus Inc., Cermalloy Division; and Charles Free, Middlesex University

A new low loss, low temperature cofired ceramic (LTCC) technology that, when combined with a photo-patterned thick-film technology, offers outstanding interconnect density and microwave performance

PRODUCT FEATURES

180 A Microwave Antenna Path-alignment Test Set

XL Microwave Inc.

A test set that offers an accurate and cost-effective method of microwave antenna alignment that is easily performed by two technicians without the use of system radios

186 Inverted Mesa Fundamental-mode Crystals

Champion Technologies Inc.

Low cost, high frequency crystals developed using a proprietary processing technology that produces crystals with low series resistance, high pulling ability and good unit-to-unit and lot-to-lot repeatability

190 Programmable Attenuator Subsystems

Weinschel Corp.

A flexible, easy-to-program, low cost attenuator solution for benchtop test and calibration setups and subsystem applications

DEPARTMENTS

15...Coming Events

18...Workshops & Courses

53...News from Washington

57...International Report

61...Commercial Market

64...Around the Circuit

166...Catalog Update

194...New Products

216...New Literature

218...The Book End

220...Ad Index

224...Sales Reps

STAFF

PUBLISHER/EDITOR: HARLAN HOWE, JR.

ASSOCIATE PUBLISHER: EDWARD JOHNSON

MANAGING EDITOR: AMY E. NORCROSS

TECHNICAL EDITOR: FRANK M. BASHORE

STAFF EDITOR: CHRISTINA M. SCIAMMACCO

EDITORIAL SECRETARIES: ALLISON GRECO

GAIL SANZI

CONSULTING EDITOR: HOWARD J. 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: JUDY WIKLUND

ART DIRECTOR: ROBERT PIKE

DTP COORDINATOR: JANET A. MACDONALD

GRAPHIC DESIGNER: SACHIKO STIGLITZ

GRAPHIC DESIGN GROUP:

SANDRA DENEALUT

SARA KEATING

ANDREW ROSS

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

EDITORIAL REVIEW BOARD:

Dr. S.F. Adam

Dr. I.J. Bahl

Dr. R.C. Baird

D.K. Barton

Dr. C.B. Bebohouck

K.J. Button

Dr. K.L. Carr

H.F. Chappell

N.R. Dietrich

G. DiPiazza

Dr. Z. Galani

Dr. F.E. Gardiol

Dr. A. Giaridini

Dr. P. Goldsmith

Dr. M.A.K. Hamid

J.L. Heaton

E.E. Hollis

Dr. W.E. Hord

Dr. L. Lewin

Dr. J.C. Lin

Dr. Stephen Mass

Dr. R.J. Malloux

S. March

Dr. G.L. Matthiae

W.G. Matthiae

Dr. D.N. McQuiddy

Dr. R.L. Mettifer

C.K.S. Miller

Dr. F.R. Morgenthauer

Dr. N.S. Nahman

Dr. J.M. Oserchuk

S.M. Perlow

Dr. W.L. Pritchard

Dr. L.J. Ricciardi

Dr. U. Rohde

Dr. G.F. Ross

Dr. J.A. Saloom

Dr. P. Stauecker

H. Stuehlför

Dr. H.E. Stockman

J.J. Taub

Dr. J.G. Tenedorio

G.D. Vendelin

Dr. W.A.G. Voss

Dr. B.O. Weinschel

Dr. P. Weissglas

Dr. J. Wiltse

EXECUTIVE EDITORIAL OFFICE:

685 Canton Street, Norwood, MA 02062

Tel: (781) 766-6750

Fax: (781) 766-5037

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

604 Semi-Flex® Cable Assemblies...

TIGHT Applications with TIGHT Delivery Schedules




.13
Bend
Radius

.047
Cable
Diameter

- .047" Cable Maximum Diameter
- .13" Minimum Bend Radius
- .38" Preferred Bend Radius
- -65 / +105°C Temperature Range

Now, over **40,000** QMI Cable Assemblies are in stock at **Richardson Electronics**.

In stock, fully specified Assemblies with selected lengths and Connector combinations. Data sheets available at www.qmiinc.com.

Connector Specifications at QMIINC.COM	Impedance Nominal (Ohms)	Capacitance Nominal (pF/FT)	Velocity of Propagation Nominal (%)	Relative Shielding (dB Min)	Insulation Resistance (Megohms Min)	Dielectric Withstanding Voltage (VRMS Min.)	Electric Delay (ns/FT)	Electric Delay (ps/Inch)	Max. Pulse RF Power (Watts)*	F (in GHz)	Max. CW Watts
 SMA.604	50	31.40	70.5	-100	1000	1000	1.44	120	1250	1 2 4 6 12 18	33 24 18 16 13 10
 MCX.604	50	31.40	70.5	-100	1000	1000	1.44	120	500	0.5 1 2 4 6	45 33 20 17 13
 MCXRT.604	50	31.40	70.5	-100	1000	1000	1.44	120	500	0.5 1 2 4 6	45 33 24 18 16

*Into a 50 OHM System, with duty cycle less than CW rating.



MADE IN THE USA



Tensolite

QMI®

A CARLISLE Company

Microwave
Interconnects

301 Ballardvale St. Wilmington, MA 01887

1-800-362-FLEX

FAX: (978) 988-9393

www.qmiinc.com Email: sales@qmiinc.com



"Do it Yourself" - call QMI for cable and connector price and availability. Selected options and lengths in stock for immediate delivery from QMI's Worldwide Distributor:

Richardson Electronics
Engineered Solutions
1-800-RF-POWER

Introducing...



TESTMART™

The Global Test and Measurement Center

TestMart is the Internet's premier website for test and measurement equipment

TestMart Offers:

Search and Compare on over 8,000 Products

Search on up to eight parameters in each of 40 different product categories such as spectrum analyzers, oscilloscopes, signal sources and logic analyzers. Search criteria are category-specific and include parameters such as bandwidth, acquisition speed, record length, minimum SSB noise and list price. Evaluate and download side-by-side comparisons across manufacturers.

eStore

Search for and Buy from an extensive offering of thousands of New and AccuCal™ Refurbished instruments. Save big with TestMart eStore Specials. Can't find what you are looking for? Try our Custom Sourcing service and let our experts perform an exhaustive search.

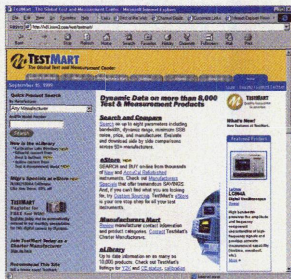
Manufacturer's Mart

Information on over 500 manufacturers searchable by product category, manufacturer name and product type. This is the industry's most complete product research tool.

eLibrary

Up to date information on over 10,000 products; e.g. Y2K and CE status, calibration intervals, product introduction and out-of-support dates, and application notes. Pinpoint a Calibration Lab nearest to you with our worldwide Calibration Labs Directory. Browse new editorial features from industry sources such as Frost & Sullivan and Test & Measurement World.

Buy and Sell over
2,000 products at
our eStore



Manufacturers: Become a TestMart partner and receive tremendous benefits including increased sales, hot leads, and onsite banner advertising. Contact Don McCook at 650-853-5993 or email sales@testmart.com.

www.testmart.com

A Technical Communities Website

CIRCLE 172 ON READER SERVICE CARD



COMING EVENTS

1999 International Semiconductor Device Research Symposium (ISDRS '99) December 1-3, 1999 Charlottesville, VA

Sponsors: IEEE MTT and ED Societies. Topics: Fundamental concepts in novel devices and advanced processing technologies, including new material and device characterization, microwave and millimeter-wave devices, microelectrical mechanical systems, nanoelectronics and optoelectronics. Contact: Lori Tawney, conference coordinator (804) 924-3744 or e-mail: engineering-outreach@virginia.edu. Additional information is available at www.ee.virginia.edu/~isdrs/.

54th ARFTG Conference December 2-3, 1999 Atlanta, GA

Sponsors: The Automatic RF Techniques Group (ARFTG). Topics: Characterization of broadband access technologies, automated microwave and RF measurements, simulation tools and associated products including network analysis, calibration techniques, on-wafer measurements, power and noise. For exhibition information, contact: Leonard Hayden (503) 601-1580 or e-mail: Leonard@cmicro.com. Additional information is available at www.arftg.org.

Sixteenth Annual IEEE Semiconductor Thermal Measurement and Management Symposium March 21-23, 2000 San Jose, CA

Sponsors: Components, Packaging and Manufacturing Technology Society of the IEEE and the National Institute of Standards and Technology. Topics: New developments relating to the thermal characterization of electronic components, subsystems and systems, including generation and removal of heat from within semiconductor devices, measurement of device temperatures and simulation of device and system thermal behavior. Contact: Bonnie Crystall, conference manager, C/S Communications Inc., PO Box 23899, Tempe, AZ 85285 (520) 323-2870, fax (520) 323-2803 or e-mail: cscom@indirect.com.

2000 International Conference on GaAs Manufacturing Technology May 1-4, 2000 Washington, DC

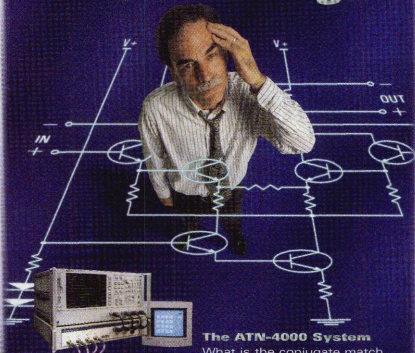
Call for papers. Topics: Compound semiconductor manufacturing, 150-nm conversion, cycle time reduction, CIM tools for manufacturing environmental impact and cost management; processing, lithography, gate formation, low capacitance crossovers, high and low dielectric constant materials, failure mechanisms and module integration issues, test and reliability, high speed, high volume and low cost testing; device technologies, yield enhancement

(MESFET, pHEMT, HBT, HFET, PIN) and thermal enhancement; and optical devices and materials and packaging. Send: original abstract with supporting data and 45 copies. Send to: Bruce Bernhardt, Motorola, MD EL-720, 2100 East Elliot Rd., Tempe, AZ 85284 (408) 413-4427. Submissions also can be sent electronically in PDF format to abstractsubmission2000@gaasmantech.org. **Deadline: November 1, 1999.** Additional information is available at www.gaasmantech.org.

50th Electronic Components and Technology Conference May 21-24, 2000 Las Vegas, NV

Sponsors: IEEE Components, Packaging and Manufacturing Technology Society and Electronic Industries Alliance. Topics: New developments in electronics technology, including advanced packaging, components and RF, connectors and contacts, education, interconnections, manufac-

Take the guesswork out of differential circuit design



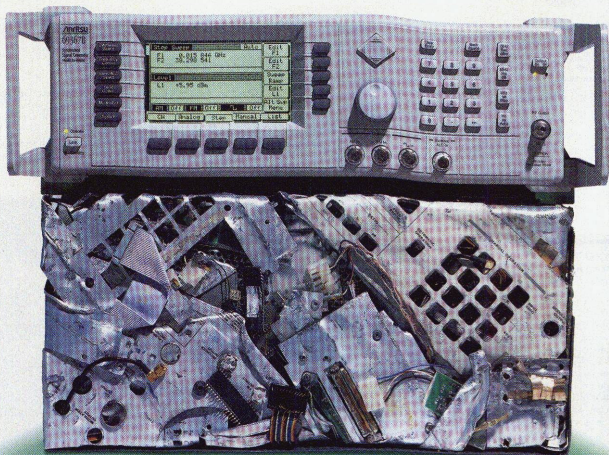
The ATN-4000 System

What is the conjugate match of your differential 2-port device? How much common mode rejection does it have? How much of the differential input signal is being converted to common mode? If the answers to these types of questions have been eluding you, check out the new ATN-4000 Multiport S-parameter Test System at www.atnmicrowave.com. The answers have never been so easy to find.

atnmicrowave

Tools for Advanced Products

101 Billerica Avenue, Building 4, North Billerica, MA 01862-1256 USA
877-ATN-TOOLS • 978-667-4200 • Fax 978-667-8548 • www.atnmicrowave.com



Waste Not. Want Not.

If you're throwing out your old technology every time you upgrade, perhaps what you're really scrapping is your productivity. Introducing the fully-upgradeable El Toro[®] Microwave Synthesizers from Anritsu: the 68C and 69B. With 42 levels of technology to choose from, you can upgrade to a higher-performing model at anytime without buying a completely new synthesizer.

Choose from the widest frequency coverage and the lowest phase noise available today. Whether you want

CW signals to 8 GHz, fully modulated signals to 65 GHz, or anything in between, Anritsu can configure the right signal generator for you. And because you're buying an Anritsu, you'll also enjoy the peace of mind that comes with owning one of the hardest working and longest lasting synthesizers on the market.

For more information call 1-800-ANRITSU or check out our website at www.global.anritsu.com. The El Toro from Anritsu. The end to disposable technology.



El Toro 68C/69B Microwave Synthesizer

©1999 Anritsu Company Sales Offices: United States and Canada, 1-800-ANRITSU, Europe 44(0)1582 433200, Japan 81(03)3446-1111, Asia-Pacific 65-2822400, South America 55(21)527-6922, <http://www.anritsu.com>

Anritsu

One world. One name. Anritsu.

CIRCLE 10 ON READER SERVICE CARD



turing, materials and processing, modeling and simulation, optoelectronics, and quality and reliability. Contact: Michael McShane (512) 933-6403, fax (512) 933-5844.

Fifth International Workshop on Finite Elements for Microwave Engineering
June 8-9, 2000

Sponsors: Worcester Polytechnic Institute, the University of Florence and Ansoft Co. Topics: Application areas of antennas and scattering problems, microwave electronics and the finite element method. Contact: J.F. Lee, Worcester Polytechnic Institute, e-mail: jinlee@ece.wpi.edu or R. Lee, Ohio State University, e-mail: lee@ee.eng.ohio-state.edu. Additional information can be found at www.ece.wpi.edu/~jinlee.

2000 IEEE Radio Frequency Integrated Circuits (RFIC) Symposium
June 11-13, 2000
Boston, MA

Sponsors: MTT-S. Topics: Highly integrated ICs and system IC solutions in the RF/microwave frequency range, including semiconductor technology; mixed-signals, cellular/PCS/TSM, receiver, transmitter, and microwave and mm-wave ICs; multifunction ICs and multichip modules; RF/microwave subsystems; integrated filters and antennas; and packaging, testing and reliability. Contact: Christian Kermarrec (781) 937-1217 or e-mail: christian.kermarrec@analog.com. Additional information is available at www.ims2000.org/rfic.htm.

2000 IEEE MTT-S International Microwave Symposium and Exhibition
June 11-16, 2000
Boston, MA

Call for papers. Sponsors: IEEE MTT-S. Topics: Advancement and application of RF and microwave theory and techniques, including analysis and design; components and assemblies; passive and active microwave technology; frequencies greater than 30 GHz; fabrication, integration and test; and applications. Electronic submissions are highly recommended via www.ims2000.org. For hard copy submissions, send to: International Microwave Symposium c/o LRW Associates, 468 Walden Trail, Waxhaw, NC 28173 (704) 841-1915. Send: author registration form, including 30- to 50-page abstract, and four-page summary. **Deadlines:** December 3, 1999 (electronic submissions), November 29, 1999 (hard copy submissions). For symposium information, contact: Peter Staecker, technical program chair (781) 861-7643, fax (781) 863-5751 or e-mail: p.staecker@ieee.org. For exhibition information, contact Kristen Dednahl, Horizon House Publications, 685 Canton St., Norwood, MA 02062 (781) 769-9750, fax (781) 769-5037 or e-mail: kdednahl@mvjournal.com. Additional information is available at www.ims2000.org.

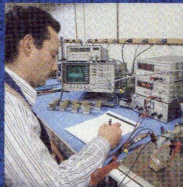
ARFTG Conference
June 15-16, 2000
Boston, MA

Sponsors: ARFTG and IEEE MTT-S. Topics: Issues in nonlinearity characterization for RF and microwave components, subsystems and systems, including digital mobile (CDMA and GSM), PCS and third-generation wireless technology, local multipoint distribution sys-

COMING EVENTS

tems, multichannel multipoint distribution systems and other broadband wireless access systems, digital cable and broadcast television, low earth orbit satellite and other satellite communications systems, wireless local loop applications and wireless local area networks. Contact: Mike Fennelly, Roos Instruments Inc., 2285 Martin Ave., Ste. C, Santa Clara, CA 95050 (978) 258-4101 or e-mail: mfennelly@roos.com. Additional information is available at www.ims2000.org/arftg.htm.

We're Gunn Ho on Repairs



MDC is a world-leading supplier of quality Gunn oscillators in the 13, 15, 18, 23 and 38 GHz bands. If your microwave radio requires changes to its Gunn oscillators, we can help. MDC offers timely

and cost-effective Gunn oscillator solutions. We are "GUNN HO" to repair, replace, or upgrade Gunn oscillators from any manufacturer.

MDC also offers repair services for solid state sources, amplifiers, klystron power supplies, and other microwave radio components.

**MICROWAVE
DEVELOPMENT
COMPANY, INC.**

EST. 1961



Forty One Northwestern Drive • Salem, New Hampshire 03079

Sales: (603)-870-6280 • Fax: (603)-870-6210

E-Mail: microwav@mdc.usa.com

www.mdc-inc.net

Precision

MCLI

RF-Microwave Components

- Immediate Delivery
- High Performance
- Low Cost
- Superior Selection
- 0.005 - 26.5 GHz
- New Catalog Available



Power Dividers

Directional Couplers

Switches

- Power Dividers
- Couplers
- Switches
- Hybrids
- Isolators/Circulators
- Attenuators
- Terminations
- Oscillators
- Filters
- Amplifiers
- Waveguide
- Custom Designs

Visit
us at:
www.mcli.com

See Online Catalog at:
<http://www.mcli.com>

1-800-333-MCLI (6254)
Fax: (727) 381-6116

Microwave
Communications
Laboratories Inc.
7255 30th Avenue North
St. Petersburg, FL 33710
<http://www.mcli.com>

MICROWAVE COMMUNICATIONS LABORATORIES INC. Toll Free: 1-800-333-6254



WORKSHOPS & COURSES

PRINCIPLES OF MODERN RADAR

■ **Topics:** Basic radar principles, techniques and technology, including antennas, transmitters, receivers, signal processing, Doppler polarization and reflectivity measurements. Fee: \$1295.

■ **Site:** Atlanta, GA

■ **Date:** November 1-5, 1999

■ **Contact:** Continuing Education, Georgia Institute of Technology, Atlanta, GA 30332 (404) 894-2547 or e-mail: conted@gatech.edu.

LTCC MEASUREMENT AND TESTING FOR WIRELESS APPLICATIONS

■ **Topics:** Measurement and testing of low temperature co-fired ceramic (LTCC) technology, including reproducible dielectric measurements at frequencies above 1 GHz, modeling of tape processes and phase equilibria data for electrode/ceramic interactions.

■ **Site:** Gaithersburg, MD

■ **Date:** November 4-5, 1999

■ **Contact:** Steve Freiman or Carolyn Sladic, National Institute of Standards and Technology (301) 975-6119 or e-mail: stephen.freiman@nist.gov.

DIGITAL WIRELESS TELECOMMUNICATIONS: AN INTRODUCTION

■ **Topics:** Analog and digital cellular technologies, applications and regulatory status in the US and Europe; PCS trends; and mobile, LEO and MEO satellite systems. Fee: \$1125.

■ **Site:** Washington, DC

■ **Date:** November 15-17, 1999

■ **Contact:** P.J. Mondin, George Washington University Continuing Engineering Education Program, 2029 K St. NW, Suite 200, Washington, DC 20052 (800) 424-9773 or e-mail: pj@ceep.gwu.edu.

BASICS OF WIRELESS FOR NONENGINEERS

■ **Topics:** Wireless terminology; microwave, satellite, cellular/PCS and WLL systems; the history of telecommunications; and key players in the wireless industry. Fee: \$795.

■ **Site:** Reston, VA

■ **Date:** November 16-17, 1999

■ **Contact:** Comsearch Center for Technical Training, 2002 Edmund Halley Dr., Reston, VA 20191 (800) 318-1234 or e-mail: info@comsearch.com.

FREQUENCY SYNTHESIS TECHNOLOGY AND APPLICATIONS IN WIRELESS SYSTEMS

■ **Topics:** Direct digital, direct analog and digital signal processing principles; phase noise theory and testing; and simulation and practical considerations of CAD tools. Fee: \$1250.

■ **Site:** Orlando, FL

■ **Date:** December 1-3, 1999

■ **Contact:** Besser Associates, 201 San Antonio Circle, Bldg. E, Mountain View, CA 94040 (650) 949-3300, or e-mail: info@bessercourse.com.

HF COMMUNICATION TECHNOLOGY: ADVANCED TECHNIQUES

■ **Topics:** Traditional and modern approaches to high frequency (HF) communications system design and operation; HF direction-finding technologies; and ionospheric and HF channel variability. Fee: \$1445.

■ **Site:** Washington, DC

■ **Date:** December 6-10, 1999

■ **Contact:** P.J. Mondin, George Washington University Continuing Engineering Education Program, 2029 K St., NW, Ste. 200, Washington, DC 20052 (800) 424-9773 or e-mail: pj@ceep.gwu.edu.

RF AND WIRELESS COMPONENT DESIGN USING ELECTROMAGNETIC SIMULATION

■ **Topics:** Solutions to complex geometries, discontinuities, transistors in multilayer structures, planar antennas and calibration structures, and choosing the appropriate CAD package.

■ **Site:** Denmark

■ **Date:** December 9-10, 1999

■ **Contact:** Continuing Education Institute-Europe, PO Box 910, S-612 25 Finspong, Sweden, +44 122 175 70 or e-mail: cei.europe@cei.se. Additional information is available at www.cei.se.

SELF-STUDY RADAR COURSE

■ **Topics:** Radar principles, functions and parameters, the radar equation, target detection, tracking and track-while-scan, radar hardware, signal processing and case studies. Textbook included. Fee: \$384

■ **Contact:** IEEE Customer Service Dept., 445 Hoes Lane, PO Box 1331, Piscataway, NJ 08855 (800) 678-4333 or e-mail: customer-service@ieee.org.



We make
noise...

To make
your products
quiet!

Noise Com is the global provider of Noise Generators, Noise Sources, Noise Power Ratio Test Sets, Noise Diodes and specialized Noise Test Solutions.

For more information about our products, applications or how we may solve your testing needs, contact us:

Noise Com
E. 64 Midland Avenue, Paramus, NJ 07652
Phone: (201) 261-8797 Fax: (201) 261-8339
Email: info@noisecom.com
Web Site: <http://www.noisecom.com>

NOISE/COM

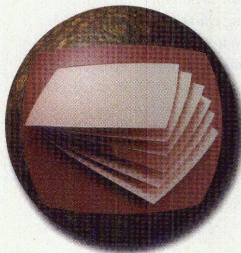
NOW THERE'S A
WHOLE WORLD OF LAMINATES FOR A
UNIVERSE OF HIGH FREQUENCY, HIGH PERFORMANCE
APPLICATIONS. ALL UNDER ONE ROOF.



INTRODUCING ROGERS ULTRALAM®1000 WOVEN GLASS PTFE LAMINATES.

With the introduction of new **ULTRALAM®1000** Woven Glass PTFE Laminates for base station antenna and power amplifier applications, Rogers extends its capabilities to offer competitively priced laminates. And Rogers ExpressSM next-day shipping service is available for customers who need laminates right away.

ULTRALAM®1000 materials are available in up to 4'x10' sheets, making them ideal for large panel antennas. Standard thicknesses include 0.020"



(.5mm), 0.031" (.75mm), and 0.062" (1.5mm) for dielectric constants of 2.17, 2.50, and 3.0.

ROGERS HAS IT ALL.

For more than 30 years, Rogers has led the industry in the design and manufacture of high frequency and high performance printed circuit board laminates for RF and microwave applications. Today, we offer the broadest product range on the market, whether you are designing cellular and

PCS base station antennas, power amplifiers, LNB's for direct broadcast systems, patch antennas, or high speed digital circuits. More design engineers and purchasing managers are turning to the convenience of a single source to meet their needs.

WORLDWIDE SERVICE AND DELIVERY.

With an additional new laminate manufacturing plant in Ghent, Belgium, Rogers has further extended its ability to serve global customers. With offices in the U.S., Belgium, Japan, Hong Kong, and Taiwan, you're never far from the source. In fact, many products can be shipped next-day via Rogers ExpressSM. And as always, Rogers Technical Support Specialists are available to answer your questions and help you choose the right laminates for your design challenges.

CONTACT US TODAY.

To learn more about Rogers high frequency and high performance laminates, including ULTRALAM®1000 material, call a Materials Specialist today at 480-961-1382, or visit our web site at www.rogers-corp.com/mwu.

Either way, you'll discover that doing business with Rogers makes a world of difference.

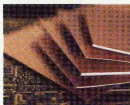
ROGERS

SINCE 1832



RO4000®

- Ability to laminate multilayer hybrid circuits in a single lamination cycle
- Easier and less costly to fabricate
- Improved performance



RO3000™

- Outstanding electrical performance
- Uniform mechanical properties over a range of dielectric constants



TMM®

- Stable electrical and mechanical performance vs temperature
- Can be manufactured using standard PCB fabrication techniques



RT Duroid®

- Reinforced PTFE laminates
- Superior electrical characteristics
- Low dissipation factor
- Highly predictable performance

DIGITAL PREDISTORTION TECHNIQUES FOR RF POWER AMPLIFIERS WITH CDMA APPLICATIONS

Power amplifiers (PA) used in the next-generation wireless communication systems based on spread spectrum techniques must exhibit exceptional linearity. This linearity must be achieved without sacrificing efficiency to a great extent. Digital predistortion techniques have been shown to improve the linearity of PAs for narrowband applications. In this article, digital predistortion is applied to both GaAs and laterally diffused metal oxide semiconductor (LDMOS) amplifiers with narrowband and wideband input signals. The efficacy of the digital predistortion under various input signal peak-to-average power ratios is also considered.

With the increasing importance of spectral efficiency in mobile communications, linearity of the RF PA has become a critical design issue for non-constant-envelope digital modulation schemes.¹ This issue is particularly significant in spread spectrum applications such as CDMA and wideband CDMA (W-CDMA) base stations, where the peak-to-average ratio of modulated RF signals can vary over a range of 3 to 12 dB. The concern for linearity is primarily due to the stringent restrictions on intermodulation products and out-of-band power emission requirements. Furthermore, amplification of multicarrier (multichannel) signals requires adequate amplifier linearity in order to avoid significant cross modulation. Additionally, for bandwidth-efficient modulation the amplifier nonlinearity can produce substantial signal distortion and, hence, increased bit error rates (BER).²

Linearity is achieved, in part, through the use of more linear amplifiers such as class A amplifiers, and by operating the amplifier backed off from the saturation range so that the signal level is confined to the linear region of the amplifier characteristics. However, this approach results in low DC-to-RF conversion efficiency, which is particularly costly in base station applications. Furthermore, low DC-to-RF conversion necessitates high current oper-

[Continued on page 24]

FRANK ZAVOSH, MIKE THOMAS,
CHRIS THRON, TRACY HALL, DANIEL
ARTUSI, DAVID ANDERSON, DAVID NGO
AND DAVID RUNTON
Motorola Semiconductor Product Sector,
Networking and Computing
Systems Group
Tempe, AZ

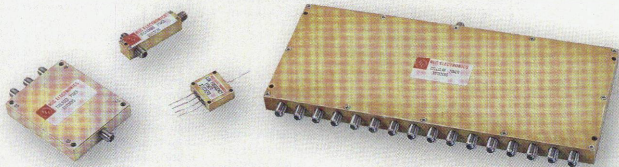
A Formal Invitation

To Try RLC

Power Dividers

2 to 32 Way • 0.01 to 26 GHz • Wide Bandwidths
Multiple Outputs • Low Insertion Loss • Low VSWR

*RLC Power Dividers are ideal for Cellular, PCS, ISAT,
Microwave Radio, LANs, and Wireless applications.
Delivery responsive to your needs.*



*Miniature, Surface Mount,
Flatpack and Connectorized*

Excellent Phase and Amplitude Balance

Extremely High Isolation

SMA, N, BNC, TNC, or Pins

50Ω or 75Ω

MIL-E-5400, Class 3

ISO-9002 Certified

*Custom Integrated Components
(Per Your Requirements)*

Cellular (800 - 900 MHz)

PCS (1.8 - 2.0 GHz)

Standard (0.01 - 26 GHz)

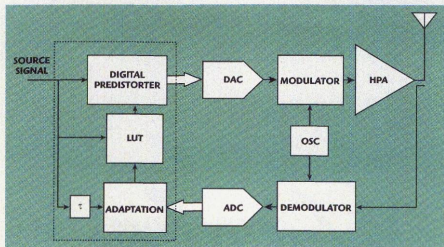
*Send for Our
Catalog Today!*



RLC ELECTRONICS, INC.

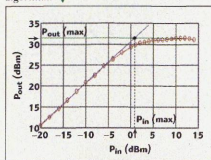
83 Radio Circle, Mount Kisco, New York 10549 • Telephone: 914-241-1334 • Fax: 914-241-1753
e-mail: sales@rlcelectronics.com • www.rlcelectronics.com

RLC is your complete Microwave Component source...
Switches, Filters, Couplers, Terminations, Attenuators, DC Blocks, Bias Tees & Detectors.



▲ Fig. 1 An adaptive digital predistortion system schematic.

Fig. 2 Limitation of the predistortion algorithm. ▼



ating points, resulting in undesired thermal effects.

A viable alternative to low efficiency linear amplifiers is the application of a linearity technique to more efficient amplifiers such as class AB or class C PAs. A number of linearization techniques have been reported in recent years, including Cartesian feedback, adaptive baseband predistortion, envelope elimination and restoration (EER), linear amplification with nonlinear components/combined analog locked loop universal modulator and feedforward.³⁻⁵ Although these techniques have been shown to improve linearity in certain applications, many of them suffer from limitations in bandwidth, precision or stability. Any linearization technique considered for third-generation (3G) cellular base station applications must contend with input signals exhibiting both wide bandwidth and large peak-to-average ratios.

One technique that can potentially compensate for PA nonlinearities in such an environment is adaptive digital predistortion. In this approach, since the predistortion is implemented digitally, a greater degree of precision

can be achieved when computing the predistortion coefficients. Also, unlike analog systems, there is no concern for stability in adaptive digital predistortion schemes. Finally, with the availability of high speed digital signal processors (DSP), adequate million instruction per second (MIPS) levels are available to treat the wideband signals found in today's advanced spread spectrum systems.

ADAPTIVE DIGITAL PREDISTORTION

The simplified schematic of an adaptive digital predistortion system is shown in **Figure 1**. A fully adaptive digital predistortion system requires the addition of a predistorter circuit consisting of a digital predistorter and look-up table (LUT) to the transmission path in addition to a feedback path consisting of a demodulator, analog-to-digital converter (ADC) and adaptation circuit for updating the LUT. Most common implementations of digital predistortion utilize standard DSPs. Such processes typically operate with a wordlength of 16 or 32 bits, which provides sufficient accuracy for most applications. In specific applications, application-specific ICs (ASIC) are designed to implement the predistorter system, providing flexibility in controlling wordlength and power consumption.

The functionality of digital predistortion can be best described by representing the signal at various points in the system as baseband complex envelopes. The block diagram assumes that all components of the system except the predistorter and high power amplifier (HPA) have a linear

response and, hence, can be ignored in the analysis. The predistorter is equivalent to a nonlinear circuit with gain expansion response that is the inverse of the PA gain compression (AM/AM) response, and a phase rotation that is the negative of the PA phase rotation (AM/PM). Hence, in the most ideal case, the following relationships hold for all levels of input power:

$$|F(x_i)| \bullet |G(x_i) F(x_i)|^2 = K$$

$$\Phi_F = -\Phi_G$$

where

x_i = amplitude of the input signal

F = complex voltage gain of the

predistorter

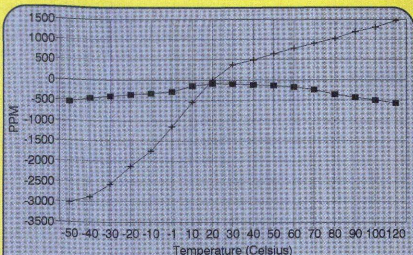
G = complex voltage gain of the PA

For a practical PA, however, these relationships can be achieved only up to the saturation point of the amplifier, as shown in **Figure 2**. For any instantaneous input power greater than $P_{in(max)}$, the PA will not provide any additional headroom to compensate for the AM/AM nonlinearity response. Therefore, the peak-to-average ratio of the input signal will determine how close to saturation the PA can operate and still behave linearly once the predistortion coefficients are applied. Note that for spread spectrum applications with a high number of users, even with predistortion, the PA would have to operate substantially backed off from the optimally efficient operating point to avoid substantial spectral regrowth. Furthermore, as is evident by the data plot, the type of compression also can determine how well the predistortion algorithm will perform. In the case of hard compression (that is, a sharp transition from linear to saturation mode), there won't be adequate headroom for the predistortion to compensate for the PA nonlinearities. However, in the case of soft compression (a slow transition from linear to saturation mode), the PA can provide a few decibels of gain in the compression region to allow for the predistortion algorithm to perform well. Note that soft vs. hard compression is primarily a function of process technology.

Early implementations of digital predistortion were based on a point-

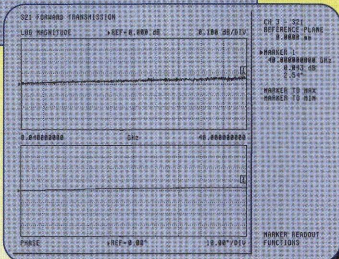
[Continued on page 26]

New Phase Stable Coaxial Cable Assemblies



**With
Temperature**

and Flexing



IW has developed a new series of low loss, phase stable cables (diameters from 0.1" to 0.480") which exhibit excellent stability under both temperature changes and repeated flexing. Now, when you need flexible cable assemblies with smaller diameters, lighter

weight, lower insertion loss and enhanced electrical stability, come to the technology leader with the broadest line to solve your most demanding requirements for both military and commercial applications.

Just give us a call or visit us at www.insulatedwire.com

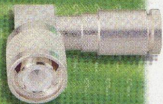


Since 1970... Specialists in the manufacture of
high-performance microwave transmission lines.

20 East Franklin Street • Danbury, CT 06810
Tel: 203-791-1999 • Fax: 203-748-5217
e-mail: iwconn@insulatedwire.com
www.insulatedwire.com



OBSCURE?



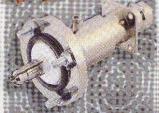
We Stock It.

HIGH POWER?



We Handle It.

UNIQUE?



We Encourage It.

What do your specs demand? A standard connector? A cable assembly? How about a hard to find model? Or maybe something that doesn't even exist yet? We suggest you visit www.tru-con.com. There you'll find a complete line of connectors — even those models you just can't find anywhere else. And if a custom connector is what you're looking for, we encourage you try our innovative "Build Your Own Connector" page where you can order what you want right away.

So get connected to the ultimate connector resource.

www.tru-con.com



TRU-CONNECTOR CORPORATION

It Pays to be Well Connected.

245 Lynnfield Street, Peabody, MA 01960

1-800-COAX-TRU • 978-532-0775 • Fax: 978-531-6993

CIRCLE 179 ON READER SERVICE CARD

TECHNICAL FEATURE

by-point mapping LUT from the input drive to the desired PA drive. This method required a large LUT and suffered from low accuracy due to residual noise. The more recent digital predistortion approach capitalizes on the fact that most PAs have amplitude and phase characteristics that are phase invariant with respect to the input signal. This assumption allows the predistortion to be applied as a gain and phase multiplication to the input signal based only on its amplitude.⁶⁻⁷ It is important to note that proper operation of the linearizer in such a system is based on the assumptions that the amplifier is memoryless and that the signal is not filtered before the PA.¹²

The key components of the digital predistorter system are shown in **Figure 3**. The measurement of the input magnitude V_i provides the index to the LUT and subsequent multiplication with the LUT gain coefficient to provide the predistortion input V_d . The values designated as G and F depict the complex voltage gains of the PA and predistorter, respectively, at a specific power level. By basing the indexing on input power $|V_i|^2$, a higher proportional number of LUT levels are assigned to the higher power levels where PAs exhibit their most nonlinear behavior, hence, enhancing the LUT resolution at these levels. The following equations describe the important relationships depicted in the block diagram. Each complex gain is only a function of its input magnitude. The relevant signal powers

$$x_d = |V_d|^2$$

$$x_i = |V_i|^2$$

are used to express the PA output and input voltages

$$V_o = V_d \cdot G(x_d)$$

$$V_d = V_i \cdot F(x_i)$$

The forward path transfer function is then expressed as

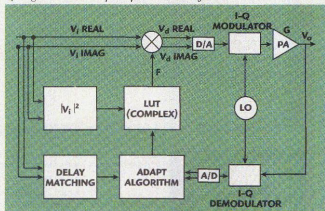
$$\frac{V_o}{V_i} = K$$

where K is the target gain through the LUT and PA, and is expressed by

$$K = F(x_i) \cdot G(x_i) |F(x_i)|^2$$

When the predistortion is optimized, the value of K is a constant over all values of input level and the forward path is completely linear. Since the equation for K is highly non-

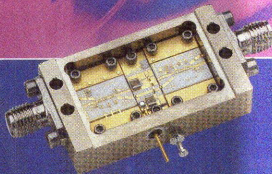
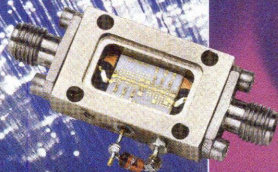
▼ Fig. 3 A basic adaptive predistortion system.



[Continued on page 28]

AMPLIFIERS

10 MHz to 18 GHz Ultra-Broadband for Fiberoptic and Telecommunications



MODEL NUMBER	FREQ. RANGE GHz	GAIN dB MIN	NOISE FIG. dB MAX	GAIN FLATNESS +/- dB	1dB COMP. PT. dB MIN	3rd Order ACP TYP.	VSWR IN/OUT MAX	DC CURRENT MA
JCA008-201	.01-8.0	25	*5	2.0	0	10	2.0:1	175
JCA008-202	.01-8.0	24	*5	2.0	5	15	2.0:1	200
JCA008-203	.01-8.0	22	*5	2.0	10	20	2.0:1	225
JCA008-301	.01-8.0	35	*5	2.5	0	10	2.0:1	300
JCA008-302	.01-8.0	34	*5	2.5	5	15	2.0:1	325
JCA008-303	.01-8.0	32	*5	2.5	10	20	2.0:1	350
JCA010-201	.01-10.0	24	*5	2.0	0	10	2.0:1	175
JCA010-202	.01-10.0	22	*5	2.0	5	15	2.0:1	200
JCA010-203	.01-10.0	20	*5	2.0	10	20	2.0:1	225
JCA010-301	.01-10.0	34	*5	2.5	0	10	2.0:1	300
JCA010-302	.01-10.0	32	*5	2.5	5	15	2.0:1	325
JCA010-303	.01-10.0	30	*5	2.5	10	20	2.0:1	350
JCA012-201	.01-12.0	23	*5	2.0	0	10	2.0:1	175
JCA012-202	.01-12.0	21	*5	2.0	5	15	2.0:1	200
JCA012-203	.01-12.0	20	*5	2.0	10	20	2.0:1	225
JCA012-301	.01-12.0	33	*5	2.5	0	10	2.0:1	300
JCA012-302	.01-12.0	31	*5	2.5	5	15	2.0:1	325
JCA012-303	.01-12.0	30	*5	2.5	10	20	2.0:1	350
JCA018-201	.1-18.0	22	**5	2.5	3	13	2.0:1	200
JCA018-202	.1-18.0	20	**5	2.5	5	15	2.0:1	250
JCA018-203	.1-18.0	20	**5	2.5	7	17	2.0:1	300
JCA018-301	.1-18.0	31	**5	2.5	3	13	2.0:1	250
JCA018-302	.1-18.0	29	**5	2.5	5	15	2.0:1	300
JCA018-303	.1-18.0	29	**5	2.5	7	17	2.0:1	350

* Noise Figure is specified above 300 Mhz

** Noise Figure is specified above 500 Mhz

- Ideal for Fiberoptic, Telecommunications, and Test Equipment
- Drop-in Style Packages
- Multi-Octave Operation
- Compact Size
- Competitively Priced

DELIVERY IN 2-4 WEEKS ARO

**JCA
TECHNOLOGY**

4000 Via Pescador, Camarillo, CA 93012
(805) 445-9888 Fax: (805) 987-6990

email: jca@icotech.com • www.icotech.com

TECHNICAL FEATURE

linear and a closed-form solution is not possible, the problem can be solved iteratively by minimizing an error function given by

$$e_g(F) = V_o(F) - K V_i$$

The error function is simply the difference between the target output power and the measured output power during a specific iteration. This equation can be solved using an iterative technique such as Newton's method. However, since this method is computationally intensive, a simpler technique such as the Secant method is generally applied. A further refinement can be added to the solver by applying a method such as weighted least squares to provide greater accuracy at the high signal levels where the PA is most nonlinear.

The accuracy of the predistortion technique discussed previously is predicated on how well the gain function G matches the actual response of the PA. In general, G is obtained either through processing of empirical data or by developing a theoretical model of the PA based on a traveling-

wave tube (TWT) amplifier approximation. The most common TWT approximation represents the PA with a normalized AM/AM and AM/PM response expressed as⁶⁻⁸

$$M(\rho) = \frac{2\rho}{1+\rho^2}$$

$$\Phi(\rho) = \frac{2\Phi_0\rho^2}{1+\rho^2}, \quad \Phi_0 = \frac{\pi}{6}$$

where

ρ = amplitude of the PA input signal

In the empirical approach, the AM/AM response is obtained by sending a training sequence through the PA and measuring the P_{in} vs. P_{out} response using a power meter. The type of training sequence used can vary greatly in both spectral and statistical distribution. The AM/PM response can be obtained by inputting a single RF tone into the PA and measuring the phase shift using a high frequency scope. Alternatively, the PA output can be downconverted and the rotation in the output constella-

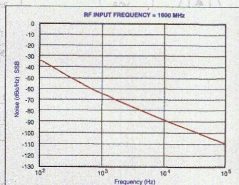
tion measured. A curve-fitting technique (such as cubic spline) is used to fit a polynomial function to the measured AM/AM and AM/PM response. The functions obtained are used in the predistortion algorithm discussed previously. In an alternative empirical technique, the demodulated PA output is compared to the baseband input signal to estimate the AM/AM and AM/PM characteristics.^{3,9}

HARDWARE SETUP

In this article, measurement results were emphasized over pure simulated results due in part to the fact that simulated results do not compensate for any memory effects exhibited by the PA or LO feedthrough and I and Q amplitude and phase imbalances caused by the quadrature modulator.¹⁰⁻¹¹ These effects can substantially alter the behavior of the modeled vs. measured results. Secondly, since an open-loop system was utilized, only measured data can provide insight into the accuracy of the PA transfer functions used in the predistortion algorithm.

[Continued on page 30]

NEED A LOW COST, HIGH FREQUENCY VCO THAT'LL DO AN OCTAVE?



ELCO-MPR-168/328-03

Frequency Range:	1600-3200 MHz
Min Tuning Voltage:	0 V
Max Tuning Voltage:	20 V
Min Output Power:	8 dBm
Max Output Power:	12 dBm
Min Mod Sens:	60 MHz/V
Max Mod Sens:	180 MHz/V
Harmonics (Worst Case):	-15 dBc
Spurious Outputs (Worst Case):	-70 dBc
Pulling into a 12 dB RTN Loss:	25 MHz
Pushing:	8 MHz/V
Temperature Range:	-20 C to +70 C
Vcc:	15 V
Icc:	45 mA

EMHISER MICRO-TECH
Miniature Voltage Controlled Oscillators



Sales: (408) 446-3582 Tech: (775) 345-0461 Fax: (775) 345-2484

E-mail: vco@emhiser.com Web: www.emhiser.com/vco



Contactless Phase Shifters: Designed for Reliability Under All Conditions

KMW's rugged phase shifters feature phase accuracy in any conditions.



KPH90OSCL000



KPH90OSCL001

■ Features

1. Reliability

Thanks to the non-contact structure, you can get remarkably stable Phase even under hard environmental conditions such as Temperature, Humidity and Vibration.

2. Low Insertion Loss

Using Dielectric material with high "Q" results low Insertion Loss.

3. Linearity

Phase is linearly varied by controlling rotated angle of axis which is co-centered with transmission line.

4. High Power Handling Capability

Low IMD with non-contact structure.

Product Code No.	A type : KPH90OSCL000 B type : KPH90OSCL001		
Frequency Range	~ 1GHz	1 ~ 2GHz	2 ~ 3GHz
Insertion Loss (max.)	0.15dB	0.25dB	0.35dB
VSWR (max.)	1.25 : 1	1.25 : 1	1.25 : 1
Incremental Phase Shift	90 degree min. @ 2GHz		
Electrical Delay	125 psec min.		
Nominal Impedance	50 ohm		
I/O Port Connector	SMA(F) / SMA(F)		
Average Power Handling	20W @ 2GHz		
Temperature Range	-30°C ~ +60°C		
Dimension (inch)	A type : 1.496*1.102*0.470, B type : 1.225*1.102*0.470		

SMD type is also available.



13131 East 166th Street, Cerritos, CA 90703-2202
1-800-8320-KMW • www.kmwinc.com
tel: 562-926-2033 • fax: 562-926-6133

KMW
RF & Microwave Products

TECHNICAL FEATURE

To provide a platform in the lab to accurately measure PA characteristics and gauge the PA response to predistortion, careful consideration was given to the setup of the RF portion of the system. A simple block diagram of the lab setup is shown in **Figure 4**. In this setup, both the RF transmit and receive chains are included on a board specifically designed for this analysis. A direct-conversion scheme was used to simplify the system and reduce the number of RF components that can potentially produce nonlinear effects.

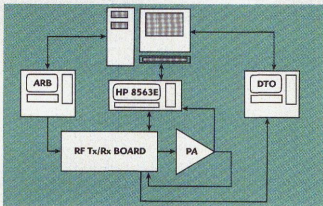
The system board consists of various off-the-shelf vendor-supplied components. A Mini-Circuits amplifier (VNA-25) is used to amplify the LO power source to the

I/Q modulators. Two Motorola GaAs driver amplifiers (MR6IC1817) are used to provide the needed input power for different HPAs under test. Gain range is achieved with the use of Alpha variable attenuators (AV102-12), creating flexibility throughout the test system. Passive I/Q modulators from RF Prime (RFIQ-2000) are used in the direct-conversion system, thereby removing bias requirements and improving repeatability in comparison. In order to maintain the received I and Q channels in quadrature, a KDI phase shifter (SQ 0003) is used.

The PA module is set up on a separate fixture with input and output ports tied back to the main RF board. This configuration allows for simple and rapid analysis of various PA circuits. The baseband signals are generated via a PC and transferred to an arbitrary waveform generator (ARB), which operates as the digital-to-analog converter (DAC). To eliminate any limitations in dynamic range due to the signal-to-noise ratio of the DAC, an ARB with a 14-bit DAC is used. A digital test oscilloscope (DTO) is used to perform the analog-to-digital (A/D) conversion and pass the data to the PC for further analysis. The DTO has the capability to oversample the received data in order to enhance the accuracy of the measurements. A PC-controlled spectrum analyzer is interfaced with the PA input and output ports to evaluate the gain and adjacent-channel power (ACP) response of the amplifier. Note that in a fully adaptive digital predistortion system, the ARB and DTO would be replaced with DAC and A/D circuits and the functionality of the PC would be performed by a DSP board. This configuration provides the ability to perform real-time training of the system and updating of the LUT in the predistortion system.

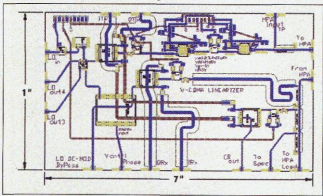
The layout of the RF board is shown in **Figure 5**. The board consists of a transmit chain, receive chain and carrier recovery system. The board receives baseband I and Q channels from the ARB, outputs the modulated RF carrier to the PA board, receives the PA RF output and outputs the demodulated baseband I and Q signals to the DTO. In addition, ports are provided for the LO input signal, carrier recovery LO bypass, LO feedthrough compensation circuit and spectrum analyzer output.

The transmit (Tx) and receive (Rx) chain components are shown in **Figure 6**. The input LO signal is passed

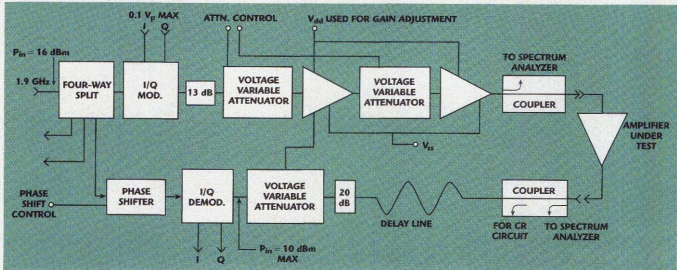


▲ Fig. 4 Lab setup for digital predistortion PA linearization.

▼ Fig. 5 The RF Tx/Rx board layout.



▼ Fig. 6 Components of the RF Tx and Rx chains.



[Continued on page 32]



FROM WATKINS-JOHNSON

NEW FETs

Introducing a new series of Low Noise and High Dynamic Range FETs

FH1

*For wireless
applications
to 3GHz*

FHF1

*For wireless
applications
above 3GHz*

Cutting-edge performance at an amazingly low price

- ✓ **DC-6GHz**
- ✓ **IP3 up to 45dBm**
- ✓ **Noise Figure Down to 1.5dB**
- ✓ **Low Cost SOT-89 Package**
- ✓ **Proven WJ Quality and Reliability**

WJ's new series of FETs combines low noise, high dynamic range, and up to 20 dB of gain. Call our toll free number, fax us at 650-813-2447 or e-mail us at wireless.info@wj.com to request data sheets and a complete catalog.

The Wireless Edge™



WATKINS-JOHNSON

1-800-WJ1-4401

Distributed in U.S.A. by Microwave Components: 800-282-4771; Nu Horizons Electronics: 888-747-6846; Richardson Electronics: 800-348-5580.
In Europe call WJ: +44-1252-661761 or your local Richardson Electronics Office: France: (01) 55 66 00 30; Germany: (089) 800 21 31; Italy: (055) 420 10 30 UK: (01753) 733010;

CIRCLE 18A ON READER SERVICE CARD



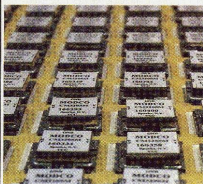
Quality & Dependability

VCO'S

0.2" x 0.2" x 0.075"

**Super miniature VCO'S
for existing and
emerging wireless
applications.**

- Over 300 standard models.
- 29 package styles to select from.
- No setup charges for custom VCO'S.
- Available on tape and reel.



Volume Production

Modco, Inc. offers a complete line of Voltage Controlled Oscillators, from 5 MHz to 7 GHz at very low competitive prices. Call the VCO hotline toll free at 1-800-672-4552.

www.modcoinc.com

Modco, Inc.

VCO'S For Wireless Communication

808 Packer Way - Sparks, Nevada 89431

Phone (775) 331-2442

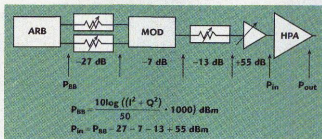
Fax (775) 331-6266

Sales 1-800-672-4552

E-mail: sales@modcoinc.com

<http://www.modcoinc.com>

TECHNICAL FEATURE



▲ Fig. 7 Forward path gain and loss values.

through a four-way splitter to provide signals for the modulator, demodulator bypass and carrier recovery circuit. The chain of voltage-controlled driver amplifiers and attenuators provides a linear response over a range of 50 to 60 dB as required in most CDMA and W-CDMA systems. In the receiver chain, an attenuator is used to adjust the RF power level entering the demodulator to maintain circuit linearity. In addition, a carrier recovery circuit based on reverse modulation is included as well as a bypass LO signal with external phase adjustment.

The developed RF system provides a highly linear response in both transmit and receive chains over a wide bandwidth, assuring that any nonlinear behavior observed is a function of the PA circuit only. However, some level of LO feedthrough and amplitude and phase imbalance in the quadrature modulator still exists, which can result in some degradation of system performance. The LO feedthrough can be compensated for by combining an LO signal with proper amplitude and phase level to the modulated signal at the input of the PA.

Since the predistortion coefficients applied to the input signal are determined as a function of the instantaneous PA input power, it is necessary to accurately measure any gain or loss in the forward path of the system from the I and Q output ports of the ARB to the PA input port. The gain and loss of all forward path components are carefully measured to accurately translate the power of the baseband signal to the input of the PA, as shown in **Figure 7**. Note that all components (except for the GaAs driver amplifier) are fixed loss elements in the system. The combination of driver amplifiers and voltage-controlled attenuators is the only adjustable element in the forward path

and is used to vary the HPA operating point in the study of the digital predistortion algorithm. The forward-path element loss/gain information is added to the predistortion algorithm to properly adjust for the input power of the HPA when test simulations are performed.

RESULTS

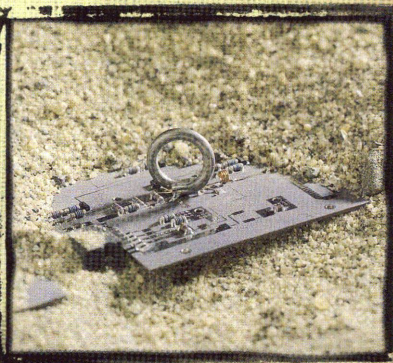
The first task in developing a predistortion algorithm for a given PA is to obtain an accurate estimate of the PA transfer function. In this analysis, the AM/AM and AM/PM response of the PA is obtained empirically. In obtaining the gain and phase response, two important parameters should be considered: what measurement technique to utilize (that is, what equipment to use) and what input signal to use as the training sequence. Equipment accuracy as well as the bandwidth and peak-to-average ratio of the input training data may have some impact on the accuracy of the measured response.

For these experiments both a GaAs PA (Motorola MRFIC1818 – 2 W) and an LDMOS PA (Motorola MHW19338 – 4 W) were considered. The GaAs PA tends to exhibit a hard compression response; the LDMOS exhibits more of a soft compression response. A number of input training signals are used in conjunction with the described system. Specifically, a number of digital baseband signals were constructed and sent through the RF board for upconversion and amplification. The baseband signals used included a fast ramp function, slow ramp function, constant-envelope Gaussian minimum-shift keying (GMSK) and single-user W-CDMA signal. These signals exhibit a wide range of peak-to-average ratios and modulation bandwidths.

The AM/AM response was measured using a power meter, and the AM/PM response was measured by downconverting the PA output and measuring the phase shift in the output constellation using the DTO. Additionally, two other measurements were

[Continued on page 34]

Board layout issues, insertion loss optimizing and power handling challenges were as real in 1973 as they are today. That's when Sage patented Wireline technology. Originally created to provide jumper style board design flexibility, engineers found the balanced, twin conductor technique offered many other design, performance and cost advantages. Its popularity flourished in the 1970's with many important programs employing it. The advent of surface mount technology and the push for automated assembly in the 80's tempered its use, as companies sacrificed performance for production speed. But next generation cellular and PCS applications are creating new design challenges. And today's professional is finding surface mount devices still can't match the insertion loss, power handling and flexibility of this proven technology. Packaging variations and enhanced automation capabilities are making it a born again staple of wireless design.



REDISCOVERING THE CLASSIC PERFORMANCE OF THE TWISTED PAIR

Wireline® and Wirepac® hybrids and couplers are still the ideal solution for many of today's high performance amplifier designs. This proven 4-port technology offers insertion loss as low as 0.1 dB and isolation values as high as 30 dB. Average power handling is as high as 200 Watts for Wireline, and 500 Watts for Wirepac.

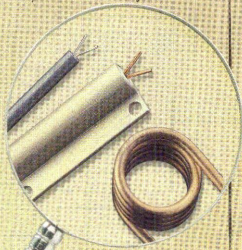
Wireline can be delivered in bulk lengths or cut to size in narrow or octave band versions with 2, 7, 3 and 10 dB coupling values. Wirepac offers a variety of solid casing and flange mount options. Plus, premier power handling and varied coupling factors up to 18 GHz.

Log on to a classic discovery and get your free Wireline Kit — it includes a Designer's Guide, a useful slide rule, and a custom cut sample to your frequency.

www.sagelabs.com

 **sage**
LABORATORIES, INC.
A Filtronic plc Company

11 Huron Drive, Natick, MA 01760 • 508-653-0844 • Fax 508-653-5671



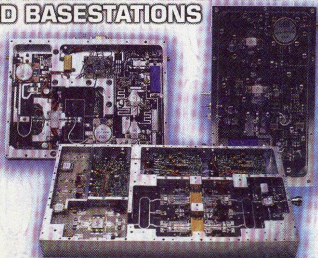
TECHNICAL FEATURE

conducted using a high frequency (HF) digital scope and a vector network analyzer (VNA) with single-tone RF signals as the input. In both cases the power meter was used to measure the AM/AM response. The AM/PM response for the HF scope was obtained by measuring the phase difference between the input and output of the PA as it is displayed on the scope. In the case of VNA, the phase of S_{21} was used to obtain the AM/PM response.

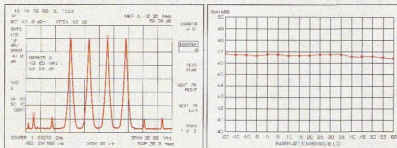
Figure 8 shows the AM/AM response of the MRFIC1818 GaAs PA using the various techniques discussed previously. Excellent agreement is achieved between the various measurements. The AM/PM response of the same PA is shown in Figure 9. Although all of the signals exhibit similar trends, large differences in the relative values are obtained. For these measurements, there appears to be a correlation be-

tween the peak-to-average ratio of the signal used and the AM/PM response, with the small peak-to-average ratio signals at the top and the large peak-to-average signals at the bottom of the graph. The LDMOS PA's AM/AM and AM/PM responses are shown in Figures 10 and

SOLID STATE POWER AMPLIFIERS FOR WIRELESS REPEATERS AND BASESTATIONS



- Cellular, PCS, WLL, MMDS, LMDS
- Linear Multichannel operation
- CDMA and W-CDMA
- Forward and/or Reverse Power Detector
- VSWR protection and Alarm
- Overtemperature Shutdown
- Remote TTL Muting
- Temperature Compensation for Gain



4 Channel Performance of PCS 4BA Amplifier

Gain vs. Temperature Performance of PCS 4BA Amplifier

CONTACT US FOR LARGE OR SMALL VOLUME REQUIREMENTS



WAVESAT
TÉLÉCOM INC.
SOLUTIONS FOR THE FUTURE

4600 rue Cousins, St-Laurent,
Quebec, Canada, H4S 1X3
Tel (514) 956-6300
Fax (514) 956-8587
www.wavesat.com

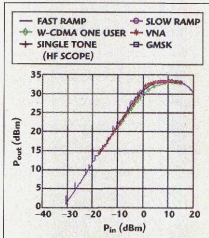


Fig. 8 The GaAs PA's measured AM/AM response.

Fig. 9 The GaAs PA's measured AM/PM response.

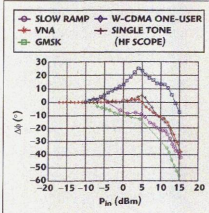
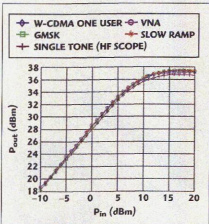


Fig. 10 The 4 W LDMOS PA's measured AM/AM response.



[Continued on page 38]



EVERYTHING
YOU'D EXPECT
FROM THE COMPANY
THAT INVENTED
THE COUNTER.



STARTING AT \$1,575*

AND LESS.

**HP 53181A
FREQUENCY COUNTER**

Performance

10 digits of resolution per second

Frequency Range

225 MHz and 1.5, 3, 5 and 12.4 GHz
additional channel options

Measurements

Up to 200 measurements per second

Ease of Use

One button frequency measurements

Price

Starting as low as \$1,575*

MORE DIGITS, LESS MONEY.

Ever since we developed the first frequency counter, we've been improving on it. Now we're even improving on the price.

Starting at just \$1,575, the HP 53181A gives you an amazing 10 digits of resolution per second. Buy just the performance you need—the HP 53181A has 225 MHz bandwidth and 1.5, 3, 5, and 12.4 GHz additional channel options. And for ease of use, you get a high-visibility display and one-button frequency measurements. What you don't get are complicated features you don't want or need.

The HP 53181A frequency counter. It may be more than you'd expect for the price. But not less than you'd expect from HP.

For more information about the HP 53181A frequency counter, help selecting the counter that's right for you, or for a free booklet titled *8 Hints for Making Better RF Counter Measurements*, call your local HP sales office or one of the numbers listed below.



*U.S. list price
©1998 Hewlett-Packard Co. TM2MD808/INTL

Australia 13-1347 Ext. 2002 • Austria (0660) 8004 • Belgium (02) 778-3417 • Finland (00) 8872 2100 • France 1 69 82 41 14
Germany (07031) 14-6333 • Hong Kong 2569-7070 • India (11) 647-2311 • Ireland (01) 2844 683 • Italy (02) 92 122 241
Korea (2) 760-0900 • Malaysia (3) 290-0213 • Netherlands (020) 547 0222 • New Zealand (0800) 738-378 • Norway 47 2279 5769
Philippines 894-1451 Local 2022 • PRC (10) 565-0149 • Singapore 250-6375 • Spain (91) 631 1333 • Sweden (08) 444 42 77
Switzerland (01) 735 7200 • (022) 780 4485 • Taiwan 089-212-535 • Thailand (2) 254-6720 • United Kingdom 01344 366666

**hp HEWLETT
PACKARD**
Expanding Possibilities

NEW!

Silicon Germanium RFICs from

Stanford Microdevices

As low
as 35¢
in quantity

Silicon Germanium (SiGe), Stanford Microdevices' latest RF semiconductor process, offers benefits not attainable by conventional silicon-bipolar technologies: lower noise figures, lower power consumption, high output power at high efficiency, and high integration level.

As part of a series of Stanford Microdevices' initiatives to apply silicon germanium technology to a broad spectrum of communications applications, we are now offering the wireless market devices built using a patented silicon germanium manufacturing process. As these devices enter the marketplace, consumers will benefit from cellular phones, pagers, and other wireless communications devices that have extended battery life, carry out multiple functions, and are smaller, lighter, and less expensive.

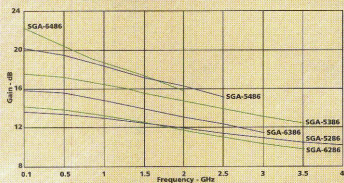
PRODUCT SELECTION GUIDE General Purpose Amplifiers

Part Number	Vd (V)	Id (mA)	3dB BW	P1dB (dBm)	IP3 (dBm)	Gain ⁽¹⁾ 1 GHz	Gain ⁽¹⁾ 2 GHz	NF 50 Ohm
SGA-2186	2.2	20	DC-5.0	+7.0	+20.0	10.5	10.2	4.1
SGA-2286	2.2	20	DC-3.5	+7.0	+20.0	15.0	14.0	3.2
SGA-2386	2.7	20	DC-2.8	+7.0	+20.0	17.4	16.4	2.9
SGA-2486	2.7	20	DC-2.0	+7.0	+20.0	19.6	18.0	2.5
SGA-3286	2.7	35	DC-3.6	+12.0	+26.0	14.8	13.4	3.5
SGA-3386	2.5	35	DC-3.6	+12.0	+25.0	17.4	16.2	3.0
SGA-3486	2.9	35	DC-2.0	+12.0	+25.0	21.5	19.4	2.6
SGA-4186	3.2	45	DC-6.0	+15.0	+29.0	10.4	10.2	4.6
SGA-4286	3.2	45	DC-3.5	+15.0	+29.0	13.8	12.6	3.3
SGA-4386	3.3	45	DC-2.5	+15.0	+29.0	17.0	15.2	2.8
SGA-4486	3.2	45	DC-2.0	+15.0	+29.0	19.0	16.8	2.5
SGA-5286	3.5	60	DC-4.0	+17.0	+30.0	13.5	12.7	4.1
SGA-5386	3.6	60	DC-3.2	+17.0	+31.0	17.3	16.0	3.5
SGA-5486	3.5	60	DC-2.4	+17.0	+31.0	19.7	18.0	2.8
SGA-6286	4.2	75	DC-3.5	+20.0	+34.0	13.8	12.4	3.9
SGA-6386	5.0	80	DC-3.0	+20.0	+34.5	15.4	13.8	3.8
SGA-6486	5.2	75	DC-1.8	+20.0	+34.0	19.7	16.7	2.9

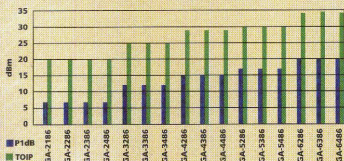
SGA 2000 through 4000 series are also available in SOT-363
SGA 5000 and 6000 series are also available in SOT-89 & SOT23-5



POWER GAIN vs. FREQUENCY



OUTPUT 3RD ORDER INTERCEPT POINT



Typical performance at 900MHz

Stanford Microdevices

produces the highest performance products utilizing cutting edge technology at the lowest possible cost. All Stanford MMICs are 100% tested and qualified annually to ensure reliable field performance even under the harshest environments, making Stanford Microdevices a favorite among major OEMs worldwide. Over the past five years Stanford Microdevices has become the preeminent leader in the design and manufacturing of GaAs, LDMOS and SiGe amplifier and switch products.

ALSO COMING SOON!
DISCRETE SiGe HBTs and
LOW NOISE SiGe MMICs

Stanford
Microdevices

1-800-764-6642

Dept. SGMJ1

Visit our web site at
www.stanfordmicro.com/sige

DISTRIBUTED BY:

AVNET
electronics marketing

800-332-8638 www.em.avnet.com

Richardson
Electronics
Engineered Solutions

800-348-5580 www.rfpower.net

FEATURES

- Low Cost
- SiGe HBT Technology
- Low Power Consumption
- High Linearity
- Industry Standard Packages

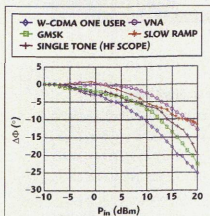


Call for Evaluation Kit
1-800-764-6642

**For performance, reliability and value,
count on Stanford Microdevices.**

All company and/or product names are trademarks and/or registered trademarks of their respective owners.
©1999 Stanford Microdevices

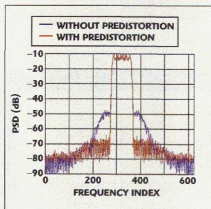
CIRCLE 162 ON READER SERVICE CARD



▲ Fig. 11 The 4 W-CDMA PAs measured AM/PM response.

11, respectively. Once again, the AM/AM responses are well correlated while the AM/PM responses deviate greatly. Note that no correlation is observed between the signal's peak-to-average ratio and the AM/PM response as in the GaAs case. The different methods used in obtaining AM/PM response should provide bounds on the values to be used in the algorithm. This limitation was necessary since an accurate measurement of the PA phase response proved to be difficult.

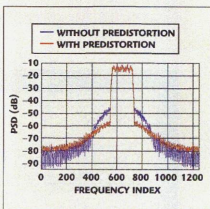
Data for the various PA characteristics obtained from the measurements were added to the digital predistortion algorithm developed in MatLab®. Since for both GaAs and LDMOS PAs considered the deviation in the various data sets was main-



▲ Fig. 12 Theoretical PSD of the GaAs PA with and without predistortion for one-user W-CDMA modulated signals.

ly in the AM/PM response, in theory the algorithm is able to compensate for the phase variation in all cases. In performing the simulations, the PA operating point is varied by adjusting the driver amplifier gain until the optimal ACP response is obtained. This operating point is a function of the peak-to-average ratio of the PA as well as the PA transfer function used in the simulation.

Both two-tone and W-CDMA modulated signals were considered. Figure 12 shows the simulated power spectral density (PSD) results obtained for the GaAs PA using a one-user W-CDMA signal with a peak-to-average ratio of 5.2 dB. The theoretical results predict a 20 dB improvement in ACP. The driver amplifier gain is set to +31 dB for this



▲ Fig. 13 The theoretical PSD of the GaAs PA with and without predistortion for 256-user W-CDMA modulated signals.

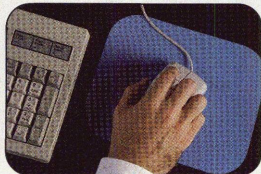
simulation. Since the transfer function obtained in this analysis was computed at only one frequency (1.9 GHz), the simulator does not account for any frequency dependency of the gain curve and, hence, only a frequency index is shown. However, for all the theoretical and experimental studies conducted, the bandwidth of the modulated signal was narrow enough so that the GaAs PA exhibits a flat gain response over the entire range. Figure 13 shows the results of a second simulation for the same PA operating point with a 256-user W-CDMA input signal. The peak-to-average ratio of this signal is 10.5 dB and, as expected, a smaller ACP improvement of only 10 is observed.

[Continued on page 43]

Get **FASTER** Reader Service Response

Want more information from *Microwave Journal* advertisers? Now you can request it online. It's as easy as a click of a mouse! Here's all you have to do:

1. Simply log onto our Web site, www.mwjjournal.com.
2. Click on the LEADnet™ Reader Service icon.
3. Request your information (by advertiser name, circle number or product type).



www.mwjjournal.com

PureSource.

Your new source

for maximum

data transfer.

You'll never get the optimum performance from your system if your DRO has to be constantly adjusted. Now there's a new line of high performance sources that truly allow your system the maximum data transfer you want.

PureSource delivers reliability without cutting

back on performance.

How reliable? How's

ten years of trouble-free

operation. Maintenance-free. Plus low

microphonics, low phase jitter and low spurious

products. Get the data transfer you demand.

Let PureSource help take you to the max.



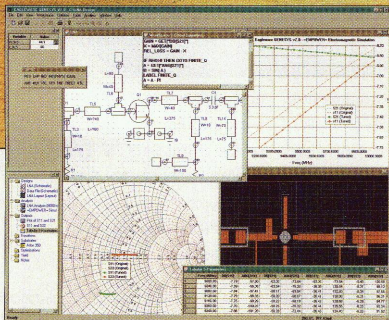
 **PureSource**

Lasting reliability at last.

A Microwave dB product • Tel: 805-499-0410

Fax: 805-498-0054 • www.microwavedb.com

PREPARE FOR THE NEXT GENESYS



Continuing a 15 year tradition of excellence,
Eagleware announces the new version 7 of its
GENESYS software. A new GUI, new multi-layer
capability in the EM simulator, a faster simulation
engine and much more. Now even faster, even
easier and just as affordable. For more
information call us or visit our website at

www.eagleware.com

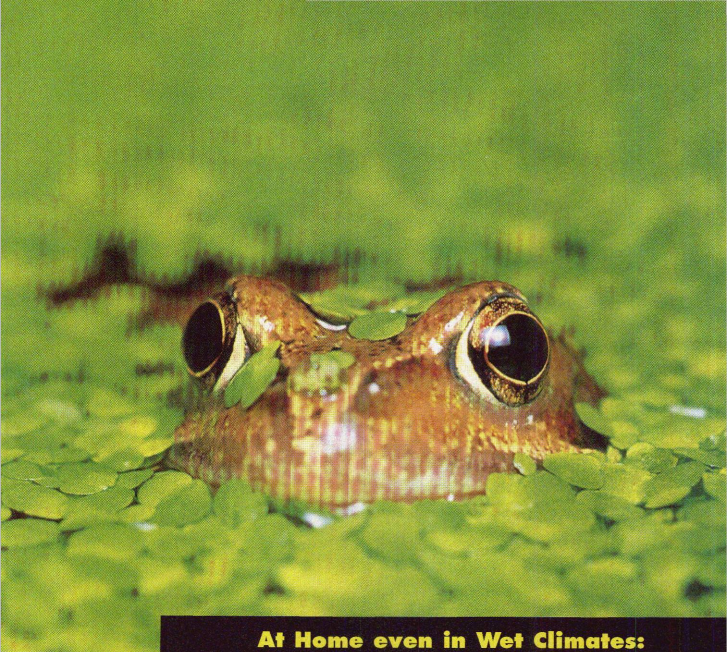
fast, easy, affordable

EAGLEWARE 

RF and Microwave Design Software

tel: 770.939.0156 | fax: 770.939.0157

CIRCLE 36 ON READER SERVICE CARD



At Home even in Wet Climates: the New Generation of SUHNER QUICK-FIT



**The new generation of SUHNER QUICK-FIT connectors:
quick and easy assembly, absolutely watertight.**

- Absolutely watertight (IP 68) even under extreme conditions, thanks to our three-stage sealing concept
- Very easy, reliable and quick assembly
- Rugged mechanical design – stable electrical characteristics
- Excellent intermodulation performance, better than -155 dBc



HUBER+SUHRNER AG
RF Interconnection Division
9100 Herisau, Switzerland
Phone +41 (0)71 353 41 11
Fax +41 (0)71 353 44 44
www.hubersuhner.com

AFFILIATED COMPANIES (Phone-No): **Australia:** 0061 2 9905 0000; **América Latina:** 0055 12 323 4131; **Canada:** 001 613 271 9771; **China:** 00852 28 66 66 00; **Shanghai:** 0086 21 5298 5008; **France:** 0033 1 30 68 37 60; **Germany:** 0049 89 6 12 01 0; **Singapore/Malaysia:** 0065 861 81 80; **Sweden:** 0046 8 447 5200; **United Kingdom:** 0044 1869 364 100; **USA:** 001 802 878 0555; **AGENTS:** **Austria:** Tonak Electronics GmbH 0043 1 61003; **Belgium:** HUBER+SUHRNER 0032 2 735 51 61; **Denmark:** Cimp A/S 0045 48 100 500; **Finland:** Olsis Oy 00358 9 478 830; **India:** Rashmi Enterprises 0091 80 668 77 42; **Israel:** E.I.M. International Electronics Ltd. 00972 3 921 50 01; **Italy:** Alfa di A. Hoffmann SRL 0039 02 261 42 500; **Japan:** Repic Corporation 0081 3 3918 5110; **Netherlands:** Sinac Electronics B.V. 0031 416 376 900; **New Zealand:** INTELCOM SERVICES Ltd. 0064 4 801 6120; **Norway:** Bredengen AS. 0047 22 65 44 20; **Philippines:** New Global Technologies Inc. 0063 2 812 3207; **South Africa:** Dartcom Pty. Ltd. 0027 11 907 9520; **Spain:** Radislogar Internacional S.A. 0034 91 413 91 11; **Taiwan:** Ring-Line Corporation 0088 62 2709 4520; **Turkey:** Elnox SA 0041 0124 466 54 61

TECHNICAL FEATURE

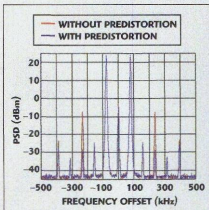
Once an optimal operating point is obtained through simulation, the predistorted signals are loaded onto the ARB to evaluate the measured response of the PA. As in the simulation case, the various PA transfer functions obtained previously were used in the measurement and the results were compared. As expected, different levels of ACP improvements were obtained for the various transfer functions. The GaAs PA transfer function that yielded the best measured ACP performance is a composite of the AM/AM data from the GMSK measurement and AM/PM data from the VNA measurement. For all the measurement results presented, this composite transfer function is used in the predistortion algorithm.

To better understand the bandwidth dependency of the predistortion algorithm, both the two-tone and modulated signal measurements are carried out for three different band-

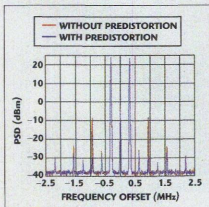
widths. **Figure 14** shows the PSD of the PA output for a two-tone signal with 150 kHz tone separation (signal peak-to-average = 3 dB, $P_{in} = -4$ dBm, $P_{out} = 27$ dBm). To generate this signal, the function $\cos(\omega_1 t)$ was generated at baseband and used as the I input to the modulator with the Q signal set to zero. The frequency ω_1 determines the tone spacing. Since the modulator is designed for

balanced input, the imbalanced signal produces a large LO leakage, which is depicted as a tone at the center of the figure. The results indicate a reduction of 20 dB in the third-order intermodulation (IM3) levels and a 2 to 3 dB reduction in the fifth-order intermodulation (IM5) levels. These results are in line with previously reported data.^{3,8} **Figures 15** and

[Continued on page 46]



▲ Fig. 14 Measured PSD of the GaAs PA with and without predistortion for two-tone input signal, 150 kHz tone spacing.



▲ Fig. 15 Measured PSD of the GaAs PA with and without predistortion for two-tone input signal, 0.6125 MHz tone spacing.

"PASSIVE POWER SOLUTIONS"



QUADWRAP SMT COMPONENTS

All edges metallized
for full periphery solder fillets.

<p>Terminations</p> <p>82-3999: 15WATTS, 4 GHz 82-3998: 40 WATTS, 2 GHz</p>	<p>Attenuators</p> <p>83-3999: 15WATTS, 4 GHz 83-3998: 40 WATTS, 2 GHz</p>
<p>Temperature Sensing Terminations</p> <p>84-3999: 15WATTS, 4 GHz 10K NTC Sensor</p>	<p>Ask for our Catalog & CD with application notes about SMT PCB's and designing with Temperature sensing components.</p>

QUICK RESPONSE FAX (888) 544-5594
Toll Free Voice (800) 544-5594
Website: www.rflabs.com



15. EN ISO 9001
REG. NO. M2039

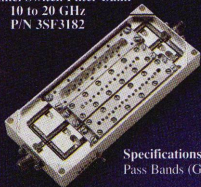
PO Box 899, Stuart, Florida 34995-0899

FLORIDA
RF
Labs

If You Need to Switch

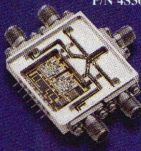
Don't Fight It !!

3 Channel Switch Filter Bank
10 to 20 GHz
P/N 3SF3182



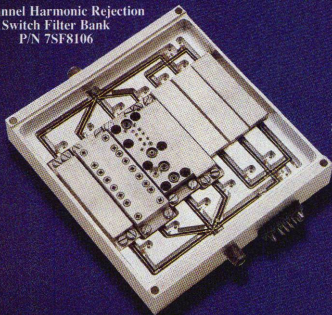
Specifications	
Pass Bands (GHz)	10.3 - 11.7 15.8 - 17.7 18.8 - 19.7
Insertion Loss	6.0 dB max
Rejection (DC-24 GHz)	70 dB min
Switching Speed	200 ns max

SP4T
PIN Diode Switch
2.0 to 18 GHz
P/N 4S3068



Specifications	
Frequency Range	2.0 - 18 GHz
Insertion Loss	2.9 dB max
Isolation	55 dB min
VSWR	2.0:1 max
Switching Speed	50 ns max

7 Channel Harmonic Rejection
Switch Filter Bank
P/N 7SF8106



Specifications	
Pass Bands (GHz)	0.5 - 0.8 0.8 - 1.3 1.3 - 2.0 2.0 - 3.5 3.5 - 6.0 6.0 - 10.4 10.4 - 18.0
Insertion Loss	6.0 dB max
VSWR	2.0:1 max
2nd Harmonic Reject.	50 dBc min
Harmonics	65 dBc max

...join the Big Easy with

MVS

High Performance
PIN Diode Switches &
Switch Filter Banks

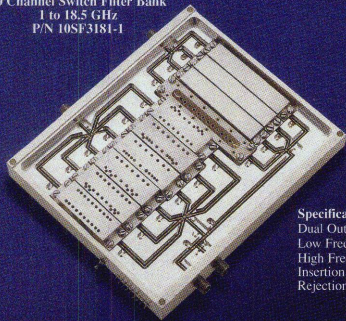


SPDT
PIN Diode Switch
0.3 to 20 GHz
P/N 2S3025

Specifications

Frequency Range	0.3 - 20 GHz
Insertion Loss	3.0 dB max
Isolation	70 dB min
VSWR	2.0:1 max
Switching Speed	100 ns max

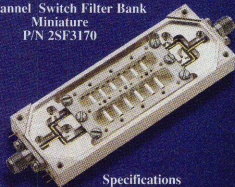
10 Channel Switch Filter Bank
1 to 18.5 GHz
P/N 10SF3181-1



Specifications

Dual Outputs	1.0 - 18.5 GHz
Low Freq Input	6 Pass Bands (1-10.5 GHz)
High Freq Input	4 Pass Bands (10.5-18.5 GHz)
Insertion Loss	9 dB max
Rejection Range(55 dB)	DC - 19 GHz

2 Channel Switch Filter Bank
Miniature
P/N 2SF3170



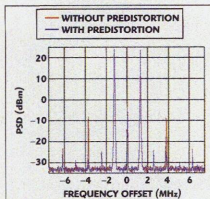
Specifications

Pass Bands (GHz)	6.66 - 7.66
	7.66 - 8.66
Insertion Loss	3.0 dB max
VSWR	2.0:1 max
Switching Speed	100 ns max
Size(Inches)	3.0 x 1.1 x .35

"Quality by Design"

MVS

also specializes in Microwave
Integrated Assemblies. Think of us for your
packaging and assembly integration needs.



▲ Fig. 16 Measured PSD of the GaAs PA with and without predistortion for two-tone input signal, 2.5 MHz tone spacing.

Fig. 17 Measured PSD of the GaAs PA with and without predistortion for 300 kHz wide modulated signal.

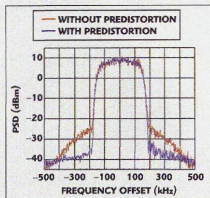
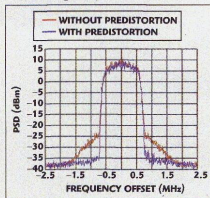
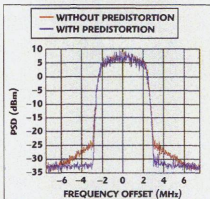


Fig. 18 Measured PSD of the GaAs PA with and without predistortion for 1.25 MHz wide modulated signal.



16 show the two-tone response of the PA for tone spacing of 612.5 kHz and 2.5 MHz, respectively. The results are similar to the 150 kHz case, however, for the 2.5 MHz tone spacing, a slight degradation in the IM3 results can be observed.

Figure 17 shows the measured PSD of the GaAs PA output for a 1.9 GHz modulated carrier with a modulated bandwidth of 300 kHz with and without predistortion applied to the baseband signals (signal peak-to-aver-



▲ Fig. 19 Measured PSD of the GaAs PA with and without predistortion for 5 MHz wide modulated signal.

Fig. 20 Theoretical PSD of the 4 W LDMOS PA with and without predistortion for one-user W-CDMA modulated signals.

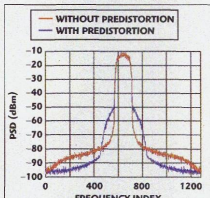
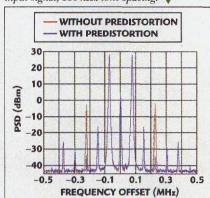
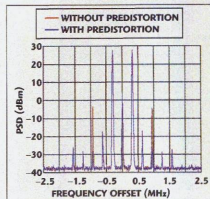


Fig. 21 Measured PSD of the 4 W LDMOS PA with and without predistortion for two-tone input signal, 150 kHz tone spacing.

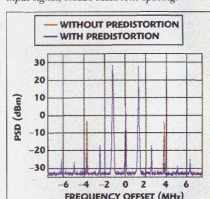


age = 5.2 dB, $P_{in} = -4$ dBm, $P_{out} = 27$ dBm). An improvement of approximately 15 dB is observed in the ACP of the predistorted signal for the same level of output power.

The measured PSD for 1.25 and 5 MHz bandwidth signals is shown in Figures 18 and 19, respectively. As the bandwidth of the modulated signal is increased the improvement in the ACP decreases. In the 5 MHz case, the ACP improvement has been reduced to 7.5 dB or half the 300



▲ Fig. 22 Measured PSD of the 4 W LDMOS PA with and without predistortion for two-tone input signal, 612.5 MHz tone spacing.



▲ Fig. 23 Measured PSD of the 4 W LDMOS PA with and without predistortion for two-tone input signal, 2.5 MHz tone spacing.

kHz bandwidth signal. This result could be due in part to the construction of the PA module, the memory effect of the amplifier, LO feed-through, and phase and amplitude imbalance in the quadrature modulator, or some limitation of the predistortion algorithm.

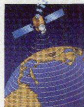
The analysis performed for the MRFIC1818 GaAs PA was repeated for the MHW19338 4 W LDMOS PA. As in the GaAs case, since the main difference in the measurements is in the AM/PM response, the theoretical results are consistent for a given operating point. The optimal operating point for the PA was obtained through simulation, and the results are shown in Figure 20 for a signal peak-to-average of 5.2 dB and driver gain of 40 dB. As in the GaAs example, a 20 dB improvement in ACP is observed. For this PA, the optimal measured results were obtained using the VNA data set. The two-tone measured data for 150 kHz, 612.5 kHz and 2.5 MHz tone separation are shown in Figures 21, 22 and 23, respectively (signal peak-

[Continued on page 48]

THE GLOBAL SOLUTION... AND BEYOND!



10MHz to 7GHz AMPLIFIERS **\$99⁹⁵** from (1-9 qty)



From amateur radio to cellular to satellite applications, with medium output power up to 17dBm, Mini-Circuits versatile ZJL and ZKL connectorized amplifiers offer the broad range of choices designers demand for achieving high system performance goals. Ultra-wideband models deliver gain ranging from 9 to 40dB and IP3 up to +32dBm. But beyond the performance and reliability built into these miniature 12V amplifiers lies another important feature, the low price...from only \$99.95! Call now for fast delivery.

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

SPECIFICATIONS

Model	Freq (MHz)	Midband (dB)	Gain (typ) Flat (±dB)	Max. P _{out} 1 (dBm)	Dynamic Range (Typ @2GHz±2) NF(dB) IP3(dBm)	Price Sea. (1-9)
ZJL-5G	20-5000	9.0	±0.55	15.0	8.5 32.0	80 129.95
ZJL-7G	20-7000	10.0	±1.0	8.0	5.0 24.0	50 99.95
ZJL-4G	20-4000	12.4	±0.25	13.5	5.5 30.5	75 129.95
ZJL-6G	20-6000	13.0	±1.5	9.0	4.5 24.0	50 114.95
ZJL-4HG	20-4000	17.0	±1.5	15.0	4.5 30.5	75 129.95
ZJL-3G	20-3000	19.0	±2.2	8.0	3.8 22.0	45 114.95
ZKL-2R7	10-2700	24.0	±0.7	13.0	5.0 30.0	120 149.95
ZKL-2R5	10-2500	30.0	±1.5	15.0	5.0 31.0	120 149.95
ZKL-2	10-2000	33.5	±1.0	15.0	4.0 31.0	120 149.95
ZKL-1R5	10-1500	40.0	±1.2	15.0	3.0 31.0	115 149.95

NOTES:

1. Typical at 1dB compression.
2. ZKL dynamic range specified at 1GHz.
3. All units at 12V DC.



Mini-Circuits®

P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718)332-4661 **INTERNET** <http://www.minicircuits.com>

For quick access to product information see MINI-CIRCUITS CATALOG & WEB SITE • EEM • MICROWAVE PRODUCT DATA DIRECTORY • WWW.REGLOBAL.NET.COM

US 104 INTL 105
CIRCLE READER SERVICE CARD

TECHNICAL FEATURE

to-average = 3 dB, $P_{in} = 3.5$ dBm, $P_{out} = 31.5$ dBm). The improvement in IM3 is 30 dB for 150 kHz tone spacing and decreases to 20 dB for the 2.5 MHz tone spacing. Note that no improvement in IM5 is observed.

The PSD of the LDMOS PA output for modulated signals with bandwidths of 300 kHz, 1.25 MHz and 5 MHz is shown in **Figures 24, 25 and 26**, respectively (signal peak-to-average = 5.2 dB, driver gain = 40 dB).

An improvement in ACP of 12 dB is observed for the narrow-bandwidth signal and decreases to 10 dB for the wider-bandwidth signal.

The results clearly indicate that the linearity of both GaAs and LDMOS technologies can be improved using digital predistortion techniques. Although the improvements observed in the measured results are not as good as the simulated results, the theoretical limits in ACP can be reached by im-

proving the accuracy of the PA transfer function used in the predistortion algorithm. The PA AM/AM and AM/PM can be optimized further either theoretically or experimentally by performing multiple measurements and averaging the results. In addition, a closed-loop system can be used to dynamically update the LUT.

IMA

**INTEGRATED
MICROWAVE
ASSEMBLIES**



When you need to satisfy the most critical performance, size/weight and reliability requirements, our complex IMAs can combine all the components you need to complete your subsystem.

MADE TO
ORDER

2

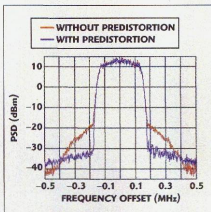
YEAR
WARRANTY



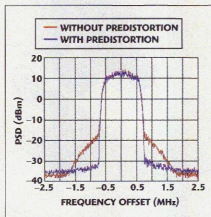
From the people you trust...

GENERAL MICROWAVE

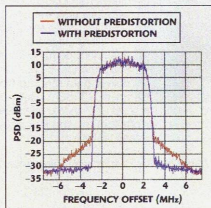
5500 New Horizons Blvd., Amityville, NY 11701
TEL: 516-226-8900 • FAX: 516-226-8966
<http://gmcwave.com>



▲ Fig. 24 Measured PSD of the 4 W LDMOS PA with and without predistortion for 300 kHz wide modulated signal.



▲ Fig. 25 Measured PSD of the 4 W LDMOS PA with and without predistortion for 1.25 MHz wide modulated signal.

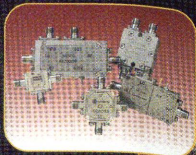


▲ Fig. 26 Measured PSD of the 4 W LDMOS PA with and without predistortion for 5 MHz wide modulated signal.

[Continued on page 50]

MITEQ

FROM COMPONENTS TO SYSTEMS



MIXERS TO 60 GHz

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

AMPLIFIERS TO 60 GHz

- Octave to ultra-broadband
- Noise figures from 0.35 dB
- Power to 10 watts
- Temperature compensated
- Cryogenic



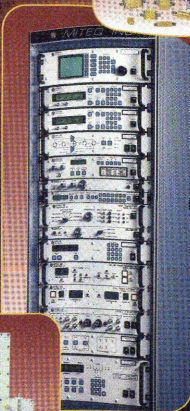
INTEGRATED SUBASSEMBLIES TO 60 GHz

- Integrated up/downconverters
- Monopulse receiver front ends
- PIN diode switches
- Ultra-miniature switch matrices
- Missile receiver front ends
- Switched amplifier/filter assemblies



FREQUENCY SOURCES TO 40 GHz

- Free-running VCOs/DROs
- Phase-locked cavity oscillators
- Phase-locked coaxial resonators
- Synthesizers for SATCOM
- Fast-tuning communication synthesizers



IF AND VIDEO SIGNAL PROCESSING

- Logarithmic amplifiers
- Constant phase-limiting amplifiers
- Frequency discriminators
- AGC/VGC amplifiers
- I/Q processors
- Digital DLVAs

SATCOM EARTH STATION EQUIPMENT TO Ka-BAND

- Synthesized up/downconverters
- Test translators
- LNA systems
- 1:N redundancy units
- INMARSAT products
- FM modems



TEL: (516) 436-7400

FAX: (516) 436-7430

100 Davids Drive, Hauppauge, NY 11788

www.miteq.com

TECHNICAL FEATURE

CONCLUSION

Based on empirical and analytical studies of the digital predistortion technique, improvement in the ACP response of digitally modulated RF carriers can be achieved for both narrowband and wideband signals. The degree of improvement observed, however, is a function of multiple system parameters, including the PA gain response (soft vs. hard compression), statistical distribution of the input signal (peak-to-average ratio), spectral distribution of the input signal (modulated bandwidth) and accuracy of the PA AM/AM and AM/PM functions used in the predistortion algorithm.

A variety of techniques were utilized in obtaining the PA transfer function with good correlation of the AM/AM response and poor correlation of the AM/PM response. The measured results indicate that the algorithm is sensitive to the PA AM/PM response and that an accurate measurement of this characteristic is difficult to obtain. However, with the limited accuracy of the described measurement, better

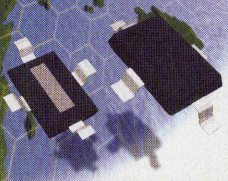
than 10 dB of ACP improvement was observed for both GaAs and LDMOS PAs for input signals with 5 dB of peak-to-average ratio. The simulated results indicate that an additional 10 dB improvement can be obtained if a more accurate PA transfer function is used in the algorithm. ■

References

1. J.K. Cavers, "The Effect of Quadrature Modulator and Demodulator Error on Adaptive Digital Predistorters for Amplifier Linearization," *IEEE Transactions on Vehicular Technology*, Vol. 46, No. 2, May 1997, pp. 456-466.
2. E.G. Jeckeln, F.M. Ghannouchi and M. Sawan, "Linearization of Microwave Emitters Using an Adaptive Digital Predistorter," *27th European Microwave Conference Proceedings*, September 1997, pp. 336-340.
3. A. Lofth, P.A. Goud and C.G. Englefield, "Power Amplifier Linearization Using Cubic Spline Interpolation," *Proceedings of the 43rd IEEE Vehicular Technology Conference*, May 1993, pp. 676-679.
4. P.B. Kenington, "Linearised RF Amplifier and Transmitter Techniques," *Wireless Systems International*, 1998.
5. B. Razavi, *RF Microelectronics*, Prentice Hall, 1998.
6. A.N. D'Andrea, V. Lottici and R. Reggiani, "A Digital Approach to Efficient RF Power Amplifier Linearization," *IEEE Transactions*, 1997, pp. 77-81.
7. A.N. D'Andrea, V. Lottici and R. Reggiani, "RF Power Amplifier Linearization through Amplitude and Phase Predistortion," *IEEE Transactions on Communications*, Vol. 44, No. 11, Nov. 1996, pp. 1476-1484.
8. I. Park, E.J. Powers and G. Xu, "Parallel Adaptive Predistortion for RF Power Amplifier Linearization," *Proceedings of the IEEE*, 1997, pp. 82-86.
9. L. Sundstrom, M. Faulkner and M. Johansson, "Quantization Analysis and Design of a Digital Predistortion Linearizer for RF Power Amplifiers," *IEEE Transactions on Vehicular Technology*, Vol. 45, No. 4, November 1996, pp. 707-719.
10. A.S. Wright and W.G. Durtler, "Experimental Performance of an Adaptive Digital Linearized Power Amplifier," *IEEE Transactions on Vehicular Technology*, Vol. 41, No. 4, November 1992, pp. 395-400.
11. M. Faulkner and M. Johansson, "Adaptive Linearization Using Predistortion-Experimental Results," *IEEE Transactions on Vehicular Technology*, Vol. 43, No. 2, May 1994, pp. 323-332.
12. A.A.M. Saleh and J. Salz, "Adaptive Linearization of Power Amplifiers in Digital Radio Systems," *Bell Systems Technical Journal*, Vol. 62, No. 4, April 1983, pp. 1019-1033.

High Frequency

GaAs Power FET In Plastic Package



Model	Freq. (GHz)	5.0GHz, V _{DS} = 5V, I _{DS} = 0.5A			
		Gain (dB)	P _{sat} (dBm)	η _{dc} (%)	IP ₃ (dBm)
AM105W-QG	DC-6.5	14dB	31dBm	38dBm	46%
AM120W-QG	DC-6.5	14dB	28dBm	42dBm	46%
AM130W-QG	DC-6.5	13dB	28dBm	45dBm	46%
AM135W-QG	DC-6.5	12dB	31dBm	47dBm	46%
AM148W-QG	DC-6.5	11.5dB	33dBm	47dBm	46%
AM177W-QG	DC-6.5	11dB	34dBm	49dBm	46%

Web Site: www.amcmosusa.com

22300 Cornish Drive, Clarkburg, MD 20671 Tel: 301-353-8400 Fax: 301-353-8401

-Band GaAs Power FET In Plastic Package

NEW!

Model	Freq. (GHz)	Gain (dB)	P _{sat} (dBm)	η _{dc} (%)	IP ₃ (dBm)
AM105W-QG	DC-10.0	14dB	22dBm	38dBm	45%
AM120W-QG	DC-10.0	14dB	28dBm	38dBm	45%
AM130W-QG	DC-10.0	13dB	29dBm	39dBm	45%
AM135W-QG	DC-10.0	13dB	30dBm	40dBm	43%
AM148W-QG	DC-10.0	12dB	31dBm	41dBm	40%
AM177W-QG	DC-10.0	11dB	33dBm	43dBm	40%

Web Site: www.amcmosusa.com

22300 Cornish Drive, Clarkburg, MD 20671 Tel: 301-353-8400 Fax: 301-353-8401

RF Micro Devices Presents

Not So Great Moments in Wireless Communication



1861 A.D. – St. Joe to Sacramento... history's greatest relay.

A cloud of dust trails across the plain as man and pony race to deliver the mail. Pounding hooves send echoes bouncing off canyon walls.

Ahead, the Sierra Madres and treacherous territory...behind, a loose lock and an open flap. Envelopes go flying. Airmail...1861-style.

1998 A.D. – It's all up to you.

There's no time to backtrack – you either deliver this design today or you're history.

You need help to reach the finish, so hand off your specs to RFMD. We're waiting and ready to supply

you with a full line of highly integrated components.

Components like our RF2510 and RF2917, a fully functional transmitter and receiver pair. These monolithic ICs are low-cost, silicon-based and ideal for

**IMMEDIATE
DELIVERY**

RF 
MICRO-DEVICES

Proprietary, State-Of-The-Art
RF Integrated Circuits

North American and European ISM band FM/FSK applications. Both components require only the addition of an external crystal to provide complete phase-locked oscillators. Best of all, they're ready-to-ship.

When you're racing against time, call RFMD...we deliver.

7625 Thorndike Road
Greensboro, NC 27409-9421

Phone 336.664.1233

FAX 336.664.0454

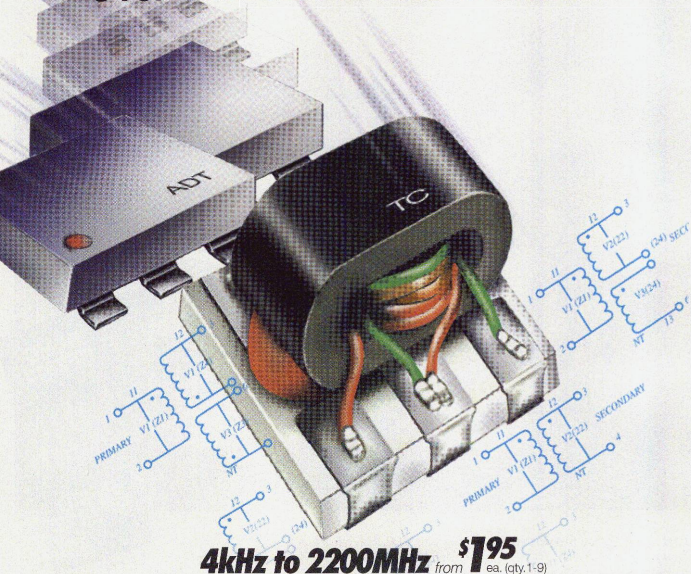
Online: <http://www.rfmd.com>

Mention NSG#5 when contacting us.

©1998, RF Micro Devices, Inc.

SURFACE MOUNT RF TRANSFORMERS

Over 100 off-the-shelf models...



What makes Mini-Circuits your single source for surface mount RF transformers? Variety, availability, performance, and price! From wide band transformers with low droop and fast risetime capabilities for pulse applications, to a particular impedance ratio from 1:1 through 1:36 specified for a wide range of impedance coverage, we will work with you on your design challenges. Tangible benefits such as very high dielectric breakdown voltage, excellent amplitude and phase unbalance for balanced to unbalanced applications, and easy to use surface mount package styles make Mini-Circuits

surface mount transformers a great value. Our new ADT transformers are changing the face of RF transformer design with patent pending **IT** Innovative Technology delivering small size, low cost, and better performance. This same leading edge transformer expertise can also develop your custom designs at catalog prices. So, simplify your transformer search...Big Time! Capitalize on the quality, design know-how, and off-the-shelf variety from Mini-Circuits. Call today!

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

 **Mini-Circuits®**

US 106 INT'L 107
CIRCLE READER SERVICE CARD

P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 994-4500 Fax (718) 332-4661 **INTERNET** <http://www.minicircuits.com>

For quick access to product information see MINI-CIRCUITS CATALOG & WEB SITE • EEM • MICROWAVE PRODUCT DATA DIRECTORY • WWW.RFGLOBALNET.COM



Joint Venture Awarded \$500 M from NATO

Air Command Systems International, a joint venture equally owned by Raytheon Co. and Thomson-CSF, has been awarded a contract valued at approximately \$500 M from the North Atlantic Treaty Organization (NATO) Air Command and Control Management Agency for the NATO Air Command and Control System Level of Operational Capability 1 (ACCS LOC1). Under the terms of the contract, the NATO ACCS LOC1 program will provide NATO with a fully interoperable, common air operations command and control system to support all offensive and defensive air operations as well as military air traffic control, command and control resource management, and airspace management in Europe. The program will replace the existing NATO air command and control system (NATO Air Defense Ground Environment) implemented in the 1970s, and will also provide centralized command and decentralized execution capability through a combination of an in-place static backbone and a deployable ACCS component.

NATO intends to employ an evolutionary implementation of full ACCS capability, which will take place in increments known as LOCs. Each increment will be implemented through development and validation phases followed by a replication phase. The initial ACCS LOC1 program includes the development of core software, its validation at the system test and validation facility and four operational sites, and its subsequent replication at other operational sites. Contracts are expected to be awarded to four additional NATO nations, including Belgium, France, Germany and Italy, for validation sites.

Program Develops Global ATM Capabilities for Fighter Aircraft

Rockwell Collins and the US Air Force have introduced key technology to bring Global Air Traffic Management (GATM) capabilities to tactical fighter aircraft. The new technology includes a miniature modular digital radio (MMDR), fast I/Q processor (FIQP) and future air navigation software. The MMDR serves as a receiver/exciter and the FIQP serves as a waveform processor. When used together, the two components form the front end of a software-programmable radio.

The GATM capabilities developed by Rockwell Collins and the Air Force under the Future Air Navigation and Traffic Avoidance Solution through Integrated Communication/Navigation/Identification (FANTASTIC) program will be combined to demonstrate a typical GATM solution in the summer of 2000. As part of the FANTASTIC program, an impact study for the F-15 and F-16 fighter plat-

forms is being conducted to develop and demonstrate potential long-term GATM solutions for tactical fighters. The study will identify requirements for each platform and potential solutions with an emphasis on commercial off-the-shelf components. Affordable retrofits providing compliance with civilian airspace navigation regulations with minimal impact also will be identified.

US Navy Awards Raytheon \$414 M to Remanufacture Tomahawk Cruise Missiles

The US Navy has modified an existing contract with Raytheon Co. to remanufacture up to 624 Tomahawk cruise missiles to the latest Block III configuration. Launched from surface ships and submarines, Tomahawk is a long-range, subsonic cruise missile used for land-attack warfare. Block III adds a GPS guidance capability to Terrain Contour Matching and Digital Scene Matching Area Correlation guidance systems. Under the terms of the \$414 M indefinite-quantity contract, the Navy will order the upgraded Tomahawks as needed. Work will be performed principally at the Raytheon Missile Systems business unit in Tucson, AZ, and is expected to be completed by October 2000.

In June 1998, Raytheon was awarded a cost-plus, fixed-fee contract for the engineering and manufacturing development (EMD) of a more versatile, lower cost version of Tomahawk designated Tactical Tomahawk. The Tactical Tomahawk will be capable of battle damage indication, in-flight retargeting, loitering and mission planning from the launch platform. The award includes the firm pricing for 1343 missiles (valued at \$800 M) delivered over five years. EMD is scheduled to be completed in 2002 and production is expected to begin in 2003.

US Army's First Digitized Division Examined

The US General Accounting Office (GAO) has released a report, "Battlefield Automation: Performance Uncertainties Are Likely When Army Fields Its First Digitized Division" (GAO/NSIAD-99-150), which examines the progress of the Army's efforts to field a digitized division by 2000. Although the overall digitization effort involves more than 100 systems, the Army intends to field 16 high priority systems to three of the division's four brigades by December 2000 and field the first digitized corps by September 2004. In general, these 16 systems are command, control and communications systems intended to support decision-making by commanders in tactical operations centers at battalion, brigade, division and corps levels, including the Maneuver Control System and



NEWS FROM WASHINGTON

upgrades to mobile subscriber equipment and satellite communication systems. One of the systems, however, the Force XXI Battle Command, Brigade and Below (FBCB2), is an entirely new technology intended to accomplish the critical objective of sharing battlefield information with the thousands of soldiers outside of tactical information centers.

Though some systems were fielded as early as 1998, the acquisition status of other systems varies. For example, the Global Broadcast Service Transportable Ground Receive Suite was delayed because the contractor's initial design required too many terminal transit cases. The report identifies other significant uncertainties the Army will confront when the division is fielded at the end of 2000. Most importantly, the operational effectiveness and suitability of FBCB2 will be unknown, and the recent restructuring of the system's test and evaluation program will prevent full testing until at least 2002. Operational performance of other fielded systems will be unknown because the results of scheduled operational tests will not be completed by December 2000. In addition, automated data sharing within tactical centers will not have been demonstrated and whether digitization can achieve the expected increases in lethality and survivability is unlikely to be resolved any earlier than 2002 — after the FBCB2 initial operational test and evaluation are completed.

Iridium Tested as Potential F-16 Communication System

As reported in *C4I NEWS*, Lockheed Martin and AlliedSignal have entered into a cooperative agreement to test and demonstrate a two-way satellite communication system on a Lockheed Martin F-16 using Iridium's existing commercial system via an AlliedSignal

AIRSAT 1. The objective of the agreement is to demonstrate the delivery of intelligence information to fighter pilots in near real time from anywhere in the world in an affordable manner. The proposed system ultimately could be integrated into the F-16, providing pilots with two-way voice and data communication to any command center, operating base or intelligence source in the world. The Lockheed Martin joint strike fighter team also could benefit from any advances made in the two-way militarized satellite communication field. Testing was scheduled to begin this summer to evaluate the operation of satellite communication technology in high speed fighter aircraft. A second test is scheduled for June 2000 to examine the integrity and security of the connection between the satellite and the aircraft. ■

JFW Industries, Inc.

Innovative Design Custom Applications

We are an innovative designer and manufacturer of matrix switches and programmable test systems for applications including cellular/PCS laboratory installation and broadcast equipment production testing.

Features Include:

- RS-232, GPIB, TTL or Parallel control
- 19" rack or bench top packaging
- Wide frequency ranges available
- Blocking and non-blocking configurations

JFW Industries, Inc.

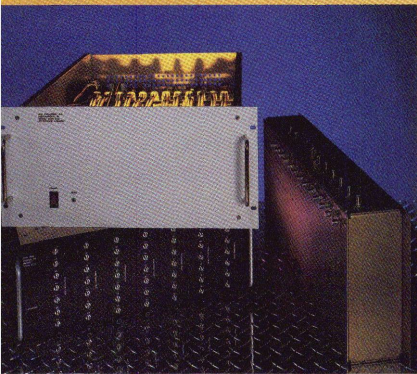
5134 Commerce Square Drive
Indianapolis, Indiana 46237

Tele. (317) 887-1340 Fax (317) 881-6790

Internet— <http://www.jfwindustries.com>

E-mail— sales@jfwindustries.com

ISO 9001 Certified



TAKE YOUR BUSINESS HIGHER, FURTHER, FASTER.



MICROSEMI AND FUTURE ELECTRONICS CONTINUE TO SUPPORT MOTOROLA LOW POWER RF BUSINESS

In our constantly changing industry, Microsemi & Future Electronics have a common vision of exactly where it's going in the next millennium.

Microsemi has been chosen by Motorola as the preferred supplier to continue supporting customers with their Low Power TO-39/TO-72 Metal Can, SORF (SO-8), and Macro-X,T & Power Macro RF requirements... all equivalent to Motorola specifications. Along with Microsemi's full line of RF Power Bipolar, MOSFET and LDMOS devices, all products

are backed by Microsemi's ZERO OBSOLESCENCE POLICY, guaranteed.

More than a worldwide leader in electronic components distribution, Future Electronics provides leading edge e-commerce supply chain solutions, state-of-the-art design centers, and one of the largest technical support teams with qualified RF engineers around the world. Our down to earth partnership with Microsemi will help you reach for the stars every day.

For online data sheets and to request a free Microsemi RF Short Form Catalogue,
go to www.future.ca/microsemirf

RF Products
Microsemi
Progress Powered by Technology

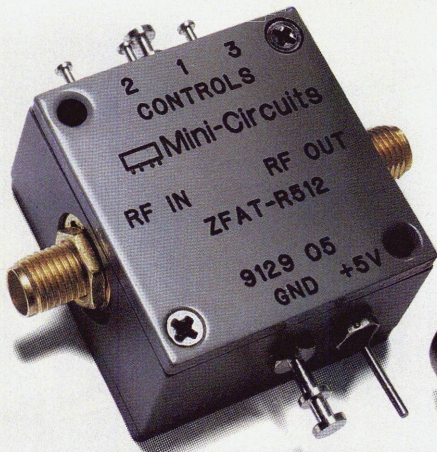


FUTURE ELECTRONICS
1-800-FUTURE-1 Ext. 2800

"The Largest Available-To-Sell Inventory... Worldwide"

CIRCLE 47 ON READER SERVICE CARD

Photo courtesy of NASA



DIGITAL STEP ATTENUATORS

up to 35dB
10 to 1000MHz
\$59.95

FROM

TOAT-R512 ZFAT-R512 Accuracy (dB) (+/-dB)	TOAT-124 ZFAT-124 Accuracy (dB) (+/-dB)	TOAT-3610 ZFAT-3610 Accuracy (dB) (+/-dB)	TOAT-4816 ZFAT-4816 Accuracy (dB) (+/-dB)	TOAT-51020 ZFAT-51020 Accuracy (dB) (+/-dB)
0.5 0.12	1.0 0.2	3.0 0.3	4.0 0.3	5.0 0.3
1.0 0.2	2.0 0.2	6.0 0.3	8.0 0.3	10.0 0.3
1.5 0.32	3.0 0.4	9.0 0.6	12.0 0.6	15.0 0.6
2.0 0.2	4.0 0.3	10.0 0.3	16.0 0.5	20.0 0.4
2.5 0.32	5.0 0.5	13.0 0.6	20.0 0.8	25.0 0.7
3.0 0.4	6.0 0.5	16.0 0.6	24.0 0.8	30.0 0.7
3.5 0.52	7.0 0.7	19.0 0.9	28.0 1.1	35.0 1.0

Price \$ (1-9 qty) TOAT \$59.95/ZFAT \$89.95

bold faced values are individual elements in the units

Finally...precision attenuation accurate over 10 to 1000MHz and -55°C to +100°C. Standard and custom models are available in the TOAT(pin)- and ZFAT(SMA)-series, each with 3 discrete attenuators switchable to provide 7 discrete and accurate attenuation levels.

The 50-ohm components perform with 6μsec switching speed and can handle power levels typically to +15dBm. Rugged hermetically-sealed TO-8 units and SMA connector versions can withstand the strenuous shock, vibration, and temperature stresses of MIL requirements. TOAT pin models are priced at only \$59.95 (1-9 qty); ZFAT SMA versions are \$89.95 (1-9 qty).

Take advantage of this striking price/performance breakthrough to stimulate new applications as you implement present designs and plan future systems. All units are available for immediate delivery, with a one-yr. guarantee, and three-sigma unit-to-unit repeatability.

 **Mini-Circuits®**

US 108 INTL 109
CIRCLE READER SERVICE CARD

P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661 INTERNET <http://www.minicircuits.com>

For detailed specs on all Mini-Circuits products refer to • 760-pg. HANDBOOK • INTERNET • THOMAS REGISTER • MICROWAVE PRODUCT DATA DIRECTORY • EEM



Greece Signs Up for ERIEYE AEW&C Radar

Following a December 1998 announcement that Greece had selected an Embraer EMB-145 airframe fitted with Ericsson's ERIEYE radar and an Ericsson/Thomson-CSF North Atlantic Treaty Organisation (NATO)-compatible mission suite to fulfill its outstanding airborne early warning and control (AEW&C) aircraft requirement, Ericsson has announced that a formal contract covering the supply of four systems has been signed. Based on the EMB-145SA platform that Embraer developed for Brazil's Sistema de Vigilancia da Amazonia (SIVAM) region surveillance programme, the Greek EMB-145s will feature a revised mission workstation format, Thomson-CSF's DR 3000 electronic support system and NATO-compatible communications and identification friend-or-foe subsystems. The ERIEYE radar is also in service aboard the Swedish air force's S 100B airborne early warning aircraft, and the EMB-145/ERIEYE combination continues to be offered to a number of ongoing AEW&C programmes. As of press time, the first Greek system is scheduled for delivery during 2002.

Russian Radar Technology Showcased

The electronics industry in Russia has highlighted new radar technology at a number of recent trade shows, with emphasis on applications in the areas of combat aircraft fire control and missile guidance. At the Paris Air Show held in June, Tikhomirov Scientific Research Institute of Russia displayed its Epaulet phased-array antenna design that is intended to act as part of an interface subsystem between Western fire-control radars and Russian air-to-air missiles. The range of missiles involved includes the R-27 (AA-10 Alamo) and R-77 (AA-12 Adder), and the equipment takes the form of guidance antennas located on the sides of the host aircraft's fuselage or its wing roots.

At the Moscow Air Show held in August, Russian contractor Phazotron-NIIR displayed a prototype of its Sokol passive phased-array radar that is intended for use aboard multirole combat aircraft such as the Sukhoi S-37. Fitted with a 1 m diameter antenna array, Sokol utilises a novel antenna element arrangement that is claimed to significantly reduce costs. The radar is equipped with a single 2.5 kW liquid-cooled transmitter (an arrangement that could be superseded by a twin transmitter/single antenna at a later stage in its development). The system weighs approximately 270 kg and provides a detection range of 180 km against a moderate size radar cross-section target. In addition, the company has developed a low weight (75 kg) variant of the basic architecture designated the Pharaon sys-

INTERNATIONAL REPORT

Martin Streetly, International Correspondent

tem. The Pharaon system has a detection range of approximately 70 km and is intended for use aboard aircraft such as the Su-27 and Su-33.

Chapter 11 Filings Delay MSC Start-up

Following Iridium's filing for US Chapter 11 bankruptcy protection, the mobile satellite communications (MSC) sector suffered a second blow when ICO Global Communications filed Chapter 11 on August 27. Prior to filing for bankruptcy protection, ICO had raised \$3.1 B to fund its 12-satellite constellation and required an additional \$1.6 B to launch consumer services during the fourth quarter of 2000. However, the failure of a recent rights issue, the need to raise \$600 M to meet immediate financial commitments and inconclusive refinancing negotiations between ICO and its major investors are believed to be the main drivers behind the company's request for court protection. European analysts also have suggested that poor marketing, high handset prices and increasing investor scepticism about the validity of the MSC concept are major factors behind the demise of both companies.

Australia Acquires AMSTAR and UK GPS Simulator

As part of its Project Nixon night-fighting, surveillance and target acquisition system upgrade programme, the Australian army has purchased 61 examples of the Australian Man-portable Surveillance and Target Acquisition Radar (AMSTAR) variant of Racal Defence Electronics' J-band (10 to 20 GHz) MSTAR sensor, which will replace its existing RASIT systems. AMSTAR leverages technology from the UK's MSTAR mid-life update effort and differs from the existing set in a number of respects, including the type of man-machine interface used and the detection range offered. In Australian service, AMSTAR will be used in the all-weather target detection and classification role, and a percentage of the new sensors are expected to be installed on the service's ASLAV-S wheeled armoured reconnaissance vehicles. The total programme value is \$32.5 M and deliveries are scheduled to begin in 2001.

Australia's Department of Defence also has acquired a Global Positioning System (GPS) simulator from UK contractor Global Simulation Systems Ltd. Computer based, the new architecture accurately replicates signals from the entire 24-satellite GPS constellation as well as those from the Russian GLONASS satellite navigation system and a number of the augmentation systems currently being proposed for use with GPS. The new simulator was scheduled for installation at the Australian Defence Science and Tech-



INTERNATIONAL REPORT

nology Organisation's Tactical Surveillance Systems Division in Salisbury, South Australia in February 2000.

Rohde & Schwarz Launches New Antenna System

German contractor Rohde & Schwarz has launched a new antenna test system aimed primarily at the mobile telephone industry. The TS9970 measures the characteristics of integrated handset antennas via their auxiliary variables. The test item is mounted on a positioning system that can rotate in both the horizontal and vertical planes and measure the antenna's gain, sensitivity and three-dimensional radiation pattern. To simulate user impact on test pieces, the mounting assembly can be combined with an artificial head or body, with the entire measurement run performed in an anechoic chamber. Parameter measurements are performed automatically at given angular increments with the processed results displayed in either tabular or graphic form. The TS9970 is also suitable for use with a range of radio communications systems that use integral antennas including radio-controlled central locking systems for cars or wireless networks used with PCs.

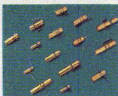
Smart Label® Alliance Formed

Netherlands contractor Philips Semiconductors Inc. and Japanese automation specialist The Omron Corp. have entered into an agreement to work on the latest generation of smart label technology. Here, radio frequency transponders and read/write memories are laminated

between layers of paper or plastic to produce low cost, consumable labels that can store information relating to a product, manufacturer or logistic process and transmit it to an appropriate read/write device at a rate of approximately 30 labels per second. More importantly, the reader and the label do not have to be in direct line-of-sight contact with each other. Under the terms of the agreement, Philips will supply Omron with smart label ICs that will work with Omron's range of 13.56 MHz label readers and transponders. The resultant technology package is suitable for all emerging applications including airport baggage handling, parcel tracking, library tracking and retail logistics. An Omron 13.56 MHz baggage label reader has been tested by British Airways and the company is currently testing retail and express parcel applications with smart labels containing Philips ICs. ■

AIR TRIMMER CAPACITORS \$0.15 PER TURN!*

OTHER FREQUENCY
TUNING PRODUCTS
FROM TEMEX COMPONENTS



Available T & R SMD: AT2723

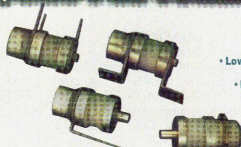


Up to 100 GHz metallic or dielectric
AT6924.0 or AT6933.2

Low ESR: slotted rotor,
proven self locking mechanism;
rugged, low dynamic
tuning noise, constant torque

High precision tuning:
multiturn design

Low loss: air dielectric;
HI Q: > 2000 @ 100 MHz



• **Low cost** (less than \$1.00 in large quantities)

• **Excellent resolution** 1.2 pF to 7 pF
(7 turns) (other capacitance ranges from
0.9 pF to 14 pF in M Series)

• **Low temperature coefficient:**
50 ± 50 ppm/°C

M120 Air trimmer capacitors

Monolithic stator and rotor
tubes machined in one pass

Choice of insulator material
flexibility for negative or positive
Temperature Coefficient

Low cost, automated gluing process;
no soldering, environmentally friendly

ISO 9001
ISO 14001



TEMEX
COMPONENTS

Find more information on
www.tekelec-temex.com

Spirit of New Technology

* based on 10 000 pieces - price for AT M 122

Our Low Noise Surface Mount Amplifiers Are Making A lot Of Noise.

Off-The-Shelf

Super Low Noise • High Dynamic Range • Low Cost

Typical performance @ +25° C

Parameter	PA1172	PA1167	PA1173
Frequency (MHz)	800-1000	1800-2000	2300-2500
Small Signal Gain (dB.)	28.0	26.0	23.0
Gain Flatness (dB.)	±0.5	±0.5	±0.5
Noise Figure Max.(dB.)	0.9	1.0	1.0
Reverse Isolation (dB.)	42	38	38
Pout @ 1 dB. compression (dBm.)	+20.0	+18.0	+18.0
IP3 (dBm.)	+30.0	+29.0	+29.0
VSWR Input/Output	1.75:1	1.75:1	1.75:1
DC Current @ +12 volts	81mA	81mA	82mA

From the company that offers the largest selection of linear amplifier modules for wireless applications comes a new breed of ultra low noise surface mount amplifiers.

These modules, targeted for the popular Cellular, PCS and WLL frequency bands, are complete amplifiers including DC biasing and 50 ohm input and output matching. They achieve extremely low noise figure performance with *high dynamic range and unconditional stability at economical prices.*

These convenient amplifier building blocks with their unmatched performance and delivery not only will reduce your design time but also enhance your system performance.

So, from your initial design concept through high volume production make Stellex Phoenix Microwave your Low Noise Amplifier partner.

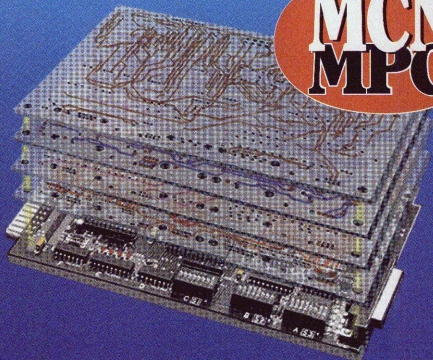
Call today: 215-723-6011
or e-mail us at
info@phnixmw.com



PHOENIX
MICROWAVE

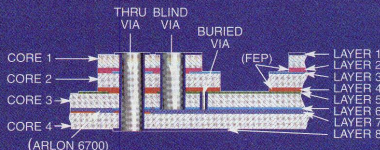
Your One Source for Microwave Circuits

**MCN
MPC**

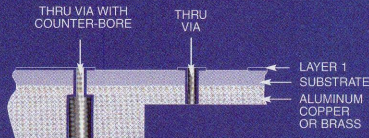


MODULAR COMPONENTS NATIONAL (MCN) / MARYLAND MPC

MULTI-LAYER BOARD



METAL BACKED BOARD



SPECIAL CAPABILITIES & NEW TECHNOLOGIES...

- Multilayers Utilizing Mixed Dielectrics
- Metal-backed Circuits with Plated-thru-Holes including Aluminum
- 2 mil Lines/Spaces
- In-house Laser Cutting
- Fine Line Etching
- Selective Plating
- Tight Tolerance Machining
- Laser Cutting
- Multilayer/Hybrids
- Heavy Metal Backed Board
- Plated Through Holes

MODULAR COMPONENTS NATIONAL, INC.

2302 Industry Court, PO Box 453, Forest Hill, MD 21050

410/879-6553 Fax: 410/838-7629

E-mail: modular@ari.net

<http://www2.ari.net/modular>

**MCN
MPC**

MARYLAND MPC LLC

81 Old Ferry Road, Lowell, MA 01854

978/452-9061 Fax: 978/441-0004

E-mail: mmpc@netway.com

<http://www2.ari.net/modular>



THE COMMERCIAL MARKET

First-half 1999

US Factory

Electronics Sales

Increase

Nine Percent

of \$41.6 B, which exceeded sales of \$35.3 B in the first half of 1998 by 18 percent. The other related products sector continues to drive the US economy forward with sales of \$39.7 B in 1999, a 14.3 percent increase from last year's sales of \$34.8 B. The remaining sectors (with the exception of industrial electronics, which dropped four percent) recorded moderate growth. The electronic components sector increased 7.6 percent from \$67.4 B in 1998 to \$72.5 B this year; the electromedical equipment sector grew 6.5 percent with \$6.6 B in sales during the first half of 1999 compared to \$6.2 B during the first half of 1998. Computers and peripherals sales increased 5.3 percent to \$45.6 B from 1998's \$43.3 B, defense communications rose 4.5 percent with \$15.6 B in sales in 1999 compared to \$15 B in 1998 and consumer electronics posted a 4.1 percent increase in sales to \$4.4 B from \$4.2 B.

FCC Authorizes

Additional Carriers

to Provide

Air-to-ground

Cellular Service

cellular providers to offer service based on AirCell's proprietary technology, which re-uses existing cellular network spectrum and infrastructure to provide cellular-like service for airborne aircraft. Pine Belt Cellular Inc., XIT Cellular, ETEX Cellular Co. Inc., WESTEX Telecommunications Inc., Tennessee RSA No. 3 Limited Partnership, North Alabama Cellular LLC and Cellular Network Partnership are the companies included in the order, which brings the number of providers commercially offering AirCell's technology to 14.

A separate FCC order granted AirCell providers additional relief that will facilitate more rapid introduction of nationwide service. The order reduces the frequency notification distance from 270 kilometers (168 miles) to 151 kilometers (94 miles), clarifies the frequency coordination process and increases the number of available channels. AirCell's technology reduces the cost of airborne telephone service and provides access to a suite of advanced communications capabilities, including fax, e-mail and the World Wide Web, at faster speeds and at a fraction of the cost of other airborne phone systems.

According to the Electronic Industries Alliance, factory sales of electronics equipment in the US reached \$244 B during the first six months of 1999, a nine percent increase over the same period in 1998. The telecommunications sector recorded the most significant growth with sales

Tenfold Growth

Forecast

for Millimeter-wave

Device Market

in 2004. Although traditional point-to-point and backhaul applications are expected to represent 90 percent of millimeter-wave device shipments this year, less than five percent of the point-to-point millimeter radios sold are expected to be used to provide access to end users. During the next five years, local multipoint distribution system (LMDS) customer premise equipment is forecast to increase from one to 14 percent of the market share, and LMDS deployments are expected to be primarily point-to-point rather than multipoint.

The demand for broadband millimeter-wave satellite system receivers is expected to account for a major share of the market growth, comprising 43 percent of the millimeter device market by 2004. The automotive radar systems segment, which is expected to account for five percent of millimeter device shipments this year, continues to make strong strides in the trucking industry. Migration of the technology to the mass market is expected within five years and is forecast to account for 21 percent of millimeter-wave shipments in 2004. The total value of millimeter-wave device shipments in 1999 is expected to reach \$28.1 M. For additional information, contact Andy Fuentes at Allied Business Intelligence (516) 624-3113 or e-mail: analysts@alliedworld.com.

Enhanced 911

Phase II

Network Caller

Location System

Demonstrated

Rural Cellular Corp. and five participating partners, including CML Technologies, 911 Datamaster Inc., GeoComm Inc., Independent Emergency Services LLC (IES) and KSI Inc., have demonstrated a new technology for 911 service that enables police to automatically pinpoint the location of a wireless telephone user calling 911 for help, thereby speeding response time. Previewed at the 1999 International Association of Public Safety Communications Officials Conference, the Enhanced 911 Phase II network-based system operates without user intervention and is independent of the wireless provider and handset used. The system also employs traditional Public Safety Answering Point equipment and technology and requires the addition of only a limited amount of equipment to 911 dispatch centers. From 1994 to 1998, the number of wireless subscribers nearly tripled from 24 million to 69 million, and close to 36 million emergency calls (an average



THE COMMERCIAL MARKET

of 68 calls per minute) were made in 1998. By 2000, when wireless subscribers are expected to number approximately 100 million, 50 million emergency calls are forecast.

Wireless Network to be Installed in 21 African Countries

Alexander Resources International Inc. has entered into an agreement to provide voice, data, Internet and video broadcasting services throughout 21 countries in Africa. Under the terms of the agreement, Alexander is responsible for the installation and operation, including capital investment and ongoing operating costs, of Tele-Trade Centres in the member countries of the Common Market for Eastern and Southern Africa (COMESA). The COMESA region currently has approximately 4.4 million telephone lines, which generate \$2.2 B in annual revenues and service more than 380 million people. A great demand for services exists in the region: The official waiting lists in Tanzania and Egypt contain 112,200 and 1,173,600 names, respectively. These figures only include those individuals who have submitted an application, which means the actual waiting list is estimated to be five-

or six-times longer. Tele-Trade Centres using very small aperture terminal satellite communications to support voice, data, Internet and video broadcasting services will be installed in the region's rural and urban areas. The major objectives of the network are to improve healthcare, education, employment and the overall quality of life in the region while increasing global connectivity and establishing a backbone for future expansion.

Ericsson to Install TDMA Networks in Argentina

Ericsson has been awarded two contracts with an aggregate value of more than \$400 M to supply national wireless networks to two newly licensed 1900 MHz operators in Argentina. Telecom and Telefonía currently operate TDMA 800 MHz networks in northern and southern Argentina, respectively, which were supplied by Ericsson. The new 1900 MHz networks will allow the two operators to support larger volumes of users and provide a platform for personalized services. Equipment deliveries from Ericsson are scheduled to begin in the second half of this year. Full network operation is expected to begin by the second half of 2000. ■

HD

HD USA

The Positioning Company

HD USA offers a wide range of positioners to meet virtually all-terrestrial based requirements. Azimuth/Elevation positioners that can handle light, medium and heavy-duty applications for airborne, shipboard and ground applications.

Featuring: ✓ Precision Positioners for Everyone!
✓ Controllers with up to four outputs

HD USA Aircraft lift AZ & EL Positioner have a dynamic range from ground up to 14 meters, azimuth rotation of ± 225 deg. and elevation of ± 30 deg.



Let HD USA technical professionals offer you the solutions you need.

For more products and capabilities information, visit our website at: <http://www.hdusa.net>

11315 Frederick Ave., Beltsville, MD 20705
Phone: 301-931-1048 Toll Free: 1-877-77HD USA
Fax: 301-931-1049 E-mail: sales@hdusa.net

IMI

**PRINTED
CIRCUIT
BOARDS**

140 Hilldale Ave., Haverhill, MA 01832

- Quick Turns Our Specialty
- Bonded Stripline
- Microstrip
- Antennas
- Mixed Dielectrics

FR4 and Polyimide Available

Your One Stop Shop For All Your Board Needs

MIL-P-55110



"Need Boards Tomorrow - Call Us Today"

Tel: (978) 373-9190/Fax (978) 521-1846

Quick-Quote Us At: www.imipcb.com

KMW Has Wide Range of Quality Attenuators To Handle All Your Needs

Designed by KMW for consistency and stability, these attenuators will be your first choice for building wireless communication system applications!



■ Step-Rotary Attenuators

Product Code No.	KAT1004SA000	KAT2004SA000	KAT1304SA000	KAT2304SA000
Operating Type	Break-Before-Make		Make-Before-Break	
Frequency Range	DC ~ 3GHz	DC ~ 3GHz	DC ~ 3GHz	DC ~ 3GHz
Insertion Loss (max.)	0.2dB	0.2dB	0.2dB	0.2dB
VSWR (max.)	1.15:1	1.15:1	1.15:1	1.15:1
Incremental Attenuation Range (dB)	0 ~ 1	0 ~ 10	0 ~ 1	0 ~ 10
Attenuation Step (dB)	0.2	1	0.2	1
Nominal Impedance	50 ohm		50 ohm	
I/O Port Connector	SMA(F) / SMA(F)		SMA(F) / SMA(F)	
Average Power Handling	2W @ 2GHz		2W @ 2GHz	
Temperature Range	-55°C ~ +85°C		-55°C ~ +85°C	
Dimension (inch)	1.93*1.56*1.51		1.93*1.56*1.51	

■ Continuously Variable Attenuators

Contactless Structure for High Power Handling Capability, up to 2W average @2GHz.

Product Code No.	A type : KAT1304CA000 B type : KAT1304CA001		
Frequency Range	DC ~ 1GHz	1 ~ 2GHz	2 ~ 3GHz
Insertion Loss (max.)	0.15dB	0.3dB	0.35dB
VSWR (max.)	1.25 : 1	1.25 : 1	1.25 : 1
Attenuation Range (max.)	4dB @ 1GHz	13dB @ 2GHz	25dB @ 3GHz
Nominal Impedance	50ohm		
I/O Port Connector	SMA(F) / SMA(F)		
Average Power Handling	2W @ 2GHz & 25°C, without Heat-Sink		
Temperature Range	-55°C ~ +85°C		
Dimension (inch)	A type : 1.496*1.102*0.470, B type : 1.225*1.102*0.470		

■ Fixed Coaxial Attenuators are available

N-type, SMA-type Connectors

CIRCLE 76 ON READER SERVICE CARD

13131 East 166th Street, Cerritos, CA 90703-2202
1-800-8320-KMW • www.kmwinc.com
tel: 562.926.2022 • fax: 562.926.6122

KMW
KALAMAZOO WIRELESS COMMUNICATIONS, INC.



AROUND THE CIRCUIT

INDUSTRY NEWS

■ **Watkins-Johnson Co.**, Palo Alto, CA, has signed a definitive agreement to sell its **Telecommunications Group** business to **Marconi North America**, a subsidiary of **The General Electric Co. plc** of the UK. The pre-adjusted purchase price of \$57.9 M, based upon a balance sheet, will be adjusted to the balance sheet at the date of closing, and the final transaction is subject to the approval of Watkins-Johnson shareholders.

■ **Noise Com's Wireless Telecom Group Inc.** has entered into a definitive agreement to merge **Boonton Electronics Corp.** into a wholly owned subsidiary. Under the terms of the agreement, each share of Boonton common stock will be converted into 1.4 shares of Noise Com common stock and an amount of cash equal to 0.175 times the closing price of Noise Com common stock on the closing date. The transaction, which is expected to be completed before December 31, is valued at approximately \$7 M and subject to Boonton shareholder approval as well as other customary requirements.

■ **Mitec Telecom Inc.** has moved its operations to a state-of-the-art, 88,000-square-foot manufacturing facility geared for very large volume production. The new facility is located at 9000 Trans-Canada Highway, Pointe Claire, Quebec, Canada H9R 5Z8 (514) 694-9000, fax (514) 694-3814.

■ **MMIC and MMIC assembly designer and manufacturer Hittite Microwave Corp.** has relocated its operations to a new facility at 12 Elizabeth Drive, Chelmsford, MA 01824 (978) 250-3343, fax (978) 250-3373. The e-mail address is hmcsales@hittite.com.

■ **RF and microwave filter and diplexer manufacturer Luna Microwaves Inc.** has moved to a larger facility at 7610-V Rickenbacker Dr., Gaithersburg, MD 20879. Telephone and fax numbers remain unchanged.

■ **Trak Communications Inc.**, a **Tech-Sym** company, has opened a new filter design center, **Advanced Filter Solutions (AFS)**, in Frederick, MD. The new facility will be responsible for sales, design and development of a comprehensive line of RF filter products for the wireless industry.

■ **Centurion International Inc.** has increased its presence globally by opening a new manufacturing facility in Tijuana, Mexico; expanding its Asian management team and relocating offices to Seoul, South Korea; and building a new campus with corporate headquarters and a manufacturing facility in Lincoln, NE. In addition, Centurion has acquired **Sigma Wireless Technologies'** portable antenna division in Dublin, Ireland and relocated it to the company's operations in Aylesbury, UK.

■ New Zealand-based **Deltec** has changed its name and look to represent the company's growing presence in the global telecommunications industry. The newly named company, **Deltec Telesystems**, will continue to design,

manufacture and market advanced base station antennas, filters and control systems and offer its line of Teletilt™ remote-controlled electrical downtilt antennas.

■ **CTS Corp.'s Electrocomponents** business unit, which designs and manufactures variable resistor, encoder and switch products, will be integrated with the company's **Resistor Products** business unit to form **CTS Resistor/Electrocomponents**. Simultaneously, CTS Electrocomponents' loudspeaker and electromechanical assembly products will integrate into CTS' **Automotive Products** business. All customer support personnel and manufacturing facilities will remain unaffected.

■ **RF and microwave specialty component distributor Richardson Electronics Ltd.**, LaFox, IL, has entered into an agreement with **Motorola Semiconductor Product Sector** to serve as its global RF, microwave and wireless components distributor. In related news, Richardson Electronics and **M/A-COM**, a division of **AMP Inc.**, have expanded their distribution agreement to include Taiwan. The distribution agreement will provide technical support and product availability to the wireless telecommunications, automotive, aerospace and defense markets.

■ **Unique Broadband Systems Inc.** has named Chilean-based **Telefonia Y Comunicaciones SA (TECOM)** a distributor of its broadband wireless equipment product line. Under the terms of the agreement, TECOM is responsible for purchasing equipment worth US\$2.1 M over the length of the agreement, which expires December 31, 2000. The agreement is expected to increase sales and create brand recognition in the South American market.

■ **Tekmark Inc.**, Atlanta, GA, has selected **Diamond Advanced Components Inc.** to serve as North American distributor for its high quality quartz frequency control products to the computer, telecommunications, wireless data communications, CEM and other OEM markets.

■ **Hewlett-Packard Co. (HP)**, Palo Alto, CA, and **Ando Electric Co. Ltd.** of Tokyo have entered into a three-year agreement to develop and market test instruments for the emerging high bandwidth DWDM and SONET/SDH functional test market. The agreement does not apply to other HP and Ando products, which the companies will continue to market and sell independently worldwide. In related news, HP and **Integrated Measurement Systems' (IMS) Virtual Test Division** have entered into an agreement to offer virtual test software tools for verifying the compatibility of test programs with high performance semiconductor designs without using a prototype. The alliance is the culmination of a two-year relationship during which the companies collaborated on developing methods to enhance the IC testing process.

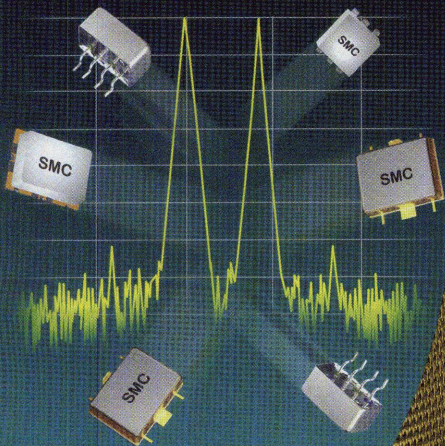
■ **IBM and Siemens Information and Communication Networks** have signed an agreement to apply next-generation system-on-a-chip products based on IBM's silicon

[Continued on page 66]

HIGH IP3

When your wireless communications system calls for very low intermodulation distortion and enhanced dynamic range, look into **Synergy's** new line of **HIGH IP3 MIXERS**. Standard models are available in specialized frequency bandwidths covering UHF, Cellular, PCS and ISM bands. Additional features are low conversion loss and high interport isolation. Most models operate at +17 dBm of local oscillator drive level and exceed +30 dBm of input third order intercept point. Higher L.O. drive level models with higher third order intercept points are also available.

Don't compromise performance...
specify **Synergy's HIGH IP3 MIXERS**.



For additional information,
contact Synergy's sales and application team:

Synergy Microwave Corporation
201 McLean Boulevard, Paterson, NJ 07504
Tel: (973) 881-8800 • Fax: (973) 881-8361
E-mail: sales@synergymw.com
Web site: www.synergymw.com

SYNERGY
MICROWAVE CORPORATION

CIRCLE 168 ON READER SERVICE CARD

MIXERS

AROUND THE CIRCUIT

germanium (SiGe) process technology to high performance mobile network communication systems. Under the terms of the agreement, **Siemen's Communication on Air** business unit will gain access to IBM's SiGe technologies currently in development. SiGe technology is a process in which the standard silicon that forms the base of microchips is augmented with germanium to make the chips operate much faster with decreased power consumption and increased integration capabilities.

■ **American Microsystems Inc. (AMI)**, Pocatello, ID, has entered into an agreement with **Rambus Inc.**, Mountain View, CA, to license the company's Direct Rambus™ technology for clock generator devices. AMI will design and manufacture a family of Direct Rambus clock generator devices to support high bandwidth Rambus® memory systems for computers, communications and consumer products as well as other high performance electronic systems.

■ **Superconductor Technologies Inc.**, Santa Barbara, CA, has entered into a five-year agreement with **US Cellular Corp.** Under the terms of the agreement, US Cellular will acquire a minimum of 100 SuperFilter® systems over the next year and a minimum of 400 systems over the subsequent four years. In turn, Superconductor Technologies will issue US Cellular a warrant, subject to vesting provisions, providing for the purchase of up to one million shares of the company's stock at \$4 per share.

■ **Gabriel Electronics Inc.**, Scarborough, ME, and **Endgate Corp.**, Sunnyvale, CA, have entered into a joint agreement to introduce a new generation of smaller and more attractive antennas for the expanding broadband wireless market. The two companies will jointly market and support FlatFire™ and GemFire™ products globally while cooperating in the development of new, integrated antenna solutions for a variety of applications.

■ **CoWare Inc.**, a provider of system-level design tools for complex system-on-a-chip development, and **Lucent Technologies** have entered into an agreement whereby Lucent will use the CoWare N₂C™ design software to minimize system-on-a-chip design time. In addition, Lucent plans to integrate some of its processor cores into the CoWare N₂C system so customers can quickly complete designs.

■ **Motorola Inc.** has presented Texas A&M University College of Engineering with a \$500 K gift to support the college's future system-on-a-chip research and development programs. The donation, which is expected to be paid over five years, will support activities of the analog and mixed-signal research program and fund research assistantships in an effort to fill the critical need for more analog and mixed-signal engineers.

■ Solid-state power amplifier manufacturer **Comtech PST** has begun supplying a two-year warranty for the company's standard general-purpose and standard wireless-band series class A linear amplifiers. The warranty will apply to module (AM series) as well as instrument (AR series) amplifiers.

[Continued on page 68]



Antennas and Accessories

100 Hz to 40 GHz



First in Line for

Radio Monitoring, Radio Location

Global Communication



SIGINT, ELINT, DF, HF/VHF/UHF



TELECOM, PCS, GPS, PCN, DECT, WLAN

11317 Frederick Ave., Beltsville, MD 20705; Phone: 301-937-8888 * Fax: 301-937-2796

For a free brochure or a quote, please contact us at: 1-877-ARA-SALE or sales@ara-inc.com
Visit our website at: <http://www.ara-inc.com>



HP ESG-DP Series RF Signal Generators

Being an engineer isn't just something you do, it's who you are. As such, it demands your complete focus. And the last thing you need is the distraction of test equipment that won't do what you need it to.

OUR CDMA SIGNAL GENERATORS ARE MADE FOR ENGINEERS WHO NEVER STOP BEING ENGINEERS.

So we set out to ask R&D engineers what they need when it comes to testing CDMA base station and mobile components.

What we found was traditional signal generators don't simulate realistic CDMA signals. So we designed our ESG digital signal generators to provide internally generated, statistically correct, multichannel CDMA signals to qualify components under realistic worst-case conditions. In addition, both CDMA and TDMA formats are supported—in one box—up to 4 GHz.

**Introducing
high spectral
purity models**

Because an uncooperative Robby the Robot is one thing. But an uncooperative signal generator is completely unacceptable.

For a free application note, "Testing CDMA Base Station Amplifiers," call your local HP sales office or one of the numbers listed below, or visit our Web site:

www.hp.com/go/esg



**HEWLETT
PACKARD**

Argentina (54 1) 787-7115 • Austria (01) 25900-7006 • Australia 1 800 629 485 • Belgium (32/2) 778-34-17
Brazil (55 11) 7097-8600 • Canada 1-877-894-4414 • Czech Republic (420) 2 61307111 • Denmark (45) 45 99-10-50
Finland (3589) 8872 2100 • France (01) 69 23 41 14 • Germany (0180) 324-0330 • Greece (30) 72604045
Hong Kong (852) 2509 7580 • Hungary (36) 1 4618111 • India (01 11) 690 6156 • Ireland (01) 615 8222
Israel 072 (03) 558-03-90 • Italy (39 02) 92-122-241 • Japan (81/3) 3331-6111 • Korea (82 2) 768 0890
Malaysia 1 80 86 8846 (0 03) 330 0210 • Mexico (52-5-256-4284 • Netherlands (020) 547 1272 • Norway (47 22 75 57 39
Philippines (632) 514 1083 • Poland (48) (022) 006770 • PRC 900 810 0189, (86 10) 6564 0238 • Singapore 1800 375 8100
Spain (34) 91 621 1822 • Sweden (460) 444 22 77 • Switzerland (01) 735 72 36 • Taiwan (86 212 535 0800 47966 press 1
Thailand (662) 661 3999, (088) 225 802 • United Kingdom (01344) 369666 • Venezuela (58-2) 297-8087

© 1999 Hewlett-Packard Co. TMMDS22/INTL

AROUND THE CIRCUIT

■ Wireless communications equipment manufacturer **Cel-wave**, a division of **Radio Frequency Systems Inc.**, has begun base station antenna production in Brazil's recently expanded kmP factory in Embu, a suburb of Sao Paulo. The facility is restricting its initial output to Brazil exclusively; export to other South American markets is being planned.

■ The Department of Defense Small Business Innovation Research (DoD SBIR) program has launched its first solicitation for FY 2000. The SBIR program is the largest source of early stage research and development funding available in the US for small, high tech companies. Qualifying companies must have 500 or fewer employees and be US owned and organized for profit. Information on solicitation topics and submission procedures can be found at www.acq.osd.mil/sadbu/sbir. Proposals will be accepted December 1, 1999 through January 12, 2000.

■ **Karl Suss** is celebrating its 50th anniversary. Founded in 1949, the company's current product range includes the world's fastest production mask aligners, spin coater product lines for high end application markets, bonders and test equipment.

■ **International Crystal Manufacturing (ICM)** has been approved by the North Texas Women's Business Council as a certified Women Business Enterprise (WBE). The certification will allow ICM to compete for business with corporations and agencies that recognize and support WBE.

■ **Sonoma Scientific** has received ISO 9001 certification.

FINANCIAL NEWS

■ **Andrew Corp.** reports sales of \$186.1 M for the third quarter, ended June 30, compared to \$204.2 M for the same period last year. Net income was \$14.7 M (18c/diluted share), compared to \$24.6 M (28c/diluted share) for the third quarter of 1998.

■ **REMEC Inc.** reports sales of \$47.3 M for the second quarter, ended July 30, compared to \$44.4 M for the same period last year. Net loss was \$2.8 M (11c/diluted share), compared to a net loss of \$6.5 M (26c/diluted share) for the second quarter of 1998.

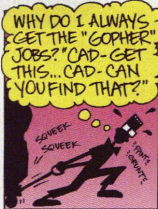
■ **Watkins-Johnson Co.** reports sales for continuing operations of \$34.9 M for the second quarter, ended June 25, compared to \$26.8 M for the same period last year. Net income from continuing operations was \$3 M (45c/diluted share), compared to \$563 K (7c/diluted share) for the second quarter of 1998.

■ **Ansoft Corp.** reports sales of \$6.9 M for the first quarter, ended July 31, compared to \$5.2 M for the same period last year. Net loss was \$893 K (8c/share), compared to a net loss of \$1.3 M (11c/share) for the first quarter last year.

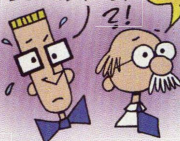
■ **Robinson Nugent Inc.** reports sales of \$18.9 M for the fourth quarter, ending June 30, compared to \$16.4 M

[Continued on page 70]

THE ADVENTURES OF CAP and CAD by



CAP-THIS IS THE BROADEST "DC BLOCKER" I COULD FIND!



VIKES

NEXT TIME CAD, YOU'D BETTER CALL THE SOLUTIONS EXPERTS @ DIELECTRIC LABS!

WE CAN ONLY HAVE HIM TILL MONDAY NIGHT FOOTBALL.



© 1999 Dielectric Laboratories, Inc.

Digital radio? BWA? Designs got you pulling out your hair? The **Solutions Experts** at **Dielectric Laboratories** have a single component solution for you... our **Broadband DC Block** in a surface mountable 0805 package. Call the **Solutions Experts** today.

Dielectric Laboratories Inc.

2777 Rte 20 E., Cazenovia, NY 13035
Phone: 315.655.8710 Fax: 315.655.8179
<http://www.dilabs.com>

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

Since then, tens of thousands of microwave amplifiers and assemblies have been delivered into applications including: ESM, radar systems, missiles, UAV's, seekers and decoys.

CTT's products contain the latest advancements in thin-film, GaAs FET MIC and MMIC technology. These high quality products include:

- Low-Noise Amplifiers
- Medium Power Amplifiers
- High Power Amplifiers
- Limiting Amplifiers
- Amplifier Subassemblies

As military budgets have continued to shrink, the threats have continued to become more lethal and diverse. CTT has, however,

continued to incorporate excellence in engineering and production technology into our products in order to make your programs – whether new or upgrade – effective.

Our goal is to be the number one supplier of amplifiers and subassemblies in the marketplace. In fact, we are currently supplying replacements for many hard-to-find assemblies – including those formerly provided by **Avantek**.

Give us a call to find out how our commitment can support your success.

*Coverage
without
compromise
continues.*



3005 Democracy Way
Santa Clara, CA 95054 USA
Phone: 408-988-8521
FAX: 408-986-9097
www.cttinc.com

AROUND THE CIRCUIT

for the fourth quarter of 1998. Net income was \$1.2 M (24¢/share), compared to a net loss of \$2.5 M (52¢/share) for the same period last year.

■ **Superconductor Technologies Inc.** reports sales of \$1.5 M for the second quarter, ended July 3, compared to \$2.2 M for the same period last year. Net loss was \$2.4 M (31¢/share), compared to a net loss of \$2.2 M (28¢/share) for the second quarter of 1998.

CONTRACTS

■ RF engineering and system deployment service firm **LCC International Inc.** has signed a contract valued at approximately \$115 M with XM Satellite Radio Inc. for the design and deployment of XM's terrestrial repeater network. The contract designates LCC as the prime contractor for the implementation of XM's supplemental terrestrial repeater sites. The repeater network will use direct satellite-to-receiver broadcasting technology to provide radio listeners with up to 100 channels of digital radio from coast to coast.

■ **Sanders**, a **Lockheed Martin** company, has been awarded a \$43 M contract for continued production of millimeter-wave transceivers for the Longbow Hellfire Missile System. The missile system is deployed on US Army AH-64D helicopters and will be installed on UK Army WAH-64 Apache helicopters. Sanders will build

4200 transceivers for Lockheed Martin Millimeter-wave Technologies Inc., a Lockheed Martin subsidiary. Deliveries are scheduled to begin in April 2000 and are expected to be completed in February 2002.

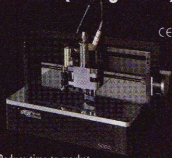
■ **L-3 Communications' Global Network Solutions (GNS)** business unit has been awarded a \$15 M contract to provide a complete private digital microwave voice and data network to the Egyptian National Railways (ENR) organization. Under the terms of the contract, GNS will install a private communications network that spans ENR's entire 6000-mile right-of-way, including site survey and facility installation work. In related news, L-3 Communications' Telemetry & Instrumentation (L-3 T&I) has awarded a contract to **EMP TrexCom** to supply three model 050 2.4-meter antenna systems to be installed in the Hebrides range facility for the Defense Evaluation Research Agency in the UK. The three systems are part of a \$3.6 M contract received by L-3 T&I for the upgrade of the facility, which will support testing of the next-generation, high energy air-to-air missiles.

■ **Andrew Corp.**, Orland Park, IL, has been awarded a contract from Level 3 Communications to supply and install equipment shelters along the company's fiber-optic communications network in the US and Canada. Under the terms of the \$14 M contract, Andrew will design, manufacture and install shelters at 96 sites along Level 3's US and Canadian route. All shelters are expected to be installed and operative by December 2000.

[Continued on page 72]

Quick Circuit Board Prototyping System

Fast
 (enough said)



- Reduce time to market
- Slash development costs
- Two models to choose from
- Standard (8k-23k) or high speed (5k-60k) spindle both variable and s/w controlled
- One year warranty / free phone support

T-TECH, INC.

5591-B New Peachtree Road, Atlanta, Georgia 30341 USA
 voice: 770.455.0676 fax: 770.455.0970
 email: sales@t-tech.com

Check out our Web site for new products www.t-tech.com

Quasar
 Leaders in Microwave technology

For Microwave point to point radio, LMDS,
 UMTS & Satellite Communications

Quasar has developed a family of microwave waveguide components for communications applications where precision, quality and reliability are paramount.

- Directional Couplers, Splitters and Combiners
- Filters and Diplexers
- Power Combiners

Quasar can combine these products into single integrated assemblies which are ideally suited to "Hot stand by" or 1+1 applications this eliminates the need for flexible waveguide. Designs and prototypes for specific customer requirements can be made within weeks from Quasar's high quality factory in the UK. Whether you are designing the next point to point radio or a satellite transmitter/receiver Quasar can help you. Call us today or take a look at our website.

Quasar
 Quasar Microwave Technology Limited
 Battle Road, Heathfield, Newton Abbot,
 Devon TQ12 6XU, England

Tel: +44 (0)1626 834222
 Fax: +44 (0)1626 832994
 Email: sales@qmtl.com

See our NEW WEBSITE www.qmtl.com



MILLIMETERWAVE MMICs! OFF-THE-SHELF!

NEW

from Hittite Microwave

CONVERTER/MIXERS FEATURE:

- ▶ SUB-HARMONIC (x2) LO INPUT
- ▶ INTEGRATED LO AND IF AMPLIFIERS
- ▶ 1.3 x 1.3 mm OR

AMPLIFIERS FEATURE:

- ▶ BROAD BANDWIDTH
- ▶ STABLE GAIN VS. TEMPERATURE
- ▶ +3V SUPPLY

For applications in the emerging market for LMDS, PT-PT, & SATCOM Ka-band communication systems, Hittite Microwave introduces a family of 5 new millimeterwave MMICs.

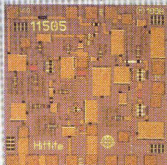
Production qualified PHEMT and MESFET processes are utilized. We offer commercial level die products, 100% RF tested & visually inspected, as well as military and space level screening.

Millimeterwave products are available now in sample or production quantities from our stock!

HMC265

20 - 32 GHz DOWNCONVERTER

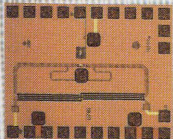
- ▶ 13 dB GAIN
- ▶ 35 dB 2LO/RF ISOLATION



HMC259

28 - 40 GHz MIXER

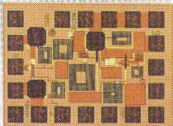
- ▶ 1.24 mm x 1.55 mm
- ▶ 50 dB 2LO/RF ISOLATION



HMC258

14 - 21 GHz UP/DOWNCONVERTER

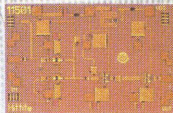
- ▶ 0 dBm LO INPUT
- ▶ 40 dB 2LO/RF ISOLATION



HMC261

20 - 40 GHz DISTRIBUTED AMPLIFIER

- ▶ 14 dB GAIN
- ▶ +3 V @ 75 mA



HMC264

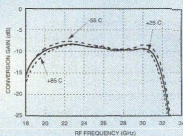
20 - 32 GHz
UP/DOWNCONVERTER



FEATURES:

- ▶ INTEGRATED LO AMPLIFIER:
- ▶ -4 dBm LO INPUT
- ▶ SUB-HARMONICALLY PUMPED (x2) LO
- ▶ HIGH 2LO/RF ISOLATION: >35 dB
- ▶ SMALL SIZE:

0.97mm x 1.32mm



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

Hittite
MICROWAVE CORPORATION

New
Address

www.hittite.com

PHONE: 978 250 3343 ▶ FAX: 978 250 3373

12 Elizabeth Drive, Chelmsford, MA 01824 USA

Request
Our 1999
Catalog/CD!



AROUND THE CIRCUIT

■ **GPS and wireless antenna designer and manufacturer Micro Pulse Inc.** has been awarded an 18-month contract valued at \$3.4 M from San Diego, CA-based QUALCOMM Inc. to supply antennas for use on QUALCOMM's OmniTRACS® Mobile Information Management system. The fully integrated information management system provides two-way mobile communications, satellite tracking, and real-time messaging and position reporting between fleets and their operation centers.

■ **Signal Technology Corp.**, Danvers, MA, has received contracts totaling \$971 K from Raytheon Systems Co. and Raytheon's suppliers to manufacture components, including isolators, mixers, limiters and limiter/filter assemblies, for the Patriot Missile System. The components will be produced at Signal Technology's California division in Sunnyvale, CA.

■ **Scientific-Atlanta Inc.**, Norcross, GA, has signed a multimillion-dollar contract with Telespazio SpA, a Telecom Italia Group company, to develop, manufacture and install the satellite ground terminals that form a major portion of the ground infrastructure network for Astrolink, a new global satellite system. Under the terms of the contract, Scientific-Atlanta will supply the Gateway Satellite Access Facility RF terminals and the Intersatellite Gateway Links comprising precision tracking antenna systems, front-end communications electronics and high speed modems. The contract covers the networks' first four regions: Europe, Asia, the Atlantic and North America. Astrolink commercial service is scheduled to begin in 2003 with full deployment planned for 2004.

■ **Berkeley Varitronics Systems Inc.**, Metuchen, NJ, has been awarded a contract by Motorola of Buenos Aires to provide CDMA test transmitters that will be used to aid in CDMA system build-out. In related news, Berkeley Varitronics Systems has been awarded a contract by World Access, Alpharetta, GA, for eight PCS 20 W class A Gator transmitters that will aid in rapid build-out of PCS networks. Financial details of both contracts were not disclosed.

■ **Chipscale Robotics Inc.**, Fremont, CA, has received an order from Coherent Inc. for a high accuracy DSH 5000 pick-and-place system for die stacking. The system will use both up- and down-looking optics for precision die stacking and inspection. Coherent will use the system in its manufacturing operations. Financial terms of the agreement were not disclosed.

PERSONNEL



▲ Thomas J. Scanio

■ **TriPoint Global Communications Inc.** has appointed **Thomas J. Scanio**, chief technical officer. Scanio has more than 25 years of experience in engineering design and management and, most recently, was VP, product development for the Antenna Control division of TriPoint's RSI group.

■ **REMEC Inc.** has appointed **Mark D. Dankberg** to serve on its board of

directors. Dankberg is the founder, chairman and CEO of ViaSat Inc.

■ **James E. Bunting** has been named CFO at SatCom Systems Inc. Most recently, Bunting was VP, CFO and COO at Intellicell Corp.



▲ John E. Warren III

■ **ANADIGICS** has announced several new personnel appointments, including **Thomas C. Shields** as CFO, **John E. Warren III** as VP, human resources and **Glenn Fraser** as VP, RF Standard Products. Most recently, Shields was VP of finance and controller at Fisher Scientific Co.; Warren was VP, human resources at Alpha-Net Solutions; and Fraser was director of the Wireless Business Unit at Fujitsu Microelectronics Inc.



▲ Glenn Fraser

■ **Rodale Electronics Inc.** has promoted **Vince Maida** to VP and director of operations. In addition, **Paul Ablequist** has been named VP, sales and marketing. Most recently, Maida was VP, engineering; Ablequist was VP, marketing for the EMS Division of Ultra Electronics plc.

■ **Acoustic signal processing product manufacturer Micro Networks/Andersen Laboratories** has appointed **Linda Plano** VP and business unit manager, frequency products. Most recently, Plano was head of the Electronic Materials and Microsystems Group at Sarnoff Corp.

■ **Custom Microwave Inc.** has appointed **Michael Kujawa** VP, business development. Kujawa has 17 years of experience in the SATCOM, aerospace and automated meteorology markets.

■ **Smart antenna system provider Metawave Communications Corp.** has appointed **Andy Merrill** VP, customer operations. Merrill has 15 years of experience in the cellular industry and, most recently, was field engineering manager of Motorola Inc.'s western region.



▲ David J. London

■ **David J. London** has been appointed VP, sales and marketing at Piconics Inc. Most recently, London served as VP at mm-Tech Inc.

■ **Stellex-Phoenix Microwave** has appointed **Mark Fornier** director of sales at its Phoenix Microwave operation.

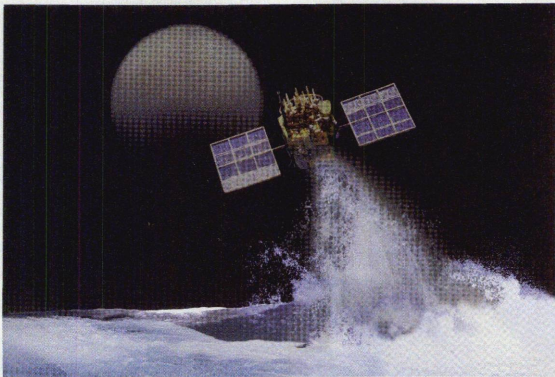
Fornier has more than 18 years of sales and marketing experience in the RF and microwave industry and, most recently, was marketing manager at M/A-COM's Aerospace and Defense business.



▲ Mark Fornier

[Continued on page 74]

WAVE OF THE FUTURE



If you want to make a splash in advanced communications technology, come to Sarnoff.

Our ideas can solve your toughest problems in microwave technology, LMDS designs for two-way wireless cable, and solutions for digital cell phones.

We'll help your products see better, send faster, communicate locally and globally, work more reliably, and cost less.

Among the flood of innovations we're pouring into new products and systems:

- Microwave HBT and FET devices, MMICs, microelectromechanical control components, antenna technology
- RF-based identification sensors and systems
- Enabling technologies for next-generation Ka-band satellite designs
- High-speed digital voice, video, and data communications

We offer innovative microwave sensors. We're the source of a tidal wave of advances in analog and digital wideband LANs.

You can use our design services, license our technology, or partner with us in a new venture. In devices, packaging, or complete systems, you'll be working at the leading edge with Sarnoff solutions.

Contact us at **609-732-2507** for more information. Or check out our web site at **www.sarnoff.com**.

201 Washington Road
Princeton, New Jersey 08540-6449

© Copyright 1998 Sarnoff Corporation. All rights reserved.

 **SARNOFF**
Corporation
Changing the World with Technology

CIRCLE 156 ON READER SERVICE CARD

AROUND THE CIRCUIT



▲ Mark Jewell

Flexible waveguide manufacturer Quasar Microwave Technology Ltd. has appointed **Mark Jewell** sales and marketing director. Jewell has experience in RF and microwave sales in the international market, including Asia, Australia and Europe.

Ron Desilets has joined Metclad International Corp.

as North American sales and marketing manager. Desilets brings to the company 20 years of experience in microwave laminates and circuits.

CTS Corp. has named **John W. Cline** director of engineering for CTS Reeves Frequency Products. Prior to joining the company, Cline served as president of Oak Frequency Control Inc.

Tensolite-QMI has appointed **Will Jensen** director of sales and marketing. Jensen brings to the company sales and marketing management experience from companies that provide products and services to the wireless telecommunication marketplace.



▲ Ron Desilets

Northrop Grumman Corp.'s Integrated Systems and Aerostructures sector has named **Frank Wagner** director and integrated product team leader for the F-14 program. Wagner has more than 20 years of F-14 experience and, most recently, was program manager for F-14 new programs at Northrop Grumman.

ARCOM Inc. has named **Dieter Kaiser** director of operations for its product line of mm-wave wireless components and subsystems. Kaiser brings to the company more than 20 years of high volume manufacturing experience and, most recently, worked at Whistler Corp.

Surface-mount technology and advanced packaging supplier Quad Systems Corp. has appointed **Jay DiGiovanni** director of software engineering. Most recently, DiGiovanni was director of systems engineering at CFM Technologies Inc.

Palomar Technologies has announced several new personnel appointments, including **Michael Criscuolo** as manager of customer service and **Gabriel Perez** and **Jerrold Olsen** as field service engineers. Criscuolo has 18 years of management experience at General Dynamics, Convair Division and Palomar Robotics Technologies; Perez most recently was a field service engineer at Devoltec; and Olsen has 13 years of technical experience and electronics training with the United States Marine Corps.

[Continued on page 76]

SHP

SPECIAL HERMETIC PRODUCTS, INC.

Hi-Rel By Design



FEEDTHRU, RF, DC, CAPACITIVE

Provides 50 combined years of qualified Engineering Experience in glass to metal seal design, manufacturing and Application.

Developed the "Aluminum Compatible" seal, which enjoys unprecedented reliability.

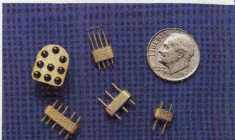
Provides full review of your product to assure the optimum selection of feedthru design.

Assures dependable delivery through a complete line of standard products that will be readily available when you need them.

Supports your needs with ancillary items, such as: Solder Preforms, Fixtures, Dielectric Bushings and Capacitive Devices.



MICROMINIATURE CONNECTORS



HEADERS, DC, CAPACITIVE, HYBRID



ANCILLARY PRODUCTS

Riverview Mill • P.O. Box 269 • Wilton, NH 03086

TEL: (603) 654-2002 • Fax: (603) 654-2533

url: www.shp-seals.com • e-mail: sales@shp-seals.com

BORDER CAP

new
from
ATC

SINGLE LAYER CAPACITORS WITH RECESSED METALIZATION

- SUPPORTS MILLIMETER-WAVE APPLICATIONS
- EXPOSED BORDERS FOR USE IN AUTOMATED ASSEMBLY
- SOLDER RESIST AREA TO REDUCE SHORTS
- STANDARD SIZES FROM 10 TO 15 MILS. SQ. CUSTOM SIZES AVAILABLE

to learn more
Click here
www.atceramics.com



American
Technical
Ceramics

Dielectric Code	Dielectric Const (K)	Temperature Coefficient (TCC) (-55°C to +125°C)	Capacitance Range (pF)
A	14	+90 ±30 PPM/°C	0.04 to 1.7
AX	23	0 ±30 PPM/°C	0.06 to 2.7
BA	36	-80 ±30 PPM/°C	0.10 to 4.3
BB	31	0 ±30 PPM/°C	0.09 to 3.7
CA	62	0 ±30 PPM/°C	0.17 to 7.4
CC	130	-750 ±200 PPM/°C	0.37 to 15
DA	165	-1500 ±500 PPM/°C	0.46 to 20
DB	200	±7.5% max. change (non-linear)	0.56 to 24
HC	350	-2000 ±500 PPM/°C	0.98 to 42
EA	650	-4700 ±1500 PPM/°C	1.8 to 77
EO	650	±10% max. change (non-linear)	1.8 to 77
ET	1100	+5% to -15% max. change (non-linear)	3.1 to 130
F	2000	±10% max. change (non-linear)	5.6 to 230
G	6000	+10% to -75% max. change (non-linear)	17 to 710
NEW - GA	4500	± 15%	13 to 530
K	9000	0% to -92% max. change (non-linear)	25 to 1000
NEW - L	15,000	±0.1-92%	42 to 1700

PHONE: 516-622-4700 • E-MAIL: SALES@ATCERAMICS.COM •

ISO 9002
REGISTERED
COMPANY



CIRCLE 7 ON READER SERVICE CARD

■ **Leo Messier** has been appointed business unit manager for HELIAX® connector products at Andrew Corp. Messier has more than 30 years of operations and materials experience. Prior to joining Andrew, he was director of operations at Huber + Suhner Inc., North America and Amphenol RF/Microwave.

REP APPOINTMENTS

■ **Fujitsu Compound Semiconductor Inc.**, San Jose, CA, has named **Kruvand Associates Inc.**, Richardson, TX, to represent its microwave, lightwave and GaAs IC DataComm products in Arkansas, Louisiana, Oklahoma and Texas (excluding El Paso County). In the past 10 months, Fujitsu has added five new sales representative firms to cover more than 30 percent of the US.

■ **Advanced Semiconductor Inc.**, North Hollywood, CA, has appointed several European companies to represent its line of microwave and RF components, including **Semic RF Electronic GmbH** to cover Germany, Austria, Switzerland and Eastern Europe; **Novacom Microwave Ltd.** to cover the UK, Ireland and the Netherlands; and **Compomill AB** to cover Scandinavia.

WEB SITES

■ **Aethercomm**, San Marcos, CA, has designed a new Web site containing information about the company's RF, microwave and millimeter-wave amplifiers, transmitters, receivers, components and ASICs for use by military, satellite communications and commercial wireless customers. The site can be accessed at www.aethercomm.com.

■ **Association Connecting Electronics Industries** has designed a new Web site dedicated to GenCAM,™ the industry standard for printed board data transfer. The site is a one-stop source for information on the format, including CAD and CAM suppliers, accuracy checkers and the standard itself. The site can be accessed at www.genecam.org.

■ **Interstate Electronics Corp.**, a division of **L-3 Communications**, has designed a new Web site to discuss the release and other authoritative material related to the defense industry and GPS. The site, which can be accessed at www.rankin-group.com/iecp, will highlight the company's developments and current products for the US Navy's Extended Range Guided Munition program and the US Army's new 155 mm Excalibur GPS receiver projectile.

■ **Microwave Solutions Inc.**, National City, CA, has designed a Web site containing product information on the latest amplifiers used in today's market, including high power, drop-in, broadband, communication, low noise and stocked. Press releases, key specifications, company information and purchasing information can be accessed at www.microwavesolutions.com.



SONET/SDH APPLICATIONS

PRECISION INSTRUMENTATION

GPS APPLICATIONS



TARGETING STRATUM III APPLICATIONS!

MAXO series precision OSCILLATOR

SPECIFICATIONS

- M-tron's MAXO is a digitally assisted compensation precision oscillator that is being introduced as an alternative to low end OCXO and higher end TCXO applications
- Offers low power consumption—less than 15 mA at 5 V. 3.3 V version is also available
- Stability as tight as 0.33 ppm is achieved over an operating temperature of 0°C to +70°C
- Long term aging is targeted at less than 3 ppm for 10 years
- Packaged in a 14 pin compatible format with TLUCMOS compatible output
- Ideal for applications requiring a precision reference oscillator



M-tron INDUSTRIES, INC.

PO Box 630, Yankton, SD 57078-0630
1-800-762-8000 • FAX 605-665-1709

www.mtron.com


ISO 9001

Standard and Precision Waveguide

- WAVEGUIDE SIZES WR650 TO WR8
- MICROWAVE COMPONENTS
- ISO 9002 APPROVED

- AMERICAN DISTRIBUTORS:
- Mega Industries
TEL: (207) 854 1700
FAX: (207) 854 2287
- A-Alpha Waveguide (California Only)
TEL: +44 1992 500818
FAX: (310) 322 0088

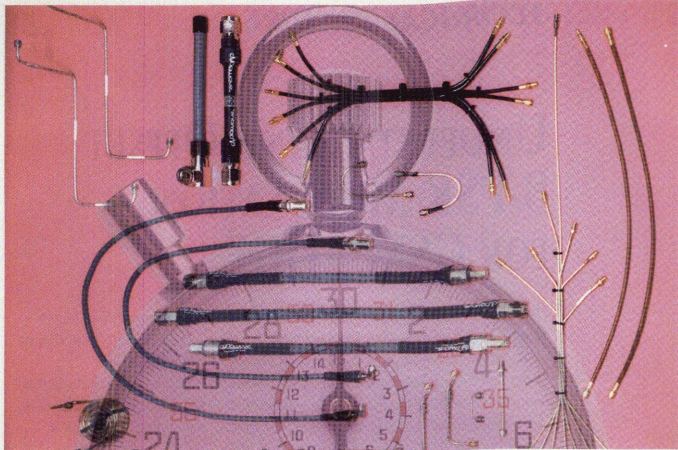
UK Fax: +44 1992 509905



Quality and Service since 1896

H. Rollet & Co. Ltd.
105/107 Fore Street, Hertford, Herts
SG14 1AS, ENGLAND
Tel: +44 1992 500818
Email: sales@hrollet.co.uk

www.hrollet.co.uk



WHEN YOU NEED YOUR CABLE ASSEMBLIES RIGHT AND RIGHT NOW, CALL THE LEADER.

To be more efficient and more competitive, call a company that's more efficient and competitive. Dynawave. For over ten years, we've been designing and manufacturing low cost, superior quality cable assemblies, delay lines, and harnesses for the wireless and military markets. Our on-demand and just-in-time delivery systems can satisfy the most stringent procurement requirements. And we can deliver prototypes, short runs, and high volume production with the same efficiency.

For high quality flexible, semi-rigid, delay lines, phase matched, and harnesses when you need them, call us today. Or send for a free brochure. Either way, it's time to switch to Dynawave.



dynawave
INCORPORATED®

135 Ward Hill Ave., P.O. Box 8224, Haverhill, MA 01835 U.S.A.
Tel: 978-469-0555 / Fax: 978-521-4589 / E-mail: connect@dynawave.com / Website: www.dynawave.com

CIRCLE 34 ON READER SERVICE CARD

UNDERSTANDING OFFSET 8-PSK MODULATION FOR GSM EDGE

The evolution of the GSM standard for mobile communications toward higher data rates embodied by the enhanced data rates for GSM evolution (EDGE) uses a variation of an eight-phase-shift keying (8-PSK) modulation scheme. Understanding of the selected modulation technique and the reasons behind it is important because they drive design choices. This article describes 8-PSK and its derivation toward the form it takes in GSM EDGE. A complete GSM EDGE transmitter/receiver baseband architecture is discussed along with simulation results.

The need to expand mobile communications systems capabilities to encompass data as well as voice means that higher data rates will be transmitted without loosening bandwidth restrictions. This enhancement requires the use of spectrally more efficient modulation techniques, that is, modulation techniques that offer a higher throughput/occupied bandwidth ratio. An evolution of the current GSM standard to provide higher data rates is GSM EDGE (812.5 kbps) where the modulation scheme to be used is pulse-shaped (Gaussian) $3\pi/8$ offset 8-PSK as opposed to GSM (270.8 kbps), which uses Gaussian minimum-shift keying (GMSK). One of the most remarkable differences between the two modulation formats is that GMSK has a constant amplitude or envelope and exhibits phase modulation; pulse-shaped 8-PSK exhibits both amplitude and phase variations.

8-PSK

Analog or digital modulation consists of varying the characteristics of a sinusoidal waveform $u(t)$ (the carrier), be it amplitude, phase, frequency, polarization or a combination of these characteristics, according to the information being transmitted. In the case of

digital modulation schemes, the information is in a digital format, usually a binary word (n bits), hence producing $M = 2^n$ possible words. Each symbol has a duration T and each bit has a duration T_b , where $T = nT_b$.

M-PSK is a digital modulation scheme where the information to be transmitted is conveyed onto the phase of the carrier. The expression for the modulated carrier $u(t)$ is

$$u(t) = A(t) \cos(2\pi f(t)t + \phi(t)) \quad (1)$$

and the phase of the carrier $\phi(t)$ is

$$\phi(t) = \sum_k \phi_k \delta(t - kT) \quad (2)$$

where

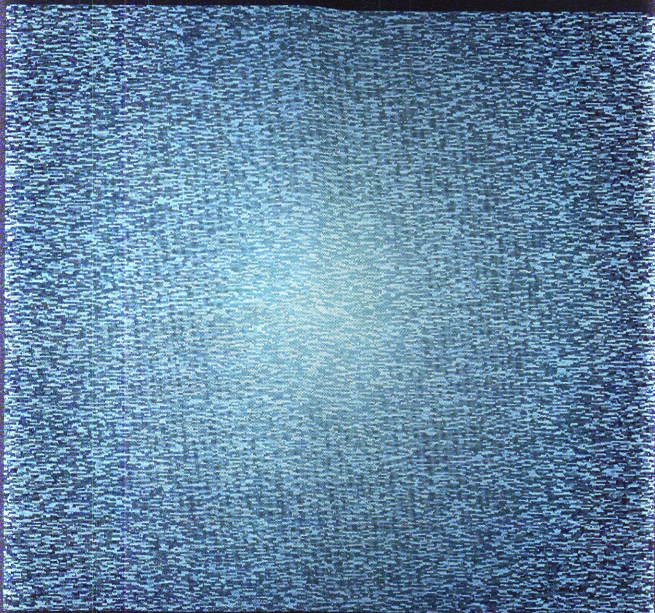
$$\phi_k = \theta_0 + (2m+1) \frac{\pi}{m}$$

$$m \in [0 \rightarrow M-1]$$

[Continued on page 80]

ASHKAN MASHHOUR
Nokia Telecommunications
Camberley, Surrey, UK

Without our active filter technology, all this talk about HDTV and Broadband would be nothing but noise.



Amidst the buzz surrounding tomorrow's hottest applications is something far less desirable. Noise. That's why design engineers are turning to Murata to keep unwanted signals out. After all, Murata's patented high speed op-amp and thick film innovations have resulted in active filters that are unmatched in functionality. By integrating many filters into a single package, we can actually deliver the specifications you need at about half the usual cost and size. From HDTV and Broadband to xDSL and CDMA, Murata is pioneering solutions that meet the demands of emerging technologies. To find out how we can help you, visit www.murata.com/tech. When it comes to technology challenges like noise, there's nothing like a partner who hears you loud and clear.

muRata
Innovator in Electronics

© 1999 Murata Electronics North America, Inc., 2200 Lake Park Drive, Smyrna, GA 30080. All Rights Reserved.

CIRCLE 134 ON READER SERVICE CARD

TECHNICAL FEATURE

ϕ_k is a set of M-ary words and $\delta(t)$ is a Dirac pulse. Therefore, the expression for the modulated carrier can be written as

$$\begin{aligned} u(t) &= A(t) \cos \left(2\pi f_c t + \sum_k \phi_k \delta(t - kT) \right) \\ &= \sum_k A(t) \cos(2\pi f_c t + \phi_k) \delta(t - kT) \\ &= \sum_k A \cos(2\pi f_c t + \phi_k) \delta(t - kT) \end{aligned} \quad (3)$$

Since amplitude and phase are constant in M-PSK, this expression can be expanded as

$$\begin{aligned} u(t) &= A \sum_k \left[\cos(\phi_k) \cos(2\pi f_c t) - \sin(\phi_k) \sin(2\pi f_c t) \right] \\ &\quad \cdot \delta(t - kT) \\ &= \sum_k \left[I_k \cos(2\pi f_c t) - Q_k \sin(2\pi f_c t) \right] \delta(t - kT) \end{aligned} \quad (4)$$

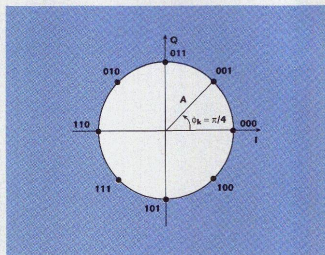
where

$$\begin{aligned} I_k &= A \cos(\phi_k) \\ Q_k &= A \sin(\phi_k) \\ f_c &= \text{carrier frequency} \end{aligned}$$

Traditionally, I_k and Q_k are referred to as the in-phase and quadrature components since $u(t)$ can be decomposed as a sum of two quadrature waveforms $\cos(2\pi f_c t)$ and

$\sin(2\pi f_c t)$. These components take their values in an M-ary alphabet formed by n bits ($M = 2^n$). This expression can be represented in the Fresnel plane (complex plane referring to a complex envelope representation of the signal).

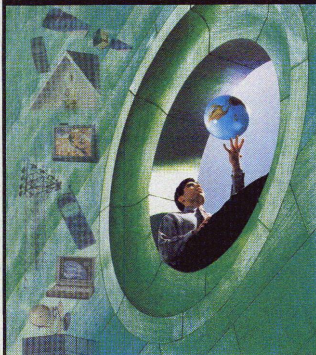
For 8-PSK, $M = 8 = 2^3$ where $n = 3$. Therefore, each symbol is formed from three bits. A vectorial illustration of this technique is shown in **Figure 1**, with $\theta_0 = 0$ and a Gray coding for mapping the bits to the symbols.



▲ Fig. 1 An 8-PSK constellation diagram with Gray coding.

[Continued on page 83]

CONTROL PRODUCTS DC to 50 GHz



VOLTAGE VARIABLE ATTENUATORS

FREQUENCY (GHz)	TYPE	SIZE (mm)	IL (dB)	ISOLATION (dB)	SWR	PART NUMBER
18-50	VVA	1.40 X 2.00	2.5	40	-4	AV850M1-00
18-50	VVA	1.05 X 1.50	2.5	36	10	AV850M2-00

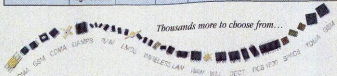
PIN SWITCHES

FREQUENCY (GHz)	TYPE	SIZE (mm)	IL (dB)	ISOLATION (dB)	SWR	PART NUMBER
18-40	SPST	1.23 X 0.67	1.0	42	33	AP640R1-00
24-40	SPDT	1.19 X 2.19	0.8	36	33	AP640R5-00

MMIC SWITCHES

Non-Reflective Switches

FREQUENCY (GHz)	DESCRIPTION	INSERTION LOSS (dB)	ISOLATION (dB)	1st CHAIN LOSS (dB)	PACKAGE	PART NUMBER
DC-6.0	SPST High Isolation	1.0-2.5	62-48	24	8 Loaded "Chip on Board"	AS006M1-93
DC-6.0	SPDT High Isolation	0.8-2.0	58-35	24	8 Loaded "Chip on Board"	AS006M2-93



CALL OR SURF TODAY

508-894-1904 www.alphaind.com

20 Sylvan Road • Woburn, MA 01801 USA

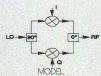
Alpha
from concept to solution...your wireless source

I&Q MODULATORS DEMODULATORS

1.15MHz to 1880MHz from \$19.95 (qty. 1-9)

Infuse your cellular, spread spectrum, and communication system projects with the performance and reliability of Mini-Circuits I&Q modulators and demodulators. Surface mount and plug-in units feature excellent 3rd and 5th order harmonic suppression, low loss, and "skinny" 4.5 mm repeatability unit-to-unit. With small quantity prices starting at only \$19.95, these compact units truly are the next generation of value on the market today! Call Mini-Circuits for guaranteed 1 week shipment, or contact our applications department for custom designs at catalog prices.

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




I/Q MODULATORS

MODEL	FREQ. (MHz)	CONV. LOSS (dB)	CARRIER REJ. (-dBc) Typ.	SIDE BAND REJ. (-dBc) Typ.	HARM. SUPPRESS. (-dBc) Typ. 3rd/5th	PRICE \$ Qty. (1-9)			
MQA-10M	9	11	5.8	0.20	41	40	58	68	49.95
MQA-21M	20	23	6.2	0.14	50	40	48	65	39.95
MQA-70M	66	73	6.2	0.10	38	38	48	58	39.95
MQA-70ML	66	73	5.7	0.10	38	38	48	58	49.95
MQA-91M	96	96	5.5	0.10	38	38	48	58	49.95
MQA-100M	95	105	5.5	0.10	38	38	48	58	49.95
MQA-108M	103	113	5.5	0.10	38	38	48	58	49.95
MQA-195M	185	205	5.6	0.10	38	38	48	58	49.95
MIQ-38M	34	38	5.6	0.10	48	37	54	65	49.95
MIQ-88M	52	88	5.7	0.10	41	34	52	66	49.95
MIQ-178M	104	178	5.5	0.10	38	37	47	70	54.95
MIQ-869M	868	895	8.0	0.10	40	40	52	58	99.95
MIQ-1785M	1710	1785	9.0	0.30	35	35	40	65	99.95
MIQ-1880M	1805	1880	5.0	0.30	35	35	40	65	99.95
MIQY-70M	67	73	5.8	0.20	40	36	47	60	19.95
MIQY-140M	137	143	5.8	0.20	34	36	45	60	19.95
Surface Mount Models									
MIQ-38M	52	88	5.6	0.1	40	35	45	65	40.95
MIQ-178M	104	176	5.8	0.1	35	35	45	65	54.95



I/Q DEMODULATORS

		FREQ. (MHz)	CONV. LOSS (dB)	AMP. UNBAL. (dB)	PHASE UNBAL. (Deg)	HARM. SUPPRESS. (-30dB Typ) 3rd/5th	PRICE \$ Qty. (1-9)
MODEL	f	T	T	T	T		
MQA-10D	5	11	6.0	0.10	0.15	1.0	50 65 46.95
MQA-21D	20	23	6.1	0.15	0.15	0.7	64 67 46.95
MQA-70D	66	73	6.2	0.10	0.15	0.7	56 58 46.95
MIQ-38D	34	38	5.5	0.10	0.10	0.5	60 65 46.95
MIQ-80D	20	60	5.3	0.10	0.15	1.0	55 67 79.95
MIQ-89D	895	895	5.0	0.20	0.15	1.5	40 55 59.95
MIQY-1.25D	1.15	1.35	5.0	0.10	0.15	1.0	59 67 29.95
MIQY-70D	67	73	5.5	0.25	0.10	0.5	52 66 19.95
MIQY-140D	137	143	5.5	0.25	0.10	0.5	47 70 19.95
Surface Mount Models							
JIQ-178D	104	175	5.5	0.1	0.15	2	52 65 54.95
JIQ-395D	895	895	5.6	0.1	0.2	1	45 65 99.95
JIQ-1785D	1710	1785	5	0.2	0.2	2	50 65 99.95
JIQ-1880D	1805	1880	5	0.2	0.2	2	50 65 99.95
NON-HERMETICALLY SEALED							
MIQA case 4 x .8 x 4 in. MIQY case 8 x .8 x 4 in.							
MIQC case .8 x .8 x 4 in. JCIQY case .9 x .8 x 25 in.							

All Models Available in New
J-LEAD Surface Mount Package.
Consult Factory for Details.

J-LEAD



Mini-Circuits®

P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661 INTERNET <http://www.minicircuits.com>

For detailed specs on all Mini-Circuits products refer to • 760-pg. HANDBOOK • INTERNET • THOMAS REGISTER • MICROWAVE PRODUCT DATA DIRECTORY • E-200 Rev. A

US 110 INTL 111
CIRCLE READER SERVICE CARD

RF & Hyper

Get the hottest news:
www.birp.com/hyper

2000
26th edition

The European trade event dedicated to Radiofrequencies,
Microwaves and Optical Fiber for military and civil applications.

January 18 - 19 - 20, 2000
CNIT - Paris-la-Défense

Radiofrequencies,
Microwaves
& Optical Fiber united
for the first time...

Get ready for a shock wave!

For the ones who know
that it's still possible
to change the world, in 2000...

Telecommunications, avionics, satellite links,
automobile, ... It is now clear that the most brisk
markets in the world owe their
technological advances to the developments in
radiofrequencies, microwaves and optical fiber.

RF & Hyper 2000 is the ultimate event of reference for
the major players on this field, who stage every year
a lot of worldwide and European previews.

RF & Hyper is dedicatedly focused on the keenest
challenges of the 21st century.

It is about time to get ready for your tour
in Paris, more seductive than ever
in the limelight of January 2000 !

organized by



For more information : Birp/RF & Hyper 2000 - 17, avenue Ledru Rollin - 75012 Paris France - Phone : +33 1 53 17 11 40 - Fax +33 1 53 17 11 45 - E-mail : hyper@birp.fr

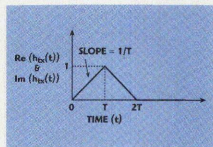
R E Q U E S T F O R I N F O R M A T I O N

I wish to receive: ☐ An invitation for RF & Hyper 2000 and a programme of conferences.
☐ A documentation to exhibit at RF & Hyper 2000.

Company :
First name :
Surname :
Function :
Address :

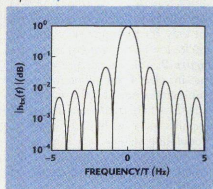
City :
Country :
Business activity :
Phone :
Fax :

TECHNICAL FEATURE

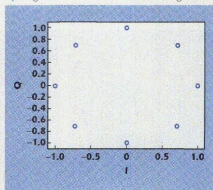


▲ Fig. 2 The triangular filter's impulse response.

Fig. 3 The triangular filter's frequency response. ▼



▼ Fig. 4 An 8-PSK constellation diagram.



PULSE SHAPING

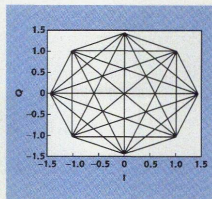
Considering the complex envelope of the signal $u_c(t)$ given by

$$u_c(t) = \sum_k \exp(j\phi_k) \delta(t - kT) \quad (5)$$

the spectrum of this signal is represented as

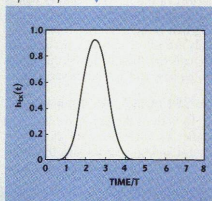
$$FT(u_c(t)) = U_c(f) = \sum_k \exp(j(\phi_k + 2\pi f k)) \quad (6)$$

Since ϕ_k has a random distribution, $U_c(f)$ also has a random distribution and can be regarded as having an infinite bandwidth. In practice, it is not tolerable to transmit such a signal since only a limited bandwidth is available. Therefore, the signal needs



▲ Fig. 5 Trajectories for the triangular filter.

Fig. 6 The GSM EDGE pulse-shaping filter's impulse response. ▼



to be filtered in order to limit its spectrum. A useful filter is a triangular filter for which the time and frequency domain responses are shown in **Figures 2** and **3**, respectively. (This filter can be derived easily.)

It is often mistakenly thought that 8-PSK signals' trajectories are linear transitions between one constellation point and the next. In fact, an 8-PSK signal as represented by its I and Q components has no trajectory as such because instantaneous phase changes occur between symbols at every T. **Figure 4** shows an 8-PSK constellation diagram. This filter produces linear monotonic trajectories, as shown in **Figure 5**, from one symbol to the following symbol and it can be seen from its impulse response that the output depends on two consecutive symbols. (T is the period of a symbol.) The frequency response of the filter displays a reduced spectrum (-3 dB BW = $0.32/T$ Hz).

The proposed filter for GSM EDGE is a Gaussian-like filter for which the impulse and frequency response are shown in **Figures 6** and

[Continued on page 84]

**Berkeley's
Newest, Advanced
Lab Testing Equipment**



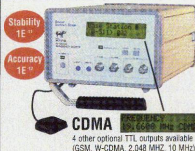
Zebrell™ IS-95 16-CHANNEL CDMA SOURCE

APPLICATIONS:

- Testing of power amps for multiple CDMA carrier signals
- Development of 3G W-CDMA products
- ACPR measurements
- Realistic characterization of power amplifiers as per IS-97 specifications

FEATURES:

- Selectable wave forms - up to 8
- Selectable data - All 0's, 1's, PRBS, custom
- Selectable multicarriers - up to 7
- 16 code channels with selectable Walsh & amplitude
- PC Independent waveform generation
- Auto code selection



Rhino II™ RUBIDIUM-LOCKED FREQUENCY SOURCE

The Rhino II is designed for both laboratory and field use where GPS reception may be unavailable, such as indoors or in large cities.

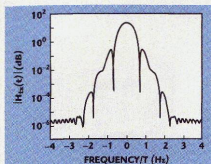
The Rhino II outputs the following buffered (500) reference signals:

- 10 MHz (8 individually buffered outputs)
- 19.6608 MHz (IS-95 clock multiple)
- 13 MHz (GSM), 3.68 MHz (W-CDMA)
- 1 PPS, 1/2 PPS (odd/even second)
- Adj. PPS (phase adjustable - to CDMA base station offsets 0-511)

BERKELEY VARITRONICS SYSTEMS

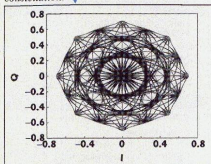
Call us today for more information:
732-548-3737 / Fax: (732) 548-3404
Internet: www.bvsystems.com
E-mail: info@bvsystems.com

TECHNICAL FEATURE

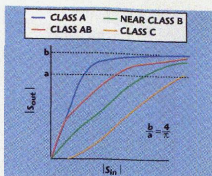


▲ Fig. 7 The GSM EDGE pulse-shaping filter's frequency response.

Fig. 8 The filtered GSM EDGE 8-PSK constellation. ▼



7, respectively. (The impulse response of the filter as it is defined in the European Telecommunications Standards

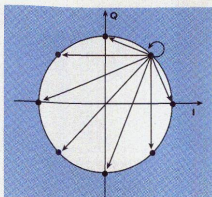


▲ Fig. 9 Typical PA characteristics.

Institute (ETSI) standards is discussed in **Appendix A.** It can be seen that the output of this filter is dependent on five consecutive symbols. The trajectory of the filtered I and Q signals is shown in **Figure 8.** It is worth noting that the nonfiltered I and Q signals are of a constant amplitude although the filtered signal undergoes both phase and amplitude variations.

OFFSET PULSE-SHAPED 8-PSK

In both of the examples discussed earlier, the trajectory of the modulating data (I and Q) goes through the origin (I = Q = 0). In practice, power ampli-



▲ Fig. 10 All possible 8-PSK transitions.

fiers exhibit a nonlinear characteristic not only for high power regions but also for low power regions, as shown in **Figure 9.** This condition is especially true for class C amplifiers where the base-emitter junction threshold is required to start conducting before the amplifier kicks in. In other words, for modulation schemes such as 8-PSK, where the trajectory crosses the origin, nonlinearity at low power regions will distort the signal and, hence, produce spectral regrowth. **Figure 10** shows all

[Continued on page 87]

How Well Protected Are You?

When T/R tubes degrade in your receiver protector applications, the consequences can be costly. Herley-MDI's Solid State Receiver Protectors are a direct replacement for traditional T/R tubes and deliver MTBF figures magnitudes higher. Our superior design is also capable of handling up to 10 KW of power. Plus, you can choose from any combination of passive limiting protection, sensitivity time control attenuation, gated transmitter pulse attenuation, built in test signals and detector monitoring. Additional features include exceptionally low insertion loss and typical VSWR of less than 1.5:1.

We're currently upgrading F-16 Fire Control, commercial weather, and shipboard radars. To give your current system maximum protection, call us or visit our web site today.

HERLEY-MDI
A HERLEY INDUSTRIES COMPANY

10 Sonar Drive Woburn, MA 01801
Tel: (781) 729-9450 • Fax: (781) 729-9547

HERLEY Microwave Products Group



www.herleympg.com

Looking for a
diode supplier
that's a bit
more personal?

*MicroMetrics.
Real People,
Real Service.*

It's a real voice. It's an unseen smile. It's a dedication to delivering the device you're looking for. With MicroMetrics you get the combination of a complete diode resource and a friendly face on the phone. Looking for a small quantity of Schottkys? No problem. Can't find that discontinued device you've always bought? We've got it. How 'bout a Tuning Varactor for high frequencies? Or a new source for PINs, Resistors, and Capacitors? It's all right here. And if we don't have it, we'll help you find it.

We'll even custom design a device just for you. That's MicroMetrics. Real people. Real service. All you have to do is call.



888-641-SEMI
7 3 6 4



MicroMetrics
The Real Source for Diodes

MicroMetrics, Inc.
136 Harvey Road, Building C
Londonderry, NH 03053

603-641-3800 • Fax: 603-641-3500

www.micrometrics.com

CIRCLE 26 ON READER SERVICE CARD

Give me five ...



{PERPETUAL THINKING PROCESS}

INFINEON PRODUCTS



PMB2341 Single RF PLL

Frequency: Up to 2.5 GHz, Steps: Down to 5 kHz.
Inband phase noise: -83 dBc/Hz @ 1 kHz, $f_c=900$ MHz.
170 μ s lock-in time; GPRS capability up to 5 slots;
2.7 to 4.5 V, BiCMOS Technology, TSSOP 10 (3x5 mm).



PMB2347 Dual RF/IF PLL

Frequency: RF 2.5 GHz IF 504 MHz, Steps: Down to 50 Hz.
Inband phase noise: -83 dBc/Hz @ 1 kHz, $f_c=900$ MHz.
2.7 to 4.5 V, BiCMOS Technology, TSSOP 10



PMB2335 Universal RF Mixer

(Succeeds Infineon's popular PMB2331)

Frequency: Up to 5 GHz, 2.7 to 4.5 V.
Bipolar Technology B6H, TSSOP 10 (3x5 mm).



PMB2362 Dual LNA

Frequency: 900/1800 MHz, 2.7 to 3.6 V.
Easy-to-handle 50 Ohm, extreme low NF.
Bipolar Technology B6H, TSSOP 10 (3x5 mm).



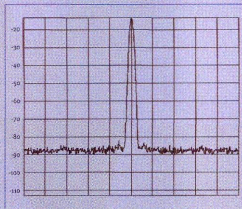
PMB2312 Direct Modulator with Integrated Mixer and 40dB dynamic-range AGC

Frequency: 1.4 to 1.6 GHz, 2.7 to 4.5 V.
Bipolar Technology B6H, TSSOP 14
(6.5 x 6.4 mm), 0.5 mm fine pitch.

Five for your success! Designed for a range of mobile applications, Infineon's new RF IC's offer dramatically improved performance in space-saving packages. These devices include single and dual PLL (Phase Lock Loop) frequency synthesizers, universal and dual-band RF-mixers/modulators/LNAs (Low Noise Amplifiers). All are fully compliant with standards like GSM (Global System for Mobile Communications), PCS (Personal Communication System), CDMA (Code Division Multiple Access), TDMA (Time Division Multiple Access) and PDC (Personal Digital Cellular). Count on the company with experience. Count on Infineon, the world market leader in high frequency ICs. Mass quantities of Infineon's new RF ICs are available for Fall '99! Order today!

www.infineon.com/building-blocks

Measured Inband phase noise of PMB 2341:



$L(f_m) = -83 \text{ dBc/Hz @ } 1 \text{ kHz } (f_c=900 \text{ MHz})$

CIRCLE 66 ON READER SERVICE CARD



Never stop thinking

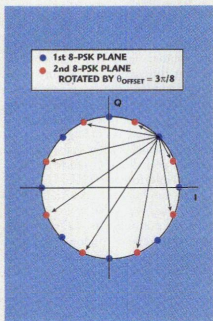
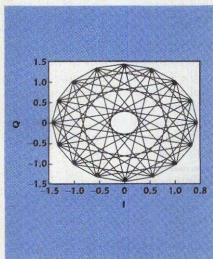


Fig. 11 Offset 8-PSK transitions.

Fig. 12 The pulse-shaped (triangular) $3\pi/8$ offset 8-PSK constellation.



of the possible transitions from one symbol to the next.

It would be useful if the origin somehow could be avoided for the modulating data. One way of doing this is to offset the modulation scheme. In 8-PSK, the symbol at present time kT is $e(jkT)$ and at time $(k+1)T$ is $e((k+1)T)$ with $\phi_{k+1} \equiv \phi_k \bmod \pi/4$.

Continuously rotating the symbols by an offset $\theta_{\text{offset}} \equiv \pi/8 \bmod \pi/4$ prevents the signal from crossing through the origin. Hence, the transmitted signal becomes

$$u_{\text{offset}}(t) = \sum_k \exp(j(\phi_k + k\theta_{\text{offset}}))\delta(t - kT) \quad (7)$$

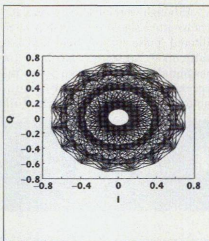


Fig. 13 The pulse-shaped (GSM EDGE) $3\pi/8$ offset 8-PSK constellation.

This condition is viewed as having two 8-PSK constellation planes offset by θ_{offset} and swapping from one plane to the other at every consecutive symbol time as shown in Figure 11, where $\theta_{\text{offset}} = 3\pi/8$. This procedure can be illustrated using the triangular filter mentioned earlier and filtering the I and Q signals, where the benefit of rotating two 8-PSK planes leads to avoiding the center region of the constellation, as shown in Figure 12. Applying the offset to the 8-PSK constellation and filtering it with the GSM EDGE pulse-shaping filter produces the output constellation shown in Figure 13. Again, it can be seen that the trajectories no longer cross the origin.

One disadvantage of this procedure is that it may put strain on the detection for which the threshold margins are reduced. However, since there is a change in planes from one symbol to the next, the decision-making process in the receiver approximates that of an 8-PSK signal rather than, for example, a 16-PSK signal.

RECEIVER FILTER

In general, the baseband signal described previously is subsequently upconverted, transmitted via the transmission channel and demodulated in the receiver where a baseband signal is recovered. However, this example assumes that there is no up- or downconversion and that the transmission channel is ideal. In other words, to keep things simple, the analysis is performed at baseband according to the block diagram shown

(Continued on page 88)

GET ON BOARD

AVAILABLE ON TAPE & REEL



WITH OUR HIGH FREQUENCY SURFACE MOUNT DIODES

MicroMetrics HFMS series diodes are ready to be designed into all your PIN, Varactor, and Limiter Diode applications up to 4 GHz. The encapsulated "chip-on-board" design features low parasitics, extremely high repeatability, and standard footprints. They're available for fast delivery — so get on board today.

Visit www.micrometrics.com to request more information and samples.



MicroMetrics

MicroMetrics, Inc.
136 Harvey Road, Building C
Londonderry, NH 03053
603-641-3800 • Fax: 603-641-3500
www.micrometrics.com
888-641-SEMI
7 3 6 4

TECHNICAL FEATURE

in **Figure 14**. (T = symbol period, T_s = sampling period (oversampling $\Rightarrow T_s \leq T$) and T_{rx} = sampling period going through the receiving filter. It is envisageable to have $T_s = T_{rx} = T_b$ (T_b = bit period) with appropriate zero padding.)

Although working at baseband, the transmitted signal, once it has been filtered (pulse-shaping filter $h_{tx}(t)$), is difficult to interpret. (Error vector magnitude can be used to assess the received signal.) Hence, it is desirable to convert the transmitted fil-

tered signal back into a constellation as done initially, and then do the comparison. As can be seen in the transmitted signal, the main obstacle is that the signal at a given time t (and, more specifically, at the symbol sampling time kT) is dependent on several samples, or symbols (depending on the undersampling rate — recall the Gaussian filter spans over five symbol periods), referred to as intersymbol interference (ISI).

The aim here is to determine a receiver filter $h_{rx}(t)$ that will enable the received constellation diagram to be recovered. The derivation of the filter coefficients is explained in **Appendix B**. The chosen filter here is an 11-tap finite impulse response filter exhibiting no ISI at the decision times (symbol period T). The response of the filter and the recovered constellation diagram are shown in **Figures 15** and **16**, respectively.

CONCLUSION

This article has described an 8-PSK modulation scheme and some of its variations as well as its application to the GSM EDGE standard. It also explained a means of determining a complete baseband transmitter and receiver architecture. Additional information can be obtained from the author. ■

References

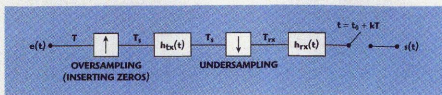
1. "Change Request A001, Rev. 1, Technical Specification GSM/UMTS: 05.04, Version 5.01 — SMG2 453/98," ETSI, November 1998.
2. John G. Proakis, *Digital Communications*, Third Edition, McGraw-Hill, New York, 1995.
3. B.P. Lathi, *Modern Digital and Analog Communication Systems*, Holt-Saunders International, New York, 1983.



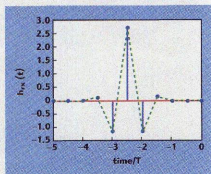
Ashkan Mashhour received his Diplôme d'Ingénieur from ENST Bretagne, France, and his MSc from University College London, UK, both in 1997. He then joined Nokia Telecommunications, Camberley, UK, where he currently works as an RF design engineer. He

is involved in the development of new RF technologies and transceiver architectures for future-generation base stations. Mashhour can be reached at +44 (0) 1276 602 024 or Ashkan.Mashhour@utc.nokia.com.

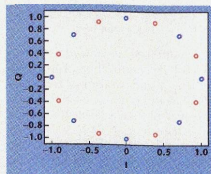
[Continued on page 90]



▲ Fig. 14 The transmit/receive chain.



▲ Fig. 15 The zero-forcing GSM EDGE filter's impulse response.



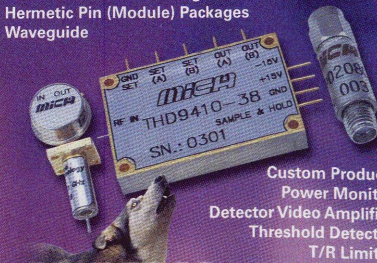
▲ Fig. 16 The received constellation with no ISI.

DETECTORS & LIMITERS

10MHz to 26.5GHz

Package Styles:

Hermetic Coaxial Tubular
Hermetic Coaxial Rectangular
Hermetic Pin (Module) Packages
Waveguide



Custom Products:
Power Monitors
Detector Video Amplifiers
Threshold Detectors
T/R Limiters

7017 Realm Drive
San Jose, CA 95119
Tel: 408-363-9200
Fax: 408-363-9220

mica
MICROWAVE
<http://www.mica-mw.com>

NEED TO UNDERSTAND THE PERFORMANCE OF 3D ELECTROMAGNETIC DEVICES, PACKAGING, WAVEGUIDES AND ANTENNAS BEFORE BUILDING PROTOTYPES

?



You got it.

Ansoft's High Frequency Structure Simulator (HFSS) allows you to design complex 3D geometries on the computer before building prototypes. Rely on Ansoft's powerful finite element method (FEM) solvers, unmatched speed and accuracy, and parameterization macros to optimize performance of your designs. HFSS from Ansoft. Do more with less hassle.

412.261.3200
www.ansoft.com

APPENDIX A

GSM EDGE pulse shaping filter impulse response h_{rx}

$$h_{rx}(t) = \begin{cases} \int_{t-0}^t S(t+iT) & \text{for } 0 \leq t \leq 5T \\ 0 & \text{elsewhere} \end{cases}$$

where

$$S(t) = \begin{cases} \sin\left(\pi \int_0^t g(x) dx\right) & \text{for } 0 \leq t \leq 4T \\ \sin\left(\frac{\pi}{2} - \pi \int_0^{t-4T} g(x) dx\right) & \text{for } 4T \leq t \leq 5T \\ 0 & \text{elsewhere} \end{cases}$$

$$g(t) = \frac{1}{2T} \left[Q\left(2\pi \cdot 0.3 \frac{t - \frac{5T}{2}}{T \sqrt{\log_e(2)}}\right) - Q\left(2\pi \cdot 0.3 \frac{t - \frac{3T}{2}}{T \sqrt{\log_e(2)}}\right) \right]$$

and

$$Q(t) = \frac{1}{\sqrt{2\pi}} \int_t^{+\infty} \exp\left(-\frac{x^2}{2}\right) dx = \frac{1}{2} \operatorname{erfc}\left(\frac{t}{\sqrt{2}}\right)$$

for GSM EDGE, $T = 3.69 \mu s$

APPENDIX B

Derivation of the Receiver Filter h_{rx}

The input signal is the complex $3\pi/8$ offset 8-PSK signal $e(t)$

$$e(t) = \sum_k \exp\left(j\left(\phi_k + k \frac{3\pi}{8}\right)\right) \delta(t - kT) \quad (A1)$$

This signal is then filtered by the Gaussian-like pulse shaping filter and filtered again by the receiver filter. The received signal $s(t)$ can be written as

$$\begin{aligned} s(t) &= e(t) \otimes h_{rx}(t) \otimes h_{rx}(t) \\ &= e(t) \otimes g(t) \quad \text{with } g(t) = h_{rx}(t) \otimes h_{rx}(t) \end{aligned} \quad (A2)$$

where \otimes stands for convolution

To recover the transmitted signal (constellation), it is desirable to make $S(kT) = e(kT)$

$$\begin{aligned} s(kT) &= e(kT) \\ s(kT_s) &= \sum_n e(nT_s) g(kT_s - nT_s) \\ \text{at } t &= kT: \\ s(kT) &= \sum_n e(nT_s) g(kT - nT_s) \\ &= e(kT) g(kT - kT) + \sum_{nT_s \neq kT} e(nT_s) g(kT - nT_s) \\ &= e(kT) g(0) + \sum_{n \neq k} e(nT) g(kT - nT) \\ &\quad \text{because } e(nT_s) = 0 \text{ for } nT_s \neq iT \\ &= e(kT) g(0) + \sum_{n, n \neq 0} e(nT) g(nT) \quad \forall e(t) \end{aligned} \quad (A3)$$

Hence, the condition to be satisfied to guarantee no ISI is

$$\forall k \in \mathbb{Z} : \begin{cases} g(0) = 1 \\ g(kT) = 0 \end{cases} \quad (A4)$$

Note that it is not necessary to define the behavior of g at all $t = nT_s$.

$$\begin{aligned} \underline{g(0)=1} &\Leftrightarrow g(0) = \sum_n h_{rx}(nT_s) h_{rx}(0 - nT_s) \\ &\Leftrightarrow \sum_n h_{rx}(nT_s) h_{rx}(-nT_s) = 1 \quad \Rightarrow \text{if } h_{rx} \text{ is causal then } h_{rx} \text{ is not causal} \\ \underline{g(kT)=1} &\Leftrightarrow \sum_n h_{rx}(nT_s) h_{rx}(kT - nT_s) = 0 \quad \text{for } k \neq 0 \end{aligned}$$

This system of linear equations leads to a matrix equation. If the receiver filter is defined every T/m step, $h_{rx}(t)$'s impulse response will be defined by a set of $2n+1$ coefficients $b_{-2n}, b_{-2n+1}, \dots, b_0$ and $k \in [-n \rightarrow +n]$. In other words, the value of g is specified at $2n+1$ points. This requires $2n+1$ samples of the transmitter pulse shaping filter $h_{tx}(t)$ (a_0, a_1, \dots, a_n) to be taken. Note that the receiver filter $h_{rx}(t)$ is noncausal here, hence the choice of negative indices. This type of filter is sometimes referred to as a zero-forcing filter. The set of equations can be written as

[Continued on page 92]

DO YOU NEED TO KNOW WHETHER YOUR HARD WORK HAS PRODUCED AN AMPLIFIER OR AN OSCILLATOR

?



Here's the answer.

Harmonica, a member of the Serenade Design Environment, provides linear and nonlinear circuit design in a 100% Windows® interface. Harmonica has the industry's most accurate models, the fastest and most robust harmonic balance engine, digital modulation analysis, the most comprehensive commercial parts library (>100,000 parts), and Ansoft's unique utilities, such as SmithTool and Filter Synthesis. Harmonica's integrated schematic capture and post-processing layout enables you to complete your work in an easy-to-use interface that allows you to focus on design tasks, not design tools. Harmonica from Ansoft. Do more with less hassle.

412.261.3200
www.ansoft.com

APPENDIX B (continued)

$$\begin{matrix}
 k = -n \\
 k = -n+1 \\
 \vdots \\
 k = 0 \\
 \vdots \\
 j \\
 \vdots \\
 k = +n
 \end{matrix}
 \begin{bmatrix}
 a_0 & 0 & \dots & 0 & 0 & \dots & 0 & 0 & \dots \\
 a_{-m} & a_{-m+1} & \dots & a_0 & 0 & \dots & 0 & 0 & \dots \\
 \vdots & \vdots & \ddots & \vdots & \vdots & \ddots & \vdots & \vdots & \ddots \\
 a_{-2m} & a_{-2m+1} & \dots & a_{-m} & a_{-m+1} & \dots & a_0 & 0 & \dots \\
 \vdots & \vdots & \ddots & \vdots & \vdots & \ddots & \vdots & \vdots & \ddots \\
 a_{-2n} & a_{-2n+1} & \dots & \dots & \dots & \dots & a_0 & 0 & \dots \\
 \vdots & \vdots & \ddots & \vdots & \vdots & \ddots & \vdots & \vdots & \ddots \\
 0 & \dots & 0 & a_{-2n} & a_{-2n+1} & \dots & \dots & \dots & \dots \\
 \vdots & \vdots & \ddots & \vdots & \vdots & \ddots & \vdots & \vdots & \ddots \\
 0 & \dots & 0 & a_{-2n} & \dots & \dots & a_{-2n+m} & \dots & \dots \\
 \vdots & \vdots & \ddots & \vdots & \vdots & \ddots & \vdots & \vdots & \ddots \\
 0 & \dots & 0 & a_{-2n} & \dots & \dots & a_{-2n+m} & \dots & \dots
 \end{bmatrix}
 \cdot
 \begin{bmatrix}
 b_{-2n} \\
 b_{-2n+1} \\
 \vdots \\
 b_0
 \end{bmatrix}
 =
 \begin{bmatrix}
 0 \\
 \vdots \\
 0 \\
 1 \\
 0 \\
 \vdots \\
 0
 \end{bmatrix}$$

A
 h_{rx}
 x

or

$$A \cdot h_{rx} = x \quad (A5)$$

The receiver filter h_{rx} coefficients are determined by multiplying Equation A5 by the inverse matrix A^{-1} , expressed as

$$h_{rx} = A^{-1} \cdot x \quad (A6)$$

This result is applied to the GSM EDGE pulse shaping filter. If the receiver filter is defined every T/2 step, $h_{rx}(t)$ will be defined by a set of 11 coefficients ($b_{-10}, b_{-9}, \dots, b_0$) (the receiver filter $h_{rx}(t)$ is noncausal here). Taking 11 samples spaced T/2 from the pulse shaping filter $h_{tx}(t)$ (a_0, a_1, \dots, a_{10}) leads to

$$\begin{bmatrix}
 a_0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
 a_{-2} & a_{-1} & a_1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
 a_{-4} & a_{-3} & a_{-2} & a_{-1} & a_0 & 0 & 0 & 0 & 0 & 0 & 0 \\
 a_{-6} & a_{-5} & a_{-4} & a_{-3} & a_{-2} & a_{-1} & a_0 & 0 & 0 & 0 & 0 \\
 a_{-8} & a_{-7} & a_{-6} & a_{-5} & a_{-4} & a_{-3} & a_{-2} & a_{-1} & a_0 & 0 & 0 \\
 a_{-10} & a_{-9} & a_{-8} & a_{-7} & a_{-6} & a_{-5} & a_{-4} & a_{-3} & a_{-2} & a_{-1} & a_0 \\
 0 & 0 & a_{-10} & a_{-9} & a_{-8} & a_{-7} & a_{-6} & a_{-5} & a_{-4} & a_{-3} & a_{-2} \\
 0 & 0 & 0 & 0 & a_{-10} & a_{-9} & a_{-8} & a_{-7} & a_{-6} & a_{-5} & a_{-4} \\
 0 & 0 & 0 & 0 & 0 & 0 & a_{-10} & a_{-9} & a_{-8} & a_{-7} & a_{-6} \\
 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & a_{-10} & a_{-9} & a_{-8} \\
 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & a_0
 \end{bmatrix}
 \cdot
 \begin{bmatrix}
 b_{-10} \\
 b_{-9} \\
 b_{-8} \\
 b_{-7} \\
 b_{-6} \\
 b_{-5} \\
 b_{-4} \\
 b_{-3} \\
 b_{-2} \\
 b_{-1} \\
 b_0
 \end{bmatrix}
 =
 \begin{bmatrix}
 0 \\
 0 \\
 0 \\
 0 \\
 0 \\
 1 \\
 0 \\
 0 \\
 0 \\
 0 \\
 0
 \end{bmatrix}
 \quad (A7)$$

The filter determined in this manner has the impulse response shown previously. In this case, $a_0 = a_{-10} = 0$, hence, matrix A^{-1} is not defined. The inverse of a submatrix B of A where $B = A_{ij}$ with $(i,j) \in [1-9]$ (that is, B is A with the first and last columns and rows removed) is required. Therefore, b_0, b_{-10} can be set to 0. The matrix A in Equation A7 becomes

$$A = \begin{bmatrix}
 -0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\
 0.031 & 0.001 & -0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\
 0.706 & 0.260 & 0.031 & 0.001 & -0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\
 0.706 & 0.927 & 0.706 & 0.260 & 0.0031 & 0.001 & -0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\
 0.032 & 0.261 & 0.706 & 0.927 & 0.706 & 0.260 & 0.031 & 0.001 & -0.000 & 0.000 & 0.000 \\
 0.000 & 0.001 & 0.032 & 0.261 & 0.706 & 0.927 & 0.706 & 0.260 & 0.031 & 0.001 & -0.000 \\
 0.000 & 0.000 & 0.000 & 0.000 & 0.001 & 0.032 & 0.261 & 0.706 & 0.927 & 0.706 & 0.260 \\
 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.001 & 0.032 & 0.261 & 0.706 & 0.927 & 0.706 \\
 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.001 & 0.032 & 0.261 & 0.706 & 0.927 \\
 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.001 & 0.032 & 0.261 & 0.706 \\
 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.001 & 0.032 & 0.261
 \end{bmatrix}$$

$$B^{-1} = \begin{bmatrix}
 1392 & 0 & 0 & -0 & 0 & -0 & 0 & -0 & 0 \\
 -12288 & 34 & -0 & 0 & -0 & 0 & -0 & 0 & -34 \\
 33598 & -111 & 5 & -0 & 0 & -0 & 0 & -6 & 1507 \\
 -44240 & 154 & -10 & 3 & -1 & 1 & -3 & 46 & -12473 \\
 33716 & -119 & 8 & -3 & 3 & -3 & 8 & -124 & 33796 \\
 -12448 & 44 & -3 & 1 & -1 & 3 & -10 & 160 & -44348 \\
 1507 & -5 & 0 & -0 & 0 & -0 & 5 & -116 & 33682 \\
 -36 & 0 & -0 & 0 & -0 & 0 & -0 & 36 & -12319 \\
 0 & -0 & 0 & -0 & 0 & -0 & 0 & -0 & 1395
 \end{bmatrix}$$

$$h_{rx} = b = \begin{bmatrix}
 0 \\
 0 \\
 -0.0032 \\
 0.1382 \\
 -1.1359 \\
 2.7318 \\
 -1.1366 \\
 0.1387 \\
 -0.0033 \\
 0 \\
 0
 \end{bmatrix}
 \quad
 h_{tx} = a = \begin{bmatrix}
 -0 \\
 0.0007 \\
 0.0315 \\
 0.2604 \\
 0.7057 \\
 0.9268 \\
 0.7057 \\
 0.2605 \\
 0.0315 \\
 0.0008 \\
 0
 \end{bmatrix}$$

The recovered signal exactly matches the transmitted 3π/8 offset 8-PSK constellation since the channel is ideal.

SO, YOU WANT TO SEE THE WIDEBAND FULL WAVE ELECTROMAGNETIC RESPONSE OF YOUR AMPLIFIER IN MINUTES RATHER THAN HOURS

?



No problem.

Give your RFIC, MMIC and planar antenna designs a boost with Ensemble, the planar MoM solver in the Serenade Design Environment. Ensemble electromagnetic simulation computes S & Z parameters, near- & far-field radiation and current distributions. With Ensemble you can place active devices into the analysis using black box circuit elements. Integration in Ansoft's Serenade Design Environment allows you to include layout related coupling and parasitics in your circuit and system simulation. Ensemble from Ansoft. Do more with less hassle.

412.261.3200
www.ansoft.com

VECTOR SIGNAL MEASUREMENT FOR 38 GHz DIGITAL RADIO APPLICATIONS

Broadband access using millimeter-wave digital radio technology has generated significant interest during the past several years. This technology is especially attractive for the implementation of a low cost, rapidly deployable last-mile interconnection solution between fiber-optic networks and service hubs. From a signal distribution point of view, two basic classes of radio systems exist: point-to-point and point-to-multipoint.

A point-to-point radio system is a dedicated link to provide short-haul voice and data communication between two business network centers. The licensed frequency spectrum allotted for short-haul radio links is 15, 18, 23, 26, 38 or 50 GHz. Data capacities range from a single DS-1 (1.544 Mbps) to DS-3 (44.736 Mbps).

A point-to-multipoint radio system provides voice and data communication services between multiple subscribers with a shared hub. The Federal Communications Commission has licensed the 27.5 to 28.35, 29.1 to 29.25 and 31 to 31.5 GHz bands for local multipoint distribution system (LMDS) service. Because of the availability of the wide bandwidth (850 MHz), very large downstream data capacity can be achieved.

With few exceptions, most millimeter-wave radio systems currently under development are based on communication implementation. Depending on the applications,

various modulation schemes are being implemented from quadrature phase-shift keying (QPSK) to 64 quadrature amplitude modulation (QAM). Data rates range from T1 (1.544 Mbps) to DS-3 (44.736 Mbps), and a higher rate to 155 Mbps (OC-3).

Modern RF wireless communication systems use advanced vector signal measurement techniques to accurately measure the dynamic behavior of the RF subsystems and the integrated digital/RF systems. In the past, these types of tests were not performed at bandwidths above 7 MHz and millimeter-wave frequencies due to a lack of suitable test capabilities. This limitation has greatly curtailed the ability for transceiver manufacturers to speedily develop low cost, high performance transceiver products for digital radio applications. However, recent advances in wide-bandwidth vector signal analyzer (VSA) test equipment

[Continued on page 96]

G. SAMUEL DOW, JEFF YANG
AND KUO-HSIUNG YEN,
TRW, *Electronics Technology Division*
Redondo Beach, CA

ROBERT MATRECI, ERIC SPOTTED-ELK,
STEPHEN PETTIS AND LONG TRINH
Hewlett-Packard Co.,
Santa Rosa Systems Division
Santa Rosa, CA

- Low Cost Machined Housing
- Low Intermod Construction
- High Volume Production Capability
- High Power Handling
- Symmetric and Asymmetric Pseudo Elliptic Designs

For over 30 years, Lorch Microwave has supplied quality microwave components and sub systems to a diverse and ever changing electronics and communications industry. With new facilities and state-of-the-art equipment, dedicated personnel, and the introduction of new products, Lorch Microwave continues to keep pace with developing markets worldwide.

LORCH MICROWAVE

Helping your ideas take wing™



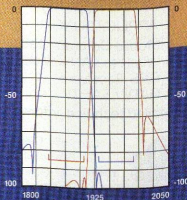
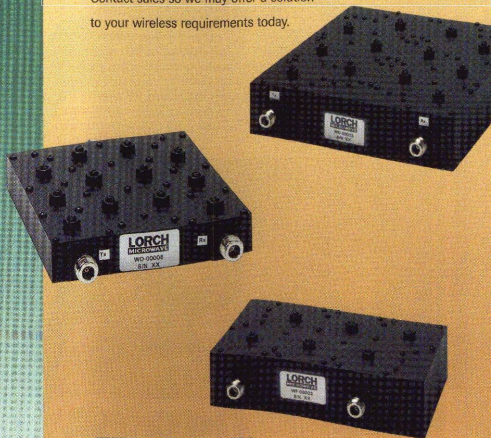
1725 N. Salisbury Blvd.
P.O. Box 2828
Salisbury MD 21802 USA
Phone 410-860-5100
Fax 410-860-1949
Web <http://www.lorch.com>
E-mail lorchsales@lorch.com

CIRCLE 90 ON READER SERVICE CARD

REAL WORLD solutions for

Wireless Applications

Lorch Microwave is now producing a full line of filters and diplexers specifically optimized for wireless applications. In addition to offering a wide range of standard designs covering the entire cellular and PCS spectrum, our engineers can assist you with developing custom filtering solutions. Contact sales so we may offer a solution to your wireless requirements today.



Example Performance:

WD-00007 FULL BAND PCS DIPLEXER

RX Passband Frequency: 1850-1910 MHz

TX Passband Frequency: 1930-1990 MHz

TECHNICAL FEATURE



tones are no longer adequate to describe the performance and behavior of RF components and subsystems

dual-frequency conversion approach, as shown in **Figures 1** and **2**, respectively. Direct frequency conversion has a simpler architecture; however, it requires a very linear millimeter-wave direct IQ modulator, which is a design challenge. On the other hand,

KEY FEATURES

- Replaces P90 Chips
- High Q / Low ESR
- SRF to 6.0 GHz
- Low cost

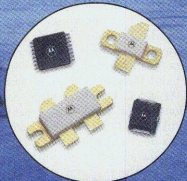
APPLICATIONS

- Mobile Communications
- Wireless LAN & Modems
- GPS Receivers
- CATV / SAT TV

Visit our website today for detailed technical information

No Matter Where You Are In The World

Richardson is Focused on your
Motorola RF Power Transistor
and RFIC Needs



As part of an ongoing focus to meet customer needs, two stars in the RF arena — Richardson and Motorola — have joined forces to provide you the best in RF technology. Richardson Electronics is now authorized worldwide to sell Motorola wireless RF and IF components.

From RF transistors...to power amplifier modules to RF/IF components including PAs and LNAs, mixers, small signal transistors and phase-locked loops... you now have access to product and service capabilities that are unsurpassed in the industry.

Motorola, recognized as the market leader in RF Power Transistors and RFICs, will continue to introduce innovative, state-of-the-art RF products. Through its worldwide network, Richardson Electronics will provide technical and logistical support for new and existing Motorola RF and wireless customers around the globe.

The combination of our resources and expertise means you can count on getting the best...from the best. All with one goal in mind — to provide timely, efficient and well-focused solutions to your RF needs worldwide.

Motorola and Richardson Electronics - A World of Difference



MOTOROLA



**Richardson
Electronics**

Engineered Solutions

More than 60 locations worldwide to serve you. Email: ssc@rell.com, Internet: www.rfpowermet.com, Toll Free: 800-RF Power or 800-737-6837 (U.S. & Canada), Mexico: Mexico City +52 (5) 674-2228, Guadalajara +52 (3) 645-4641, Brazil: São Paulo +55 (11) 820-6199, Colombia: Santa Fe de Bogotá, DC (57-1) 636-1028, France: Colombes Cedex +33 1 55 66 00 30, Germany: Puchheim +49 (89) 830 214-0, Italy: Agrate (MI) +39 (039) 853 145, Roma +39 (06) 41 73 37 51, Sesto Fiorentino (FI) +39 (055) 42 06 31, Spain: Barcelona +34 (93) 415 83 03, Madrid +34 (91) 526-3700, Sweden: Stockholm +46 8 564 705 90, Turkey: Istanbul +90 212 2643721, The Netherlands: Amsterdam +31 20 446 7070, United Kingdom: Slough +44 (01753) 733010, Australia: Castle Hill ACN 069 808 108 +61 (2) 9894-7288, Baywater ACN 069 808 108, +61 (3) 9738-0733, China: Shanghai +86 (21) 6440-0807, Japan: Osaka +81 (6) 314-5557, Tokyo +81 (3) 5215-1577, Korea: Seoul +82 (2) 539-4731, Singapore +65 487-5995, Taiwan: Taipei +886 (2) 86915238, Thailand: Bangkok +66 (2) 749-4402, Vietnam: Ho Chi Minh City +84 8 811 1919, Corporate Headquarters: LaFox, IL (630) 209-2200, for other international inquiries call (630) 208-2200, Fax (630) 208-2550, ©1999 Richardson Electronics, Ltd. MK0342



For more
information visit

www.rfpowermet.com/motorola.asp
or our Online catalog at catalog.rell.com

modulation accuracy are the modulator and output PA. For multilevel signaling, a linear quadrature modulator is required. Important properties of a linear quadrature modulator include good dynamic range with linear transfer characteristics, low I/Q gain imbalance and quadrature error, and low DC offset. It is often necessary to align the modulator by adjusting these input I and Q parameters, including possible correction for I/Q imbalance vs. baseband frequency.

Nonlinearity of a PA also degrades the transmitter's modulation accuracy by introducing AM/AM and AM/PM distortions. Traditionally, linearity of the PA is achieved by a backed-off mode of amplifier operation. Output power back off can range from 4 to 10 dB depending on the linearity requirements. Thus, for a 1 W linear transmitter, the PA requires 2.5 to 10 W output power capability. This capability significantly increases the radio equipment cost. In fact, developing a high output PA at an acceptable cost remains a major challenge to RF component suppliers.

Other impairments that could degrade the transmitter's modulation accuracy include interfering signals, close in spurs, LO feedthru and phase noise of frequency sources. The industry-wide standard to determine the modulation accuracy is EVM,⁴ which measures the phasor difference between an ideal reference signal and the measured modulated signal. This parameter is an ag-

gregated measure of the signal imperfections due to I/Q imbalance, PA nonlinearity, oscillator phase noise and filter imperfection in a single specification. The EVM specification allows circuit designers the flexibility to trade off different design approaches and permits system designers to know explicitly the hardware's capability.

A MILLIMETER-WAVE VECTOR SIGNAL MEASUREMENT SYSTEM

A millimeter-wave vector signal measurement system was configured to operate at higher Ka-band frequencies. It consists of a millimeter-wave modulator and a demodulator test bed. A functional block diagram of the complete vector signal measurement system is shown in **Figure 3**. The demodulator test bed is essentially an HP 71000T wideband VSA system, which extends the measurement bandwidth of the HP 89410 VSA from 7 MHz to over 200 MHz.¹ The system has a maximum coax-input frequency of 26.5 GHz and can be extended to 110 GHz with external harmonic mixers. The LO for the harmonic mixer is provided by the output of the HP 70910A spectrum analyzer's internal LO source module.

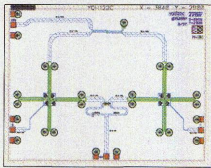
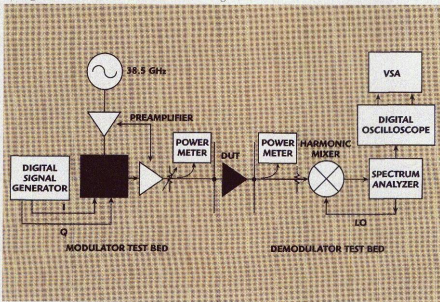
The modulator test bed includes an HP E4433B digital modulation signal source to generate a digital I/Q data stream and an HP 83650B frequency synthesizer to generate the LO for the modulator. The digital data stream was generated, intersymbol interference

(ISI) filtered and passed through a digital-to-analog converter (DAC) to form a band-limited analog waveform for driving the millimeter-wave quadrature modulator.

The modulator used in this case is TRW's model YQH122C monolithic quadrature modulator. **Figure 4** shows a layout of the YQH122C MMIC. This monolithic high electron mobility transistor (HEMT) MMIC consists of two binary phase-shift keying (BPSK) modulators, a phase shifter and a power splitter connected to perform a vector modulator function. Each BPSK modulator is based on a double-balanced ring mixer structure,⁵ which features good amplitude and phase balance. The quadrature modulator circuit performance was evaluated with a single-sideband frequency upconversion test. At 38.5 GHz, the measured conversion loss for the desired sideband is 9 dB with 20 MHz IF. The measured image rejection and carrier suppression are > 25 and > 30 dB, respectively. The overall system's data rate is limited by the digital signal generator to 12.5 Msps. Higher bandwidth signals are achieved using a VXI-based signal generator (based on a special option of the HP E6432A microwave synthesizer).

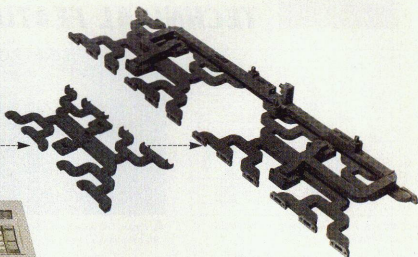
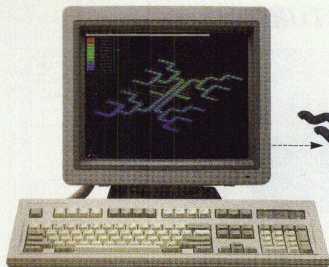
The first test is to measure the signal quality of the overall measurement system with the YQH122C modulator in place by connecting the output of the modulator test set to the input of the demodulator test set. Four different modulation formats were chosen: QPSK, offset QPSK (OQPSK), $\pi/4$ differential QPSK and 16QAM. The frequency synthesizer was set to 38.5 GHz. The I/Q digital data rate was set to 12.5 Msps along with a square-root raised cosine lowpass filter with α (excess bandwidth ratio) set to 0.5.

▼ Fig. 3 The mm-wave VSA test bed block diagram.



▲ Fig. 4 The YQH122C MMIC's layout.

[Continued on page 102]



Introducing the shortest distance between two points.

As the world's largest manufacturer of high quality cast components and sophisticated waveguide packages, we not only have to stay ahead of our competitors, we have to outrun technology.

OUR ENGINEERS ARE UP TO SPEED.

MDL's engineers are at the top of their profession. Using our proprietary software and Ansoft HFSS to compute s-parameters and full wave fields, then analyze port impedances, complex propagation constants, electromagnetic fields, and more, they can turn your designs into reality.

WE BUILD WHAT WE DESIGN.

Our machinists use the latest computer assisted equipment and specialized manufacturing machines bring designs to life. We manufacture, assemble, braze, finish and test every product right here in our plant, so quality and performance reliability are controlled from CAD to crate.

PICK UP THE PHONE.

Call 1-800-383-4189 and talk to an MDL specialist today.

Or visit our website at www.micro-dev-labs.com.

We're the shortest distance between design and done.

Microwave Development Laboratories,

135 Crescent Road, Needham Heights, MA 02494

Fax: 781-453-8629

E-mail: mdlsales@micro-dev-labs.com

WAVEGUIDE CAST BENDS & TWISTS

WAVEGUIDE FEED ASSEMBLIES

MONOPULSE COMPARATORS

ROTARY JOINTS

MICROWAVE FILTERS

ROTARY SWITCHES

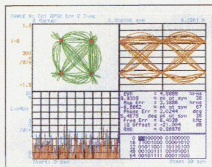
WAVEGUIDE TO COAX ADAPTERS

WAVEGUIDE PRESSURE WINDOWS

COMMERCIAL WAVEGUIDE ASSEMBLIES



The future of waveguide technology.



▲ Fig. 5 Modulator output with QPSK modulation.

Fig. 6 Modulator output with OQPSK modulation. ▼

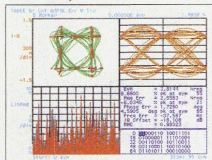


Fig. 7 Modulator output with $\pi/4$ differential PSK modulation. ▼

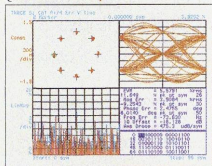
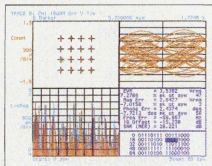


Fig. 8 Modulator output with 16QAM modulation. ▼

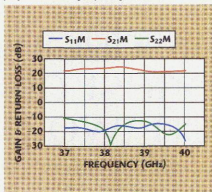


Figures 5, 6, 7 and 8 show four VSA output displays under four different modulation conditions. Each VSA display contains a vector or constellation diagram, eye diagram, error vector time display, error summary and symbol table. In all four cases, the symbols in the constellation diagrams have shown a small amount of



▲ Fig. 9 The power amplifier module with bottom-side waveguide interfaces.

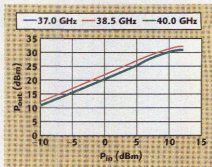
Fig. 10 The PA module's small-signal performance vs. frequency. ▼



spread. All eye diagrams show good eye openings. The average EVM ranges from three to 5.5 percent for these four cases. These levels of modulated signal accuracy should be adequate for most system applications. The measured EVMs also include contribution from the demodulator test set since no independent calibration is performed on the demodulator test bed.

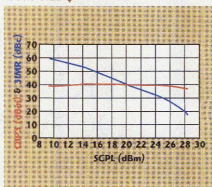
A 38 GHz 1 W PA MODULE

A vector signal measurement system was used to characterize TRW's HPA117 PA module, which operates from 37 to 40 GHz with a P1dB > 30.5 dBm across the full band. Figure 9 shows a photograph of the PA module. Internal to the PA module are three APH309C MMICs. One PA module is used as a driver, and the output stage consists of two PA modules combined through Wilkinson couplers. The APH309C MMIC is a two-stage balanced amplifier design based on TRW's 0.15 μ m InGaAs pseudomorphic HEMT (pHEMT) device technology. It delivers > 12 dB linear gain and has an output P1dB > 29 dBm. The PA module has built-in DC and control functions and requires only +6 V and -5 V supplies.



▲ Fig. 11 The PA module's CW output power with $V_d = +5.5$ V.

Fig. 12 The PA module's two-tone OIP3 and 3IMR performance at 38.5 GHz. ▼



The input and output RF ports are standard WR-28 waveguide interfaces located on the bottom side of the housing. The module is designed for 37 to 40 GHz point-to-multipoint base station applications.

The small-signal performance of the HPA117 module is shown in Figure 10. The unit has 21 to 23 dB linear gain across the 37 to 40 GHz band. The measured CW output power performance is shown in Figure 11. P1dB at 37, 38.5 and 40 GHz is 30.7, 31.4 and 30.5 dBm, respectively. Power-added efficiency is approximately 11 percent. The measured two-tone output third-order intercept point (OIP3) and third-order intermodulation rejection (3IMR) performances are shown in Figure 12. The measured OIP3 is approximately 40 dBm. A single carrier output power level (SCPL) of 26 dBm was achieved with a 3IMR level of 28 dBc.

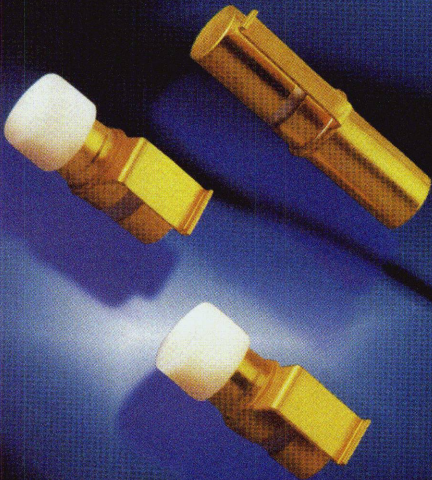
VECTOR SIGNAL MEASUREMENTS OF THE PA MODULE

An HPA117 PA module was then inserted into the vector signal measurement system. The first test used a

[Continued on page 104]

ADVANCED "C2K" TECHNOLOGY...

**TRIMMERS 30% - 40% SMALLER WITH
HIGH Q & MINIMUM ESL FOR
POWER AMPLIFIER APPLICATIONS**



- Model 57283
Capacitance Range: 0.8 to 4.5 pF
Height: 0.23"
- Model 57273
Capacitance Range: 0.8 to 8.0 pF
Height: 0.33"

- Tape and reel available
- High Resonant Frequency
- Delivery: Stock to 6 weeks

Tuned To Your Needs

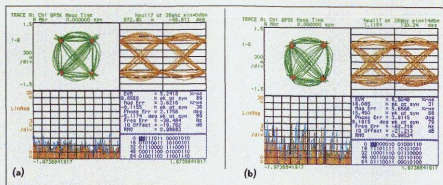
Johanson

Johanson Manufacturing Corporation

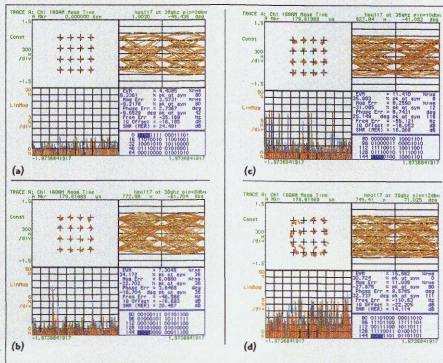
CIRCLE 71 ON READER SERVICE CARD

Rockaway Valley Road
Boonton, New Jersey 07005
Tel 973•334•2676 Fax 973•334•2954
www.johansonmfg.com

ISO-9001 CERTIFIED



▲ Fig. 13 The PA module driven with QPSK modulation at P_{in} of (a) 0 and (b) +14 dBm.



▲ Fig. 14 The PA module driven with 16QAM modulation at P_{in}/P_{out} levels of (a) 0/22.2, (b) 8/29.8, (c) 10/31.4 and (d) 12/32.4 dBm.

TABLE I

PA MODULE LINEARITY PERFORMANCE

Input Power (dBm)	Single-tone CW Output Power (dBm)	Single-tone CW Gain Compression (dB)	Two-tone OIP3 (dBm)	Two-tone SCPL/3IMR (dBm/dBc)	16QAM EVM (% rms)
0	22.2	0	40.5	13/43	4.4
8	29.8	0.4	39.4	26.4/26	7.3
10	31.4	0.8	38.3	27.8/21	11.4
12	32.4	1.8	37.4	28.4/18	15.6

QPSK digital modulation waveform. The RF carrier was set to 38.5 GHz and the I/Q digital data rate was set to 12.5 Msps with $\alpha = 0.5$. Figure 13 shows the two VSA output displays corresponding to two input power levels of 0 and +14 dBm. A vector dia-

gram displays the instantaneous output power behavior of the PA module. From these two vector diagrams, power compression is clearly evident at a $P_{in} = +14$ dBm drive level with the vector traces compressed around the corners along with symbol spreading oc-

curing at the constellation points. The EVM also increased from 5.2 percent rms to 8.5 percent rms. This amplitude compression causes the frequency spectrum to spread into adjacent channels, which could create an adjacent-channel interference problem.

The PA module was further tested with a 16QAM digital modulation input. As before, the data rate was set to 12.5 Msps with $\alpha = 0.5$. Figure 14 shows the VSA displays at four different input power levels (0, +8, +10 and +12 dBm) and their corresponding CW output power levels. As the input power level increases, the symbol constellation becomes increasingly rounded with the symbol clusters increasingly spread out at their symbol locations. In addition, the eye diagrams start to show richer accumulation of noise at the decision line due to ISI. The closure of the eye opening makes signal detection at the receiver more difficult, thus resulting in higher system BER. The measured average EVM increased from 4.4 percent rms at $P_{in} = 0$ dBm to 15.6 percent rms at $P_{in} = +12$ dBm. It is worthwhile to note that the PA module maintains fairly good modulation quality at an output power of approximately 1 W. It is also interesting to compare the EVM results from QPSK and 16QAM modulation. As expected, the QPSK modulation clearly has a better modulation quality performance, leading to a higher output power capability.

Table 1 lists the PA module linearity performance measured using three different methods: a single-tone CW, two-tone intermodulation and a 16QAM vector signal. As the input power increases from 0 to +12 dBm, the single-tone CW measurement shows a 1.8 dB gain reduction, the two-tone OIP3 decreases by 2.9 dB and the 16QAM EVM increases from 4.4 percent rms to 15.6 percent rms. All three methods characterize PA linearity performance; however, only the vector signal method provides insight into the PA nonlinear behavior under digital modulation. It should also be noted that since the modulation test bed has not gone through an alignment or calibration prior to device test, the measurement was actually for a complete direct modulation

[Continued on page 106]

Sometimes it's hard just getting to work....

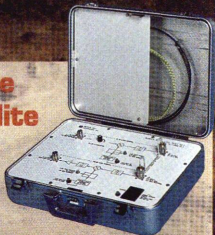
**NEW
MODEL!**



MITEQ makes it easier to get the tools there!



Mobile Satellite Test Set



The Mobile Satellite Test Set provides a test translator and block downconverter in a single transportable package. This unit offers transmit to receive, receive to L-, or transmit to L-band frequency translations. Both translations are designed for a minimum of amplitude and delay distortion.

Model	TLT/DNB-14-1
TLT Input	14.0 - 14.5 GHz
TLT Output	11.7 - 12.5 GHz
DNB Input	11.7 - 12.5 GHz
DNB Output	0.95 - 1.75 GHz

Model	TLT/DNB-14-2
TLT Input	14.0 - 14.5 GHz
TLT Output	12.25 - 12.75 GHz
DNB Input	12.2 - 12.75 GHz
DNB Output	0.95 - 1.50 GHz

Model	TLT/DNB-6-1
TLT Input	5.845 - 6.425 GHz
TLT Output	3.62 - 4.2 GHz
DNB Input	3.4 - 4.2 GHz
DNB Output	0.95 - 1.75 GHz

For additional information or
technical assistance, please
contact Chris Alfenito at
(516) 439-9108 or e-mail
calfenito@miteq.com



100 Davids Drive
Hauppauge, NY 11788
TEL.: (516) 436-7400 • FAX: (516) 436-7431/436-7430
www.miteq.com

AS OF NOVEMBER 1999, OUR NEW AREA CODE WILL BE 631

CIRCLE 127 ON READER SERVICE CARD

SCX Ultraminiature Coaxial Connectors

(.145" max diameter)



Sabritec's SCX coax connectors, with low VSWR 1.25:1 up to 20 GHz (max mated pair), meet high frequency requirements for today's

high speed digital communication environment.

The SCX series is featured as a rugged snap-on RF connector line with an impressively small diameter (.145" max dia. overall) combined with a low-profile mated pair length (.375" max). An air dielectric interface is maintained throughout the interface allowing for a constant 50-ohm characteristic impedance. The SCX series is ideal for board-to-board stacking arrangements for high density packaging.

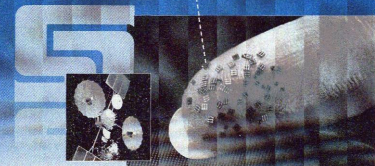
Call Sabritec today for more information!



Tel 949-250-1244 Fax 949-250-1009
http://www.sabritec.com
mcarlson@sabritec.com

CIRCLE 153 ON READER SERVICE CARD

These are
the highest reliability,
lowest failure rate resistors
on the planet (and far beyond).



State of the Art, Inc.

The Reliable Resistors

2470 Fox Hill Road, State College, PA 16803-1797
Call Toll Free: 1-800-458-3401 Fax: 814-355-2714

For launch vehicles and satellites, SOTA provides resistor technology and quality you can count on. Including unsurpassed established reliability failure levels for MIL-PRF-55342 chip resistors,

which include "S" level (0.001% per 1,000 hours) and "T" level (space level)! Plus an exclusive MIL-PRF-914 surface mount network qualification. For details, just call or visit us on the web.

e-mail: sales@resistor.com
On the Web: www.resistor.com



TECHNICAL FEATURE

transmitter, which consists of a quadrature modulator, frequency source and PA module.

CONCLUSION

A 38 GHz vector signal measurement system has been demonstrated. Key to the system are a TRW Ka-band monolithic quadrature modulator and an HP 71000T wideband signal analyzer. The system is flexible in providing various digital modulation formats. The modulation quality of the test system is measured by EVM and is less than six percent rms. The system was used to characterize a 37 to 40 GHz 1 W PA module with QPSK and 16QAM digital modulation. The PA module linearity performance was measured and compared using three different methods: single-tone CW, two-tone intermodulation and vector signal measurement. The vector signal measurement test method allows sophisticated digital/RF parametric tests to measure the dynamic behavior of the RF system under digital test stimuli. The new test method provides the possibility for more meaningful product specification, trade-offs between digital and RF functions, and the development of a streamlined test methodology for future millimeter-wave digital radio RF product development. ■

References

1. "HP 71000T E72 Wideband Vector Signal Analyzer Installation and Operating Guide," Hewlett-Packard, February 1999. Also see "HP E3830 Series Wide Bandwidth Vector Signal Analysis Systems," (<http://www.tmo.hp.com/tmo/datasheets/English/IPE3830.html>).
2. "Using Vector Modulation Analysis in the Integration, Troubleshooting and Design of Digital RF Communications Systems," Hewlett-Packard Product Note 89400-8 (<http://www.tmo.hp.com/tmo/Notes/English/5091-8687E.html>).
3. "10 Steps to a Perfect Digital Demodulation Measurement," Hewlett-Packard Product Note 89400-14A (<http://www.tmo.hp.com/tmo/Notes/English/5966-0444E.html>).
4. "Using Error Vector Magnitude Measurements to Analyze and Troubleshoot Vector Modulated Signals," Hewlett-Packard Product Note 89400-14.
5. "A Monolithic Broadband Double Balanced EHF HBT Star Mixer with Novel Microstrip Baluns," 1995 IEEE MTT-S Digest, pp. 119-122.

CHECK OUT OUR WEBSITE AT
<http://www.mwjjournal.com>

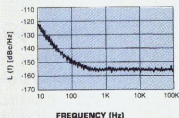
FEI Communications, the world leader in quartz oscillators, presents 3 choice units to select from. Each with Low Phase Noise and Excellent Stability. They can be packaged in a configuration of your choice.

CRYSTAL OSCILLATORS OF CHOICE



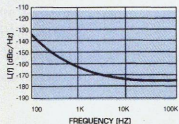
FE-101A
Subminiature Oven
Controlled Design
Only 1.27"x1.33"x1.33"
Fast warm up -
less than 2 minutes

Typical Phase Noise vs. Frequency @ 10MHz



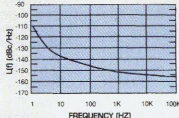
FE-102A
OPERATION
@100 MHz
Low Phase
Noise: -172 dBc

Typical Phase Noise vs. Frequency @ 100MHz



FE-103A
Double Oven
Design with
Excellent Stability:
 $1 \times 10^{-11}/\text{sec}$

Typical Phase Noise vs. Frequency @ 10 MHz



FEI Communications, Inc.
 A Subsidiary of Frequency Electronics, Inc.
 55 Charles Lindbergh Blvd., Mitchel Field, NY 11553
 TEL: 516-794-4500 • FAX: 516-794-4340
 Visit us at: www.freqelec.com

HIGH EFFICIENCY POWER AMPLIFIER DESIGN USING GAAs HFETs

The computer-aided design and performance of high efficiency amplifiers operating in class AB/F at X-band are presented. The amplifiers employ state-of-the-art power heterostructure FET (HFET) devices. The design emphasis is on maximizing the output power and power-added efficiency. Two single-ended power amplifiers are designed using the developed and scaled small- and large-signal models of a 2.4 mm unit cell HFET to represent 4.8 and 9.6 mm gate width HFET devices. The amplifier employing a 4.8 mm HFET achieved a power-added efficiency of 53 percent at an output power of 2.5 W with 8 dB small-signal gain. The amplifier employing a 9.6 mm HFET achieved a power-added efficiency of 42 percent at an output power of 8 W with 7 dB small-signal gain. The design technique employed provides good agreement between measured and predicted results.

Solid-state power amplifiers (SSPA) are one of the key components of wireless communication systems. This critical component governs much of the systems' size, cost, performance and manufacturability. Differentiating factors such as frequency, bandwidth, supply voltage, output power, efficiency and mode of operation drive the requirements for SSPAs for both commercial and military systems.

Until recently, GaAs power MESFETs have been the prime devices employed in SSPAs at RF and microwave frequencies for a variety of wireless communication systems for both commercial and military applications. The main deficiency of these devices is their inability to achieve high power-added efficiency. Depending upon the application and frequency range, the output power requirement of communication systems varies from a few watts to a few hundred watts. For example, for phased-array-type applications power levels of

up to 10 W may be sufficient, while for satellite uplink terminals several tens of watts are required. RF communication-type applications require narrow bandwidths while application areas such as electronic warfare and optical line drivers have ultra-wide bandwidth requirements.

For airborne, spaceborne and personal communications applications (that is, PCS and GSM), the DC-to-RF conversion efficiency of such SSPAs must be maximized. In particular, the SSPAs have a number of advantages over

[Continued on page 110]

A.S.VIRDEE
Filtronic Components Ltd.
Milton Keynes, UK
B.S.VIRDEE
University of North London,
School of Communications Technology
and Mathematical Sciences
London, UK

INTERFERENCE?

ELIMINATE NOISE, INTERFERENCE AND CO-LOCATION PROBLEMS WITH NARDA FILTERS AND DUPLEXERS.

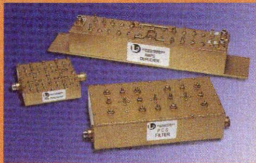
Dropped calls mean lost revenue. Period. Which is why you should choose Narda West Filters and Duplexers. They're designed to get rid of problems caused by co-location, interference and marginal performance from OEM supplied equipment.

For a competitive price, you get Narda West's "install and forget" reliability. And you get

it fast. Many of our catalog products are immediately

available from stock. We also offer a broad line of filters and duplexers covering AMPS, GSM, SMR and PCS bands.

So when you've had it with cell site interference problems, upgrade to the best: Narda Microwave West. Call us today at 916-351-4500.



narda
microwave-west

an **L3** communications company
It's Narda to be precise.

© 1996 L-3 Communications, Inc.
www.nardamicrowave.com

CIRCLE 135 ON READER SERVICE CARD

traveling-wave tube amplifiers (TWTA) employed in communication satellite applications. SSPAs are more robust and reliable, require only simple voltage supplies and are of lower mass and size. However, to date, SSPAs have seen little use in spacecraft payloads at frequencies above UHF. The main reason for this lack of use has been attributed to poor efficiency. Typical SSPA efficiencies are in the range of 20 to 30 percent, whereas TWTA efficiencies are approximately double this level. Such low SSPA efficiencies present power drain and thermal control problems onboard a spacecraft, which, in the eyes of payload system designers, outweigh the advantages of employing solid-state technology.

The SSPA RF integrated circuits (RFIC) also must achieve maximum

output power and efficiency, which have a direct correlation to how much talk time in a personal-communication-type application is obtained per battery charge. These RFIC amplifiers are employed in the lower microwave frequency range in areas such as cellular phones and base stations operating in the 900 MHz and 1.8 GHz bands. Satellite communication services and wireless local area networks at L-band are also major users of RFICs. Therefore, any improvement in SSPA efficiency—even if only moderate—makes use of the amplifier much more attractive.

Recent developments in material growth techniques (such as molecular beam epitaxy and molecular chemical vapor deposition) and realization of novel device structures are beginning to change device capabilities in terms of higher output power and efficiency. These new state-of-the-art power GaAs HFET devices have structures that are based on heterojunctions comprising AlGaAs/GaAs, InGaP/GaAs and InAlAs/InGaAs. These devices offer high gate-drain and gate-source breakdown voltages, near-constant transconductance with gate bias down to pinch-off voltage and moderately high maximum channel current that enables high efficiency to be obtained.

In this article, high efficiency microwave IC power amplifiers operating in class AB/F¹ and employing 4.8 and 9.6 mm HFET power devices are designed at X-band using computer-aided design methods. The characterization of large gate width power devices is complex and the traditional

technique for obtaining the devices' input and output impedances is the load pull power contour method.² However, the technique employed here for characterizing large gate width HFET power devices is to scale the developed small- and large-signal models of the 2.4 mm unit cell HFET. It is shown that this technique yields good agreement between measured and predicted results.

DEVICE CHARACTERIZATION AND MODELING

The design of power amplifier matching circuits differs in approach from low noise amplifiers for a number of reasons. The physical size of the 4.8 and 9.6 mm HFET power devices is large enough to require a distributed analysis.³ In addition, the devices' inherently low terminal impedances make it difficult to measure and characterize them using conventional 50 Ω characteristic impedance network analyzers. Even if a perfect distribution network was available to characterize a multicell device, this method would lead to measurement errors because the device input and output impedances are considerably less than 50 Ω . Therefore, a single cell defined as the 2.4 mm unit cell HFET is employed and characterized in a 50 Ω system.

The 2.4 mm unit cell HFET was characterized by measuring the S parameters at a $V_{ds} = 8$ V and $I_{ds} = 0.25I_{ds}$ operating point in order to achieve the optimum power-added efficiency performance. The de-embedded⁴ S parameters from the measurement fixture were employed to develop a small-signal model over 2 to 10 GHz. The 2.4 mm unit cell HFET was characterized for large-signal modeling by measuring the pulsed I_{ds}/V_{ds} and I_{ds}/V_{gs} characteristics. LIBRA[®] CAD software was employed to achieve an optimum fit to the de-embedded small-signal S parameters. **Figure 1** shows good agreement between the de-embedded and modeled S_{11} and S_{22} . **Figures 2 and 3** show S_{11} and S_{22} of the 2.4 mm unit cell HFET scaled by a factor of two to represent the 4.8 mm HFET and by a factor of four to represent the 9.6 mm HFET device, respectively.

Large-signal modeling was carried out by employing the Curtice-Quadratic,⁵ Curtice-Ettenberg,⁶ Statz⁷ and TOM⁸ large-signal models available in

[Continued on page 112]

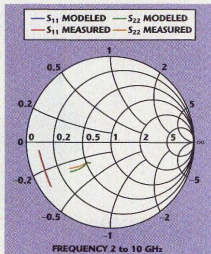


Fig. 1 De-embedded and measured S_{11} and S_{22} of the 2.4 mm unit cell HFET biased at $V_{ds} = 8$ V and $I_{ds} = 0.5I_{ds}$

Fig. 2 The 4.8 mm HFET S_{11} and S_{22} modeled by scaling the 2.4 mm unit cell HFET biased at $V_{ds} = 8$ V and $I_{ds} = 0.5I_{ds}$

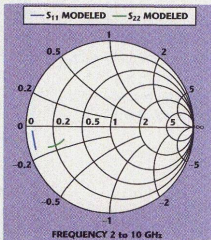
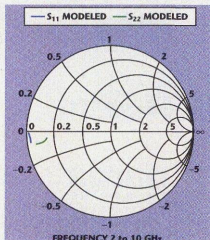


Fig. 3 The 9.6 mm HFET S_{11} and S_{22} modeled by scaling the 2.4 mm unit cell HFET biased at $V_{ds} = 8$ V and $I_{ds} = 0.5I_{ds}$

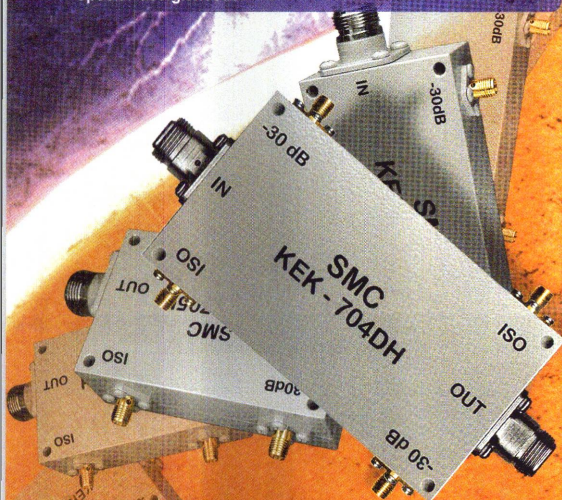


HIGH POWER

Synergy introduces *Dual & Single High Power Directional Couplers*. These couplers are capable of handling up to 500 watts of power with excellent directivity (30 dB) to guarantee precise power measurements. The low insertion loss feature of these High Power Directional Couplers ensures efficient power transmission. These couplers exhibit excellent amplitude response over the frequency band of operation.

For GSM and PCS/PCN band base station applications, Synergy's *Dual or Single High Power Directional Coupler* is the perfect choice.

As always, Synergy's Application and Engineering Team are always ready to answer technical questions and help with your special design needs.



For additional information,
contact Synergy's Sales and Application team:
201 McLean Boulevard, Paterson, NJ 07504
Tel: (973) 881-8800 Fax: (973) 881-8361
E-mail: sales@synergymwave.com
Web Site: www.synergymwave.com

SYNERGY
MICROWAVE CORPORATION
CIRCLE 169 ON READER SERVICE CARD

COUPLERS

VCO's are us

100-2500MHz SINGLE & DUAL BAND Voltage Control Oscillators.

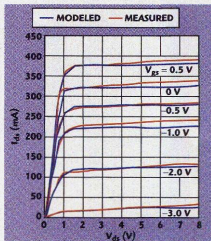
We offer:

- Very high performance VCO's.
- Mini size packages.
- Low cost.
- Short lead-time.
- Custom designed VCO's.

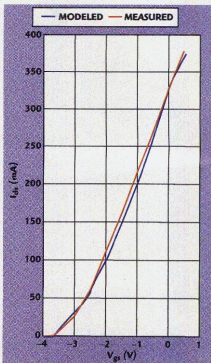
TETRA
ELECTRONIC IND. LTD.

5, Hasadan st. Holon 58117 Israel
Phone: +972-3-5562775, Fax: +972-3-5561944
E-mail: gadil@tetra.co.il
<http://www.tetra.co.il>

LIBRA. The latter models were optimized to achieve optimum fit to the pulsed I_d/V_{ds} and I_d/V_{gs} characteristics. The Statz large-signal model was determined to provide the optimum fit to the measured I_d/V_{ds} and I_d/V_{gs} characteristics of the 2.4 mm unit cell HFET, as shown in **Figures 4** and **5**, respectively. The Statz model introduces two important advances over previous device models. First, the model incorporates an improved analytic DC I-V formulation. Second, the model offers an improved charge model



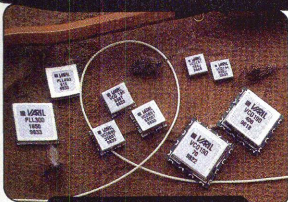
▲ Fig. 4 The 2.4 mm unit cell HFET measured and modeled I_d vs. V_{ds} employing the LIBRA Statz large-signal model.



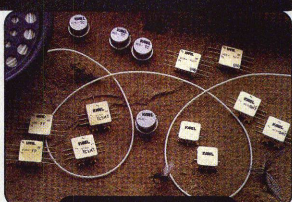
▲ Fig. 5 The 2.4 mm unit cell HFET measured and modeled I_d vs. V_{gs} employing the LIBRA Statz large-signal model.

[Continued on page 114]

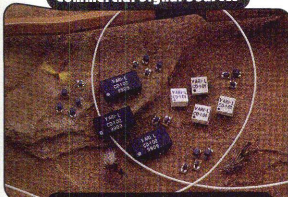
GOT A TOUGH RF JOB TO TACKLE?



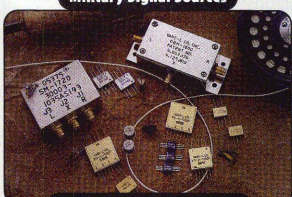
Commercial Signal Sources



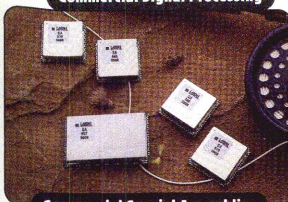
Military Signal Sources



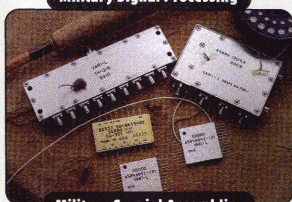
Commercial Signal Processing



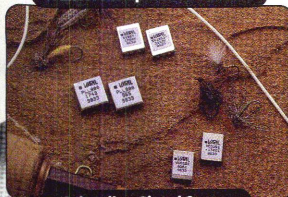
Military Signal Processing



Commercial Special Assemblies



Military Special Assemblies



Subscriber Signal Sources

VARIL

We Have A Part In Your Future

4895 Peoria Street

Denver, Colorado 80239

☎ 303.371.1560

fax 303.371.0845

e-mail: sales@varil.com

VARIL is a precision manufacturer of RF components for a wide range of aerospace, commercial, military, space and subscriber applications.

**OUR
PRODUCTS
INCLUDE:**

Voltage Controlled Oscillators

Double Balanced Mixers

Power Dividers/Combiners

IQ Modulators/Demodulators

PLL Synthesizer Modules

Wideband RF Transformers

Couplers

Special Integrated Assemblies

Contact the Varil Sales Department for your special microwave and RF component assembly needs.



PROUDLY
MADE IN
THE USA

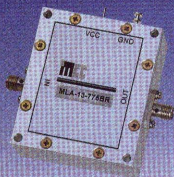
VARIL Company, Inc.

www.varil.com

ISO9001 Certified

Small Bills for Big Change GaAs LNA

For Cellular, GSM, PCS/PCN and TRS



Small, but better performance and lower cost will save your money. We deliver quick applications to your specific requirements.

■ Features

- Low Noise Figure
- High Linearity
- Single Bias
- Temperature Compensation Circuit

* Size : 49.8 × 57.0 × 19.1 (mm)

■ Also Available Power Amplifiers, Up/Down Converters, RF Integrated Modules

Specifications

Parameter	Model	MLA-13-775BR/T	MLA-23-775AR/T
Frequency Range		800~900MHz	1700~1900MHz
Gain		40 dB	27 dB
Gain Flatness (dB)		±1.0 dB	±1.0 dB
Noise Figure (typ)		0.9 dB	1.2 dB
In/Output VSWR (max)		1.5:1	1.5:1
1dB Compression Point		21 dBm	21 dBm
IMD3 (typ)		55dBc (@+5dBm)	55dBc (@+5dBm)
DC Power (typ)		9~16V/300 mA	9~16V/300 mA



Sales Representative Wanted

Microwave Communications & Components, Inc.

14th Fl. Prime Center, 546-4, Guui-Dong, Kwangjin-Gu, Seoul, Korea

Tel : 82-2-3424-0800 Fax : 82-2-3424-0808

www.mccck.com e-mail:sales@mccck.com

TECHNICAL FEATURE

representation of C_{gs} and C_{gd} as functions of both V_{gs} and V_{ds} . The Statz model modifies the Curtice-Ettenberg formulation by replacing the more computationally intensive hyperbolic tangent function with a truncated series representation. The Statz I_{ds} equation then becomes

$$I_{ds}(V_{gs}, V_{ds}) = \frac{\beta(V_{gs} + |V_p|)^2(1 + \lambda V_{ds}) \left[1 - \left[1 - \frac{\alpha V_{ds}}{3} \right]^3 \right]}{1 + b(V_{gs} + |V_p|)} \quad (1)$$

for $0 < V_{ds} < \frac{3}{\alpha}$

and

$$I_{ds}(V_{gs}, V_{ds}) = \frac{\beta(V_{gs} + |V_p|)^2(1 + \lambda V_{ds})}{1 + b(V_{gs} + |V_p|)} \quad (2)$$

for $V_{ds} \geq \frac{3}{\alpha}$

where

$$\left[1 - \left[1 - \frac{\alpha V_{ds}}{3} \right]^3 \right] = \text{the truncated series representation of } \tanh(\alpha V_{ds})$$

β = a model parameter

The equations provide unusually good control over the contour in the transition of $I_{ds} = f(V_{gs})$ as it goes from square law to linear behavior. As long as the quantity $b(V_{gs} + |V_p|)$ is $\ll 1$ (as it is when V_{gs} is close to pinch-off), then the behavior is square law since $I_{ds} = \beta(V_{gs} + |V_p|)^2$. However, when $b(V_{gs} + |V_p|) \gg 1$, then the expression is nearly linear since I_{ds} approaches

$$I_{ds} = \frac{\beta V_{ds} + |V_p|}{b}$$

The coefficient β is easily evaluated for any choice of b since

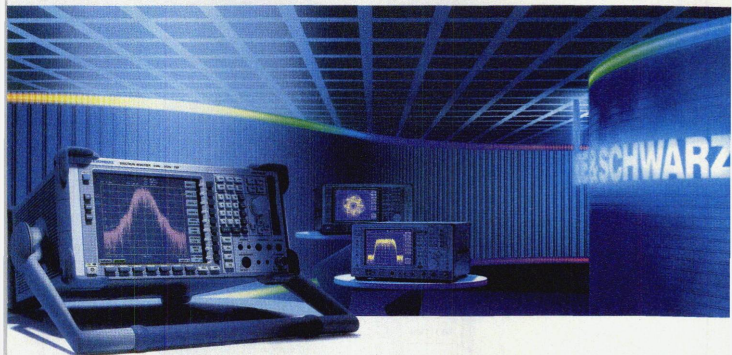
$$I_{ds} = \frac{\beta |V_p|^2}{1 + b|V_p|} \quad (3)$$

and

$$\beta = \frac{I_{ds}(1 + b|V_p|)}{|V_p|^2} \quad (4)$$

The described Statz function allows a broad latitude in I_{ds} vs. V_{ds} fitting by performing adjustments of the coefficients b and β . It can accommodate I_{ds} vs. V_{gs} behavior that varies from totally square law ($b = 0$) to totally linear (very large b). The model provides an excellent fit with measured data along the entire I_{ds}/V_{gs} curve and down to the curvature close to pinch-off. The latter fit enables amplifiers to be designed and operated in class AB mode. The developed small- and large-signal models of the 2.4 mm unit cell HFET then were appropriately scaled to represent the 4.8

[Continued on page 116]



The new mid-range prodigy (and the proud parents)

So you know all about spectrum analyzers from Rohde & Schwarz? Top of the range instruments for the most demanding requirements, superlative performance that naturally comes with a matching price tag? Then think again! And take a good long look at this box of tricks: small, light, extremely fast, big colour display, with a specification to blow the socks of all the opposition in the market for mid-range spectrum analyzers. Features like high-speed zero span? Built-in. GPIB, RS232 and printer interfaces? Standard. PC-compatible screenshots? At the touch of a button, no conversion software needed. 10 Hz to 10



MHz bandwidths? The complete range. Time-gated analysis? No extra charge. Plus a range of features not to be found in a rival mid-range analyzer for love or money. Such as the RMS detector, or statistic measurement functions like CCDF. Or highly selective FFT filters and the fast ACP measurement function. Not bad, you are thinking, but tell me about the price for such a parade of technology. Certainly we'll tell you about the price: very, very competitive. Just another feature. By the way our mid-range prodigy is called the FSP. You can find out all about the FSP on the Internet. Or give us a call.

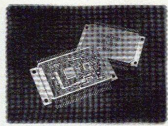
Discover more: www.fsp.rsd.de



ROHDE & SCHWARZ

Internet <http://www.rsd.de> - TEL Argentina (1) 14 331 1685 - 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 (59) 2 65 51 33 - Canada (see USA)
Chile (2) 2 77 50 50 - China (10) 64 67 23 65 - Czech Republic (2) 24 32 20 14 - Denmark (43) 43 66 99 - Finland (58) 9 47 88 30 - France (1) 41 36 11 09 - Germany (188) 512 42 42 - Greece (11) 7 22 92 13
Hong Kong (2) 5 07 03 33 - Hungary (1) 203 0282 - India (11) 4 61 52 85 - Indonesia (21) 2 52 47 88 - Iran (21) 8 73 02 82 - Italy (6) 41 59 81 - Malaysia (3) 7 03 5503 - Mexico (5) 6 66 63 33
Netherlands (30) 6 00 17 00 - New Zealand (4) 2 32 32 33 - Norway (23) 17 22 50 - Pakistan (51) 25 69 53 - Philippines (2) 8 13 29 31 - Poland (22) 6 35 06 87 - Portugal (1) 4 12 01 31 - Romania (1) 4 10 68 46
Russian Federation (095) 2 34 49 62 - Saudi Arabia (1) 4 65 44 78 - Singapore (2) 87 68 22 - Slovenia (61) 1 23 46 51 - South Africa (11) 786 3647 - Spain (1) 3 34 10 70 - Sweden (8) 6 05 19 00
Switzerland (31) 9 22 15 22 - Taiwan (2) 23 21 70 70 - Thailand (2) 6 43 13 30 - Turkey (216) 3 85 19 17 - United Kingdom (1252) 81 13 77 - USA Telexnet Tel. (800) 426 22 00, Fax (503) 2 22 15 42,
<http://www.lnk.com> - Vietnam (4) 8 34 61 86

CIRCLE 152 ON READER SERVICE CARD



DIGITAL CHIRP SYNTHESIZER HYBRID CLOCKS AT 1 GHz

- 0 to 400 MHz Output Range
- 32 bit Frequency Resolution (0.23 Hz Steps)
- Chirp and CW Modes
- Windows Compatible Evaluation Board
- Custom Designs Available

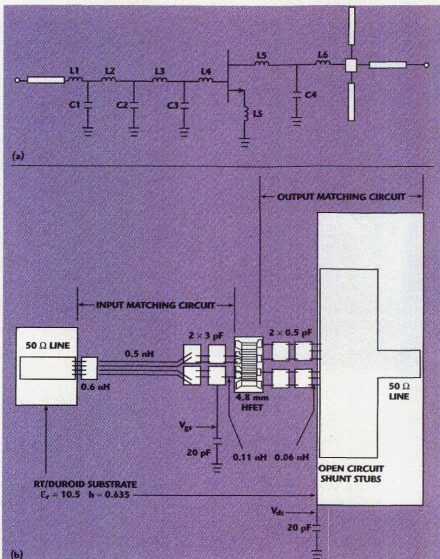
See our website for complete details.
WWW.STELMSD.COM

**STANFORD
TELECOM**

Microwave Systems

59 Technology Drive, Lowell, MA 01851
Phone: 978-441-0200 • Fax: 978-453-6299

CIRCLE 163



▲ Fig. 6 The 4.8 mm HFET power amplifier circuit (a) schematic and (b) layout.

and 9.6 mm gate width HFETs in order to carry out the design of high efficiency power amplifiers.

HIGH EFFICIENCY AMPLIFIER DESIGN PROCEDURE

The design of high efficiency amplifiers employing the 4.8 and 9.6 mm HFETs is accomplished using LIBRA in order to optimize output power and power-added efficiency performance. In employing computer-aided design, accurately scaled small- and large-signal device models of the 2.4 mm unit cell HFET are required. An accurate scaled large-signal model of the device is required to design the output matching circuits for the amplifier. The predominant nonlinearities correspond to the drain source current I_{ds} and are fitted to the pulsed I_{ds}/V_{ds} and I_{ds}/V_{gs} measured characteristics of the 2.4 mm unit cell HFET device to the nonlinear

Statz model. The Statz large-signal model achieved the best fit to the pulsed data and was employed in simulating the amplifier designs under large-signal conditions. In order to optimize the amplifier design for small-signal gain and input and output return loss, the scaled small-signal model of the 2.4 mm unit cell HFET device was used at the quiescent bias point.

4.8 MM HFET HIGH EFFICIENCY AMPLIFIER DESIGN

A single-ended amplifier design employing a 4.8 mm HFET device was carried out by initially optimizing the small-signal performance by using the small-signal model of the 2.4 mm unit cell HFET device scaled by a factor of two. This scale factor was used because the gate width ratio of the two devices was 2:1. **Figure 6**

[Continued on page 118]

HI-PWR RF RESEARCH TOOLS OFF THE SHELF DELIVERY FROM OUR VAST INVENTORY

HIGH POWER MODULATORS
HIGH POWER RF SOURCES
HIGH VOLTAGE POWER SUPPLIES

AN/APG-65 TRANSMITTER
Type T1377 used on F-18
Hi-Power TWT Amplifier

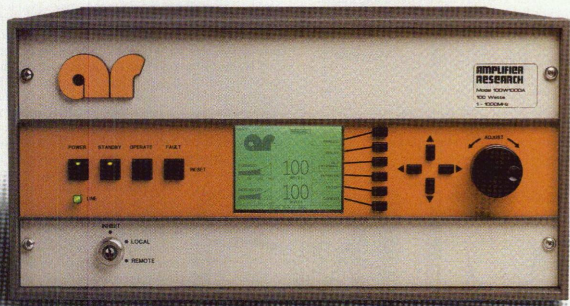
SEARCH / TRACKING RADARS
H.V. COMPONENTS
HIGH POWER ELECTRON TUBES
ANTENNAS FROM 2' TO 60'
MAGNETRONS-KLYSTRONS
TWT-CFA
WAVEGUIDE COMPONENTS

SEND FOR FREE 24 PAGE
CATALOG ON YOUR LETTERHEAD

**RADIO RESEARCH
INSTRUMENT CO., INC.**

584 N. MAIN ST. WATERBURY, CT 06704
PH 203-753-5040
FAX 203-754-2567
E MAIL radioresearch@prodigy.net
http://www.techexpo.com/WWW/radioresearch

Get Real.



Other amps can get you the power they promise. The numbers you see on the monitor match those on the spec sheet. Mismatch is low. VSWR 1:1.

Dream on.

Mismatch is reality in 99% of all test scenarios. Amps are routinely asked to output into really high VSWR ratios. And if they fold back (most do), well, you're out of luck and out of power. AR amps to the rescue.

Delivering 100% rated power to the load, even in brutal VSWR. Built for the reality of really hostile test environments. Performance guaranteed.

Want to know more about the better brand of Class A amplifiers from the world class manufacturer of RF test instruments?.

Call 800-933-8181 for an applications engineer.

ISO 9001
Certified

Copyright© 1998 Amplifier Research. The orange stripe on AR products is Reg. U.S. Pat. & Tm. Off.

30 Years Of World Class RF Instruments. 3 Year Warranty On All Our Amplifiers.

USA Souderton PA • TEL 215-723-8181 • FAX 215-723-5688 • www.ar-amps.com
In Europe, call EMV- Munich: 89-614-1710 • London: 01908-566556 • Paris: 1-64-61-63-29 • Amsterdam: 31-172-423-000

**AR[®] AMPLIFIER
RESEARCH**

The Force Behind The Field.

CIRCLE 8 ON READER SERVICE CARD

TECHNICAL FEATURE

shows a circuit schematic and layout of the optimized amplifier design.

To achieve high efficiency, a class F mode of operation was employed where the harmonic distribution of energy is such that higher voltages and lower currents are produced at the output terminals of the device. For the ideal case, that is, for the ideal drain source voltage $v_{ds}(t)$ to be a square waveform, it must contain only odd harmonic voltage components given by¹

$$v_{ds}(t) = v_{\max} \left(\frac{1}{2} - \frac{2}{\pi} \sum_{n=1,3,5} \frac{1}{n} \sin n\omega t \right) \quad (5)$$

and for the drain source current $i_{ds}(t)$ waveform to be a half sinusoid it must consist of even harmonic current components given by¹

$$i_{ds}(t) = i_{\max} \left(\frac{1}{\pi} + \frac{1}{2} \sin(n\omega t) - \frac{2}{\pi} \sum_{n=2,4,6} \frac{1}{n^2 - 1} \cos(n\omega t) \right) \quad (6)$$

where

v_{\max} = maximum drain source voltage under RF conditions

i_{\max} = maximum drain source current under RF conditions

Large-signal simulation and optimization for output power and efficiency were carried out by employing a class F mode of operation by incorporating a close-in second-harmonic short circuit at the output matching circuit. Optimization of efficiency is shown in **Figures 7 and 8**, which display the output drain voltage and current waveforms approaching square wave,⁹ a condition for optimum efficiency as the input power is increased.

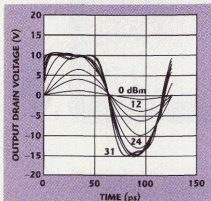
9.6 MM HFET HIGH EFFICIENCY AMPLIFIER DESIGN

A single-ended amplifier design employing four 9.6 mm HFET devices was carried out by initially optimizing small-signal performance using the small-signal model 2.4 mm unit cell HFET scaled by a factor of four. The scale factor of four was used because the gate width ratio of the two devices was 4:1. **Figure 9** shows a circuit schematic and layout of the optimized amplifier design. The input matching circuit consists of lumped element matching using lowpass networks close to the four devices. These elements offer the low impedance required to perform circuit matching to the low input impedance of the device. Lumped-element matching increases the impedance level so that further multiple transformations in impedance level to the system impedance of 50 Ω can be carried out

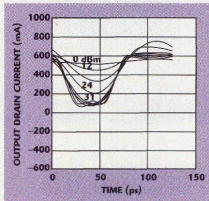
by employing a divider network comprising two-section quarter-wave impedance transformers realized as microstrip elements.

The output matching circuit employs microstrip element matching because the impedance of the scaled 9.6 mm HFET device was higher than the input impedance and, therefore, requires no lumped-element matching. It also can be observed from the diagram that the four 9.6 mm HFET devices are combined using an in-phase power combiner network comprising two-section quarter-wave impedance transformers, which simultaneously combine and match the four devices. Initial values of the impedance transformers were calculated and further optimized using LIBRA. The isolation resistors labeled R_1 , R_2 and R_3 were employed to terminate any odd modes¹⁰ that may be generated by circuits of this complexity.

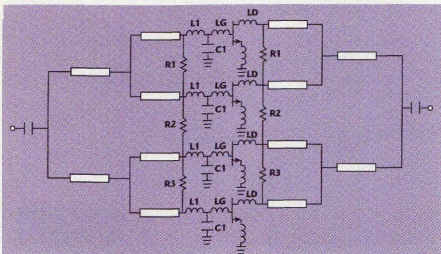
The small-signal-optimized single-ended amplifier employing 9.6 mm HFETs was optimized for large-signal performance. The LIBRA Statz large fitted model of the 2.4 mm unit cell HFET was scaled by a factor of four to represent the 9.6 mm HFET device. Large-signal simulation and optimization for output power and efficiency were carried out by employing a class F mode of operation similar to the 4.8 mm HFET



▲ Fig. 7 The LIBRA-predicted output drain voltage waveform of the 4.8 mm HFET large-signal amplifier simulation.



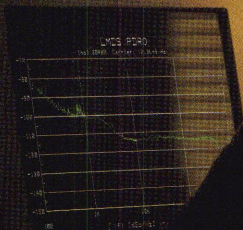
▲ Fig. 8 The LIBRA-predicted output drain current waveform of the 4.8 mm HFET large-signal amplifier simulation.



▲ Fig. 9 The 9.6 mm HFET power amplifier circuit schematic.

[Continued on page 120]

Performance that lives up to *your* ideas.

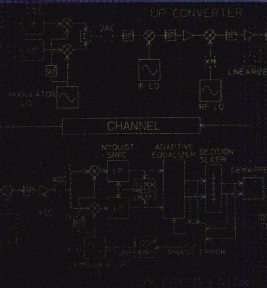


CTI PDROs are guaranteed to give you the performance and reliability you had in mind. And, we make sure it's delivered when you need it.

CTI Series PDRO has been designed specifically for use in LMDS, SDH/SONET Digital Radio and other wired and wireless systems where performance as well as cost is critical.

Features such as ultra low phase noise, high power and small size make CTI's PDRO product line the best value on the market today.

So remember when you need a PDRO, AND you need it now, Call CTI. We deliver.



Frequency:	4 to 18 GHz (in bands)
Power Output:	+17 dBm
Supply Voltage:	+12 VDC
Spurious:	-80 dBc
Harmonics:	-40 dBc
Frequency Stability:	±5 ppm
Optionally:	±2.5 ppm
Phase Noise at 12.3 GHz (Typ.):	
100 Hz	-83 dBc/Hz
1 k	-100 dBc/Hz
10 k	-110 dBc/Hz
100 k	-113 dBc/Hz
1 M	-128 dBc/Hz



**COMMUNICATION
TECHNIQUES**

A DOVER TECHNOLOGIES COMPANY

9 Whippany Rd. • Whippany, NJ 07981

TEL: 973-884-2580 • FAX: 973-887-6245

www.cti-inc.com • e-mail: sales@cti-inc.com

CIRCLE 22 ON READER SERVICE CARD

TECHNICAL FEATURE

design. Optimization of efficiency also was confirmed as illustrated in **Figures 10 and 11**, which show the output drain voltage and current waveforms approaching a square wave, a condition for optimum efficiency¹ as the input power is increased, respectively.

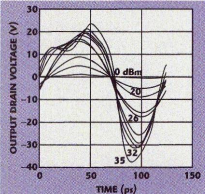
AMPLIFIER FABRICATION

The 4.8 mm HFET single-ended power amplifier was constructed by

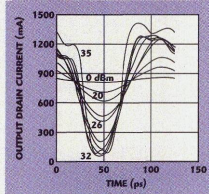
employing lumped and microstrip elements. The input matching circuit consists of a three-section lowpass lumped-element network comprising low loss microwave chip capacitors and 1 mil diameter gold bond wire employed to fabricate the required inductors. The output matching circuit consists of a single-section lowpass lumped-element network comprising two low loss shunt-mounted capacitors and inductors realized by

employing 1 mil gold wires. The final connection to the 50 Ω system impedance was carried out by employing microstrip elements fabricated on RT/Duroid softboard material with a dielectric constant ϵ_r of 10.5 and substrate thickness of 25 mils. The amplifier was fully assembled onto a machined gold-plated carrier made from copper tungsten composite material. All the components and substrates were soldered onto the gold-plated carrier.

The single-ended 9.6 mm HFET amplifier was fabricated using lumped and microstrip components. Its circuit layout is shown in **Figure 12**. The lumped components comprised low loss microwave chip capacitors and inductors that were realized employing 1 mil gold wire of appropriate lengths. The microstrip circuits were realized on 10 and 25 mil alumina substrates. The 9.6 mm HFET amplifier was fabricated onto a highly precision machined gold-plated tungsten/copper carrier. The carrier incorporated very



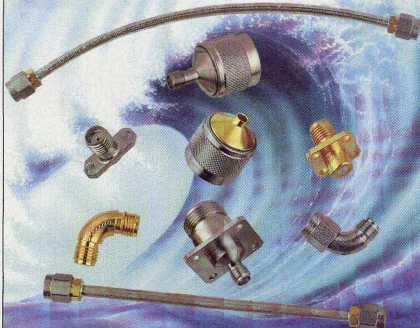
▲ Fig. 10 The LIBRA-predicted output drain voltage waveform of the 9.6 mm HFET large-signal amplifier simulation.



▲ Fig. 11 The LIBRA-predicted output drain current waveform of the 9.6 mm HFET large-signal amplifier simulation.

[Continued on page 123]

MICROWAVE CONNECTORS & CABLE ASSEMBLIES...



...FROM STOCK

Atlantic Microwave has the power to deliver an extensive range of microwave connectors & cable assemblies, often from stock, and we can even guarantee same day despatch.

Connectors

- SMA
- SMP
- TYPE N
- TNC
- BNC
- MCX
- Field Replaceable
- Panel Mount
- Bulkhead
- Radius Right Angle
- Hermetic
- Adapters

Cable Assemblies

- Reformable Semi Rigid
- Standard Lengths
- Flexible
- Low Loss Test Cables

We also provide a full sales and support service for the products of Connecting Devices Inc.

Tel +44 (0)1376 550220

Fax +44 (0)1376 552145

E mail sales@atlanticmicrowave.co.uk

Atlantic Microwave Ltd

40A Springwood Drive Baintree Essex CM7 2YN England

ATLANTIC
Microwave Limited
the POWER to DELIVER



Situation: *You need microwave test accessories ASAP.*

Option 1



HP switches and attenuators offer 0.03 dB repeatability over 5 million cycles and are available through QuickShip. HP amplifiers offer ultrabroad bandwidth from 10 MHz to 50 GHz, which simplifies test set-up.

Option 2

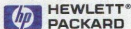
Call **HP DIRECT**. No matter what accessory you need to complete your test system, HP DIRECT is an easier way to get it.

NEW
50 GHz Switch

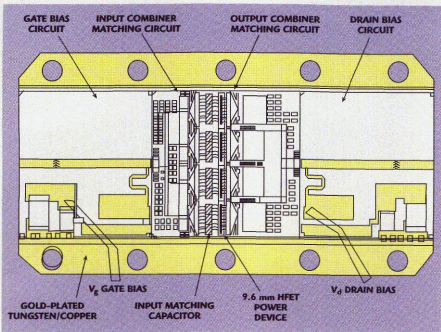
With a simple phone call, you can choose from more than 800 accessories—from switches to amplifiers to attenuators and more, including the **NEW HP 87222C transfer switch**. All offer lower cost of ownership by providing superior performance over millions of cycles, and our QuickShip program puts them in your hands fast. We can even connect you to an HP engineer who can answer technical questions you have.

So the next time you consider "borrowing" an accessory, try a faster plan of attack: pick up the phone and call HP DIRECT at one of the numbers listed below.

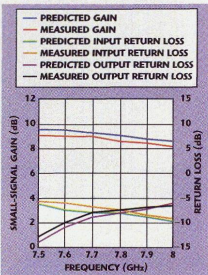
www.hp.com/go/mta



Australia 1-800-629-485 • Austria (01) 25009-7171 • Belgium (32/2) 778 3417 • Brazil (55-11) 7297-8600 • Canada 1-877-894-4414
China (36-10) 6564-3888, 800-810-0180 • Czech Republic 420 2 61307458 • Denmark 45 99-15-15 • Finland 358-9-8872 2100 • France 01 69 29 41 14
Germany (0180) 524-63 33 • Greece 01 726 40 26 • India (91/11) 6906156 • Ireland 01 615 8222 • Israel 03 53 80 377 • Italy 39 02 9212 2241
Japan 81-426-56-7832 • Korea (82-2) 769-0800 • Malaysia 1-800-88-8848, (6-03) 291-0213 • Mexico (55-5) 258-4392 • Netherlands 020-547 6869
New Zealand 0800-738-378 • Norway 47 2273 5759 • Philippines (63-2) 814-1083 • Poland 48-22-7230086 • Singapore 1800 375 8100
South Africa 27 11 806 1000 • Spain 34 91 631 13 23 • Sweden (86) 444 2277 • Switzerland (052) 011 735 72 00 • Switzerland (FR) (022) 780 4361
Taiwan (886-2) 212-6355, (886-4) 47866 press 1 • Thailand 661-3999, (088) 225-802 • United Kingdom 01344-366666



▲ Fig. 12 The 9.6 mm HFET power amplifier's circuit layout.

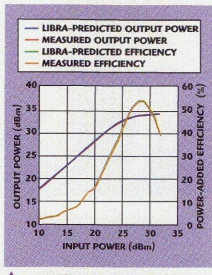


▲ Fig. 13 The 4.8 mm HFET amplifier's LIBRA-predicted and measured small-signal gain and return loss.

finely machined ribs onto which the 9.6 mm HFET devices and lumped matching capacitors were soldered. The positions of the machined ribs were calculated in order to realize the lumped-element inductor values for the input and output matching circuits.

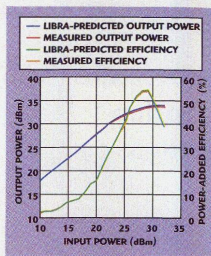
AMPLIFIER MEASUREMENTS

The measured and predicted small-signal performance of the 4.8 mm HFET amplifier is shown in **Figure 13**. The amplifiers were biased in class AB mode of operation at the $V_{ds} = 8$ V and $I_{ds} = 0.25 I_{dss}$ quiescent

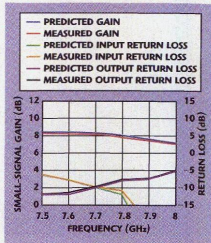


▲ Fig. 14 The 4.8 mm HFET amplifier's measured and LIBRA-predicted output power and power-added efficiency at 7.5 GHz.

operating point to achieve optimum power-added efficiency performance. The measured and predicted output power and efficiency performance at 7.5 and 8.0 GHz are shown in **Figures 14** and **15**. An output power of 34 dBm (2.5 W) at 1 dB gain compression with 53 percent power-added efficiency has been achieved. The measured and predicted small-signal performance of the 9.6 mm HFET amplifier is shown in **Figure 16**. The measured and predicted output power and efficiency performance at 7.5 and 8.0 GHz is shown in **Figures 17** and

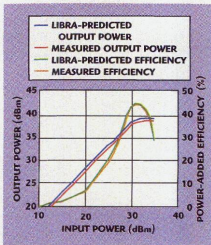


▲ Fig. 15 The 4.8 mm HFET amplifier's measured and LIBRA-predicted output power and power-added efficiency at 8.0 GHz.



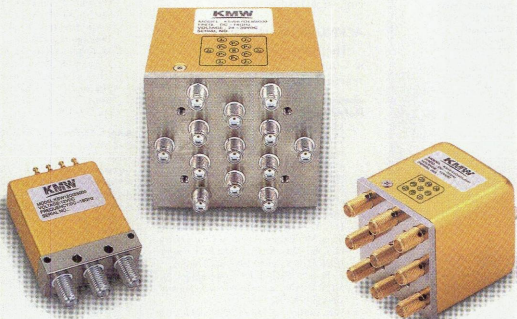
▲ Fig. 16 The 9.6 mm HFET amplifier's measured and LIBRA-predicted small-signal gain and return loss.

Fig. 17 The 9.6 mm HFET amplifier's measured and LIBRA-predicted output power and power-added efficiency at 7.5 GHz. ▼



[Continued on page 124]

Designed for Ultimate Quality



Your Complete Switching Solution from KMW

KMW new 6P7T switch is designed for W-CDMA IMT2000.

Product Code No.	KSW12012S000	KSW67042L000	KSW45042L000
Switch Type	SPDT	6P7T	4PST
Frequency Range	DC - 3GHz	DC - 3GHz	DC - 3GHz
Insertion Loss (max.)	0.2dB	0.2dB	0.2dB
VSWR (max.)	1.15 : 1	1.15 : 1	1.15 : 1
Isolation (min.)	80dB	80dB	80dB
Operating Mode	Latching	Latching	Latching
Actuating Voltage / Current (max.)	12Vdc \pm 10% /240mA (@ 12Vdc, 25°C)	12Vdc \pm 10% /165mA (@ 12Vdc, 25°C)	12Vdc \pm 10% /165mA (@ 12Vdc, 25°C)
I/O Port Connector	SMA(F) / SMA(F)	SMA(F) / SMA(F)	SMA(F) / SMA(F)
RF Power Handling	100W CW (@ 1GHz)	250W CW (@ 1GHz)	250W CW (@ 1GHz)
Dimension (inch)	1.339*1.575*0.528	2.441*2.177*2.165	1.626*1.874*1.626

Higher Frequency available, up to 18GHz

Power Handling Capability, up to 250W CW & 4KW Peak @ 1GHz

Available Options

Internal Termination, Indicator Circuitry, Suppression Diode, TTL Logic, Self De-Energizing Circuit, Various I/O Connector type, other Operating Voltage

5 million life cycle SPDT switch available upon request.

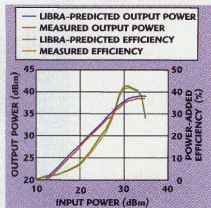


13131 East 166th Street, Cerritos, CA 90703-2202
1-800-8320-KMW • www.kmwinc.com
tel: 562-926-2033 • fax: 562-926-6133

CIRCLE 77 ON READER SERVICE CARD

KMW
RF & Microwave Products

TECHNICAL FEATURE



▲ Fig. 18 The 9.6 mm HFET amplifier's measured and LIBRA-predicted output power and power-added efficiency at 8.0 GHz.

18. An output power of 39 dBm at 1 dB gain compression with 42 percent power-added efficiency has been achieved.

CONCLUSION

In this article the design of high efficiency power amplifiers has been investigated using CAD techniques. The designs were conducted using state-of-the-art HFET devices and the technique of scaling was employed to permit the 2.4 mm unit cell HFET device to represent the 4.8 and 9.6 mm gate width HFETs. The 4.8 mm HFET amplifier achieved a power-added efficiency of 53 percent; the amplifier employing the 9.6 mm HFET achieved a power-added efficiency of 42 percent. Excellent correlation has been achieved between

predicted and measured small- and large-signal performance.

ACKNOWLEDGMENT

The authors wish to thank Filtronic Components Ltd. for its permission to publish these results. ■

References

1. M.K. Kozmierzczuk, "A New Concept of Class F Tuned Power Amplifier," *Proceedings of the Midwest Circuits and Systems Symposium (MCASS)*, June 1984, pp. 18-14.
2. S.C. Cripps, "A Theory For the Prediction of GaAs FET Load Pull Power Contours," *IEEE MTT-S Digest*, 1983, pp. 221-223.
3. D.E. Peck and D.F. Peterson, "A Measurement Method for Accurate Characterisation and Modelling of MESFET Chips," *IEEE MTT-S Digest*, 1981, pp. 310-312.
4. L. Besser, "Skillfull De-Embedding," *Applied Microwave and Wireless Journal*, 1994, pp. 86-94.
5. W.R. Curtice, "A MESFET Model for Use in the Design of GaAs Integrated Circuits," *IEEE Transactions on Microwave Theory and Techniques*, Vol. MTT-33, May 1980, pp. 448-456.
6. W.R. Curtice and M. Ettenberg, "A Non-linear GaAs FET Model for Use in the Design of Output Circuits for Power Amplifiers," *IEEE Transactions on Microwave Theory and Techniques*, Vol. MTT-33, December 1985, pp. 1383-1394.
7. H.P. Statz, I. Newman, W. Smith, R.A. Pucel and H.A. Haus, "GaAs FET Device and Circuit Simulation in SPICE," *IEEE Transactions on Electron Devices*, Vol. ED-34, February 1987, pp. 160-169.
8. A.J. McCamant, G.D. McCormack and D.H. Smith, "An Improved GaAs MESFET Model for SPICE," *IEEE Transactions on Microwave Theory and Techniques*, Vol. MTT-38, June 1990, pp. 822-824.

9. C.J. Wei, Y.A. Tkachenko and J.C.M. Hwang, "Noninvasive Waveform Probing for Nonlinear Network Analysis," *Microwave Journal*, Vol. 37, No. 2, February 1994, pp. 122-126.

10. M. Kohno, T. Fujioka, K. Hayashi, Y. Itoh, Y. Ikeda, K. Seino and M. Yamanouchi, "High Efficient C-band 27 Watt Internally Matched GaAs FET For Space Applications," *IEEE MTT-S Digest*, 1994, pp. 273-276.

Avtar S. Virdee received his BSc (Hons) degree in electrical engineering from the University of Leeds, UK and his MSc degree from the University of Cranfield, UK. His previous work experience includes two years with British Aerospace designing LNAs for spacecraft applications, six years with Plessey Microwave designing solid-state amplifiers for radar systems and four years with Electronics UK Ltd. designing broadband amplifiers for EW systems. Currently, he is an R&D technical specialist in the field of solid-state amplifiers at Filtronic Components Ltd. Virdee's research interests are in the area of efficiency improvements of broadband solid-state power amplifiers.

Bal S. Virdee received his BSc (Hons) and MPhil degrees in electronic engineering from the University of Leeds, UK and his PhD in electronic engineering from the University of London, UK. He worked for Philips, Cambridge, UK, as a research and development engineer specializing in communication systems and at Leeds Metropolitan University and the Open University as a lecturer before he joined the University of North London. He was subsequently promoted to a senior lecturer position and now leads the Microwave Research Group. Virdee has developed and run professional short courses on microwave components and techniques, microwave communications systems and DRO design. He has also chaired technical sessions at the 1996 and 1998 Asia-Pacific Microwave Conference, New Delhi, India, and Yokohama, Japan, respectively.

COMMUNICATIONS ANTENNAS

SEAVEY ENGINEERING offers: 51,000 Sq. Ft. Manufacturing Facility

- Manufacturing
- Design/Development
- Antenna Testing Services
- Currently Ship 5,000 Antennas/Month
- CAD/CAM
- Manufacturing Engineering
- J.I.T. Delivery
- Fabrication & Machining
- CNC Machine Centers
- Helicarc Welding
- Waveguide Bending

Testing Facilities:

- 100-4500 Ft. Outdoor Test Range
- Two Indoor Anechoic Test Chambers

MANUFACTURING & DEVELOPMENT

Contact us for your antenna manufacturing requirements.

SEAVEY ENGINEERING ASSOCIATES, INC.

28 Riverside Drive, Pembroke MA 02359

E-Mail: info@seaveyantenna.com • Web Site: http://www.seaveyantenna.com • Phone (781) 829-4740 • FAX (781) 829-4590



ULTRAFAST WIDEBAND MICROWAVE LOGARITHMIC AMPLIFIERS

FEATURES

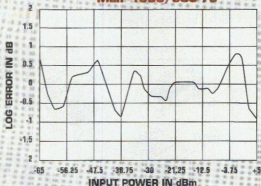
- Fast Recovery Time
- Low Output Noise for Increased Accuracy
- Improved Sensitivity Through Low Noise Figure Input Stages
- Custom Electrical Performance Available



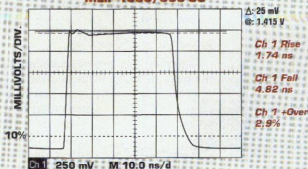
ELECTRICAL SPECIFICATIONS

Model Number	Center Frequency (MHz)	Operational Bandwidth (MHz, Min.)	Dynamic Range (dB, Min.)	TSS (dBm, Max.)	Log Linearity (\pm dB, Max.)	Video Flatness (\pm dB, Max.)	Rise Time (ns, Max.)	Recovery Time (ns, Max.)
MLIF-500/100-70	500	100	-70 to 0	-74	1	1.0	5	23
MLIF-750/500-60	750	500	-60 to 0	-67	1	1.5	2	12
MLIF-1000/300-60	1000	300	-60 to 0	-68	1	0.75	2	12
MLIF-1000/500-70	1000	500	-65 to +5	-72	1	2.0	5	25
MLIF-1500/500-60	1500	500	-60 to 0	-66	1	1.0	1.7	12
MLIF-1575/200-50	1575	200	-45 to +5	-53	1	1.0	1.5	10

LOG LINEARITY
MLIF-1000/500-70



PULSE RESPONSE
MLIF-1000/300-60



For additional information, please contact Boris Bengier
at (516) 439-9402 or e-mail bbenger@miteq.com.



100 Davids Drive • Hauppauge, NY 11788
TEL.: (516) 436-7400 • FAX: (516) 436-7430
www.miteq.com

IMPEDANCE MEASUREMENTS FOR HIGH POWER RF TRANSISTORS USING THE TRL METHOD

Impedance measurements on high power RF transistors are always a problem because of the very low values and lead widths and because the devices may be in a push-pull configuration. Calibration kits to measure wide or balanced microstrip lines are difficult to build and provide poor accuracy. This article describes a way to accurately characterize high power RF transistors, even with wide leads and in a single-ended or push-pull configuration. The impedances of the transistor or the S parameters of the input and output test fixture are obtained using the thru-reflect-line (TRL) calibration technique in order to perform de-embedding or load-pull measurements. Different options of calculation are presented.

METHOD DESCRIPTION

Generally, high power transistor characterization consists of a measurement of the optimum source and load presented to the transistor by a given test fixture. This test fixture can be tuned at each individual frequency for best performance, or included in a load-pull bench as an impedance transformer. In all cases, the impedance of the test fixture (S_{22} of the input matching network and S_{11} of the output

matching network) must be measured. In the case of a load-pull, all other S_{ij} parameters must be determined in order to perform de-embedding. To determine the S parameters, a break-apart test fixture is used and included in a calibration routine with a vector network analyzer (VNA), as shown in **Figures 1** and **2**.

If a TRL calibration is performed instead of a short-open-load-thru (SOLT) procedure, the only standard needed is a delay line. In this case, if the delay line is designed so that it has the same width as the transistor leads, the measurement will be accurate because width transitions are avoided, as well as coaxial-to-microstrip transitions, and the measurement system will be normalized to the impedance of the delay line, which will be lower than $50\ \Omega$ if

Fig. 1 The break-apart test fixture.

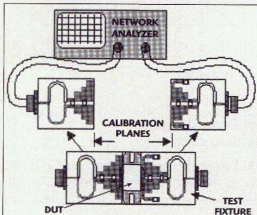
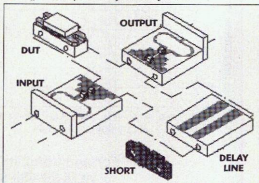


Fig. 2 Components of the test fixture.



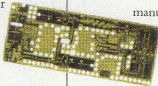
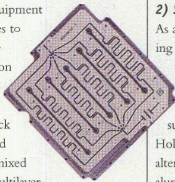
[Continued on page 128]

JEAN-JACQUES BOUNY
Motorola Semiconducteurs S.A.
Toulouse, France

We can't think of *one* single reason why we should be your microwave circuit manufacturer.

Actually, there are several reasons why you'd want to trust Filtran to produce reliable microcircuits for high-end applications like aerospace, air traffic control, satellite, automotive, and PCS—up to 100 GHz.

As a leader in our field since 1983, we've developed our own equipment and processes to manufacture truly precision microstrip, bonded stripline, thick metal-backed PTFE and mixed dielectric multilayer circuits. Take a closer look at Filtran's many superior manufacturing capabilities, and you'll see why we're the manufacturer of choice for microwave circuit designers worldwide:



1) Precision Photolithography

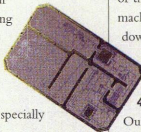
The accuracy of our circuit board imaging (1 mil lines and spaces, ± 2 mil) approaches semiconductor grade resolution through specially developed processes.

2) Sputtering Metallization

As a leader in the vacuum sputtering industry with several patents, we can sputter-deposit thin films, including resistors, onto a variety of hard and soft substrates. Our Sputtered Blind Hole process offers a superior alternative to chemical PTH on aluminum-backed PTFE substrates.

3) Accurate, On-site Machining Capabilities

Filtran maintains complete on-site manual and computer-aided machining facilities to accurately



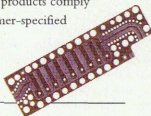
punch, rout or mill thin substrates or thick metal backings with machining tolerances: $\pm .005$ ", down to $\pm .001$ ". We also have a close association with a local laser machining facility.

4) Proprietary Sodium Etchant

Our Sodium Etchant formulation for PTH and edge plating gives us tight control of processing, resulting in reliable, high-performance circuits and excellent adhesion of copper to PTFE.

5) Strict Quality Assurance

Our stringent program of in-process inspection results in high yields on the most complex circuits. We strictly monitor all production processes, and our upfront engineering, SPC and final inspection all help to ensure that products comply with customer-specified standards.



For more information, or to get a quote, contact us today:



FILTRAN
Microcircuits Inc.

CIRCLE 43 ON READER SERVICE CARD

www.filtranmicro.com

TECHNICAL FEATURE

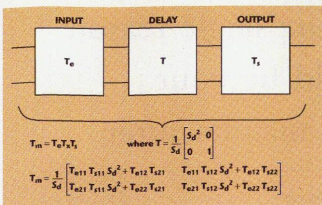
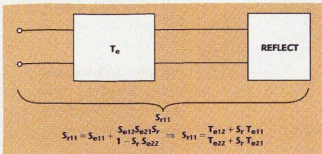


Fig. 3 The T_m measurement.

Fig. 4 The S_r measurement.



the line is wide. In the case of a push-pull configuration, the delay line design is accomplished by printing two symmetric lines, making the impedance of the delay two-times the impedance of a single line. When the three measurements of the TRL calibration are completed, it is possible to calculate the error matrix corresponding to the input and output matching networks.

IMPEDANCE CALCULATION

To calculate the parameters of the error matrix, T parameters, which are cascable, are used instead of S parameters. Translation between S and T parameters is described in **Appendix A**. T_m is measured, as shown in **Figure 3**, with the delay and thru to obtain T_{dij} (delay) and T_{tij} (thru) with $S_d = S_{21} = S_{12}$ of the delay line (equal to 1 in the case of the thru).

S_{ij} is subsequently measured, as shown in **Figure 4**, where S_r is a reflecting termination (an open or short circuit). Ten relationships now exist to calculate the values of T_{ej} and T_{sj} (T parameters of the input and output test fixture, respectively) as a function of T_{dij} , T_{tij} , S_{rij} , S_r and S_d . After some mathematical calculations (detailed in **Appendix B**), formulas are obtained where S_{s11} and S_{s22} are fully determined if S_d and S_r are presumed to be known. Note that S_d and S_r also could be calculated, however, some unknowns must be determined. For simplicity, suppose that S_d has been measured or simulated and that S_r is known (+1 for an open, or -1 for a short).

CALCULATION RESULTS

S_r and S_d now can be replaced by their values and S_{e11} , S_{e22} , S_{s11} and S_{s22} can be obtained as functions of S_{rij} , T_{dij} and T_{tij} . $S_{e12}S_{e21}$ can be extracted from the S-parameter form of Equation A9, and the crossed term $S_{s21}S_{s21}$ can be extracted from Equation A18 knowing that it is

equal to $1/T_{e22}T_{s22}$. If the input and output test fixtures are assumed reciprocal, $S_{e12} = S_{e21}$ and $S_{s12} = S_{s21}$ can be calculated as the square root of their respective products. T parameters then can be replaced by their S-parameter equivalents and the following S-parameter impedances can be obtained:

Input:

$$S_{e11} = \frac{S_{d11}S_{t21} - S_{d12}S_{t21}}{S_{t21} - S_dS_{d21}}$$

$$S_{e22} = \frac{(S_{d11}S_{t21} - S_dS_{t11}S_{d21}) - S_{r11}(S_{t21} - S_dS_{t21})}{(S_dS_{d11}S_{t21} - S_{t11}S_{d21}) - S_{r11}(S_dS_{t21} - S_{d21})}$$

$$\bullet \frac{S_dS_{t21} - S_{d21}}{S_{t21} - S_dS_{d21}}$$

$$S_{e12}S_{e21} = S_{r11}(1 - S_{e22}) - S_{e11}$$

Output:

$$S_{s11} = \frac{(S_{d22}S_{t21} - S_dS_{t22}S_{d21}) - S_{r22}(S_{t21} - S_dS_{d21})}{(S_dS_{d22}S_{t21} - S_{t22}S_{d21}) - S_{r22}(S_dS_{t21} - S_{d21})}$$

$$\bullet \frac{S_dS_{t21} - S_{d21}}{S_{t21} - S_dS_{d21}}$$

$$S_{s22} = \frac{S_{d22}S_{t21} - S_dS_{t22}S_{d21}}{S_{t21} - S_dS_{d21}}$$

$$S_{s12}S_{s21} = S_{r22}(1 - S_{s11}) - S_{s22}$$

Crossed:

$$S_{e12}S_{s12} = S_{e21}S_{s21}$$

$$= \frac{1 - S_d^2}{S_d} \bullet \frac{S_{d21}S_{t21}}{S_{t21} - S_dS_{d21}}$$

In this case, S_r is supposed to be an open; in the case of a short, the sign of S_{e22} and S_{s11} is opposite. Z_{in}^* and Z_{out}^* are given by

$$Z_{in}^* = Z_0 \bullet \frac{1 + S_{e22}}{1 - S_{e22}}$$


$$Z_{out}^* = Z_0 \bullet \frac{1 + S_{s11}}{1 - S_{s11}}$$

where Z_0 is the normalization impedance of the system — the impedance of the delay line. It should be noted that the delay must be different from the thru (indeterminable if the delay is 0° or 180°), which means that the best case is when the delay is 90°. However, in a practical case, a delay line between 30° and 150° provides good accuracy.

PRACTICAL USE

Practical measurements are quite simple to implement, however, special attention must be paid to several points. First, when assembling the break-apart test fixture, the continuity of the ground must be very good. Second, if a quarter-wave delay line is used, it will transform the impe-

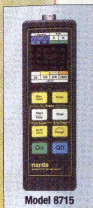
[Continued on page 130]



Our precise
new spatial
averaging meter
is so easy to use,
practically
anybody can
do it.

Just touch the ground with the probe. Press the meter's start/stop key. Slowly move the probe from toe to head. Press the key again. That's it.

And for those four baby steps, you instantly get an incredibly precise, spatially-averaged measurement based on about 400 separate readings. Now you know with certainty if you're within threshold limits.



Put this powerful microprocessing ability to work for you. You'll have the precision you need to successfully deal with the increasingly complex signal environments created by the exploding wireless industry.

Our new meter also babys you with other great features. Like a bright seven-segment numeric display. Analog bar graph. An audio alarm that

sounds if input exceeds the probe's measurement range. And a variable alarm that can be set to sound at any level.

How close are other meters to offering you all these advantages?

They're still in diapers.

Call Narda today at 516-231-1700.



© 1999 L-3 Communications, Inc.
www.nardam Microwave.com

narda
microwave-east

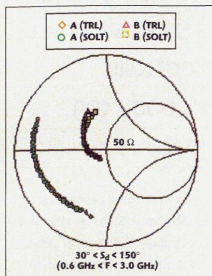
an  communications company

It's Narda to be precise.

CIRCLE 136 ON READER SERVICE CARD

TECHNICAL FEATURE

dance seen on one side (very low) to a very high impedance on the other side, and the transmitted signal will be very low. A lot of noise will be added on the measurements, and the obtained results may be unusable.



▲ Fig. 5 SOLT and TRL measurements of the first two passive networks.

Fig. 6 Difference between the real impedance presented to the device and that measured with a standard technique. ▼

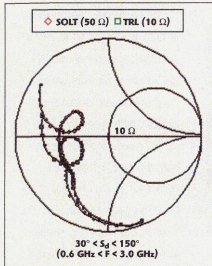


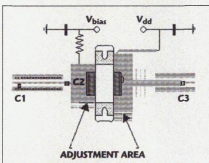
TABLE I

MRF18060 IMPEDANCES

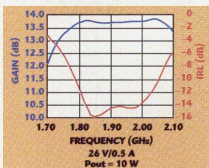
Frequency (GHz)	Z_{in} (Ω)	Z_{out} (Ω)
1.70	$0.60 + j2.53$	$2.27 + j3.44$
1.80	$0.80 + j3.20$	$2.05 + j3.05$
1.90	$0.92 + j3.42$	$1.90 + j2.90$
2.00	$1.07 + j3.59$	$1.64 + j2.88$
2.10	$1.31 + j4.00$	$1.29 + j2.99$

METHOD VERIFICATION

Two passive networks have been measured with a standard SOLT calibration and connector and with a



▲ Fig. 7 The optimized amplifier.



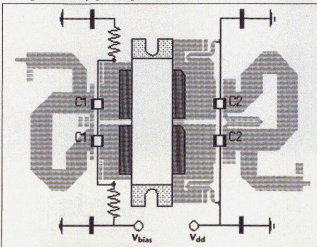
▲ Fig. 8 The amplifier's gain and IRL vs. frequency at 10 W.

TABLE II

MRF21120 IMPEDANCES

Frequency (GHz)	Z_{in} (Ω)	Z_{out} (Ω)
2.05	$2.90 + j11.82$	$6.03 + j6.38$
2.11	$2.35 + j11.42$	$5.15 + j6.70$
2.17	$2.05 + j10.80$	$4.34 + j6.69$
2.23	$1.98 + j10.53$	$3.98 + j6.61$

▼ Fig. 9 The amplifier's layout.



TRL calibration and a 50 Ω delay line. Figure 5 shows the results obtained between 0.6 and 3 GHz, which confirm that the method is valid over more than two octaves for a single delay line. Note also that even with a 50 Ω delay line, some differences exist as a result of the coaxial-to-microstrip transition.

A second set of measurements has been completed with a wide delay line (10 Ω). As shown in Figure 6, there is a big difference between the real impedance presented to the device and the one measured with a standard technique.

A DESIGN EXAMPLE

An amplifier was designed using this technique with a Motorola model MRF18060 60 W/1.8 GHz/26 V transistor. Impedances measured for 65 W and 13 dB gain at 1 dB compression are listed in Table 1. A drawing of the optimized amplifier is shown in Figure 7, where $C1 = 1.8$ pF, $C2 = 1$ pF and $C3 = 10$ pF. When the amplifier was assembled without any tuning, the results were 64 W, 12.2 dB gain and 47 percent efficiency at 1 dB compression. After adding adjustment areas at the input and output, the results became 66 W/12.7 dB gain/48.8 percent efficiency at 1.8 GHz, 67 W/12.7 dB gain/47.8 percent efficiency at 1.9 GHz and 67 W/12.8 dB gain/48.3 percent efficiency at 2.0 GHz. Gain and input return loss (IRL) are shown in Figure 8.

A SECOND EXAMPLE

Another amplifier was built using a Motorola model MRF21120 120 W/2.1 GHz/26 V push-pull transistor. Table 2 lists the measured impedances for 120 W/12.1 dB gain at 1 dB compression. The amplifier is shown in Figure 9, where $C1 = 1.8$ pF and $C2 = 4.7$ pF. Before any tuning, the measurement results were 113 W, 11.6 dB gain and 45 percent efficiency at 1 dB compression. After a slight adjustment of the position of $C1$ and $C2$ (up and down), the results were 121

[Continued on page 132]



INNOVATIVE COUPLERS

.smaller size .better performance .lower cost

5 to 1000MHz from **\$6⁹⁵**
(10-49)



Monitor, measure, and take control of signal levels with these super flat, exceptionally broadband ADC directional couplers. Excellent for use with cable TV and VHF/UHF communication technologies in the 5MHz to 1000MHz band, these ADC's really deliver by providing a vast selection of coupling values for 50 and 75 ohm systems plus high directivity, power input capability up to 1W, and very low SWR over the entire frequency range. Built with Mini-Circuits unique "Innovative Technology", they're the only surface mount couplers incorporating an ultra-slim 0.108" patent pending package, better performance, and an awesome price that allows you to tap the signal without tapping out your budget! If high quality and value price are your priorities...ADC is **it**™

ADC* SPECIFICATIONS:

Model	Freq. (MHz)	Coupling (dB)		Mainline Loss (Midband Typ. dB)	Directivity (dB)	VSWR Typ. (1)	Price (Box.) Qty. 10-49
		Norm.	Max. Flat				
ADC-6-1R	5-200	6.2±0.3	±0.3	1.7	25	1.33	7.95
ADC-10-1R	5-400	10.5±0.5	±0.5	0.8	30	1.3	7.95
ADC-10-4	5-1000	10.5±0.5	±0.75	0.8	40	1.20	8.95
ADC-15-4	5-1000	15.5±0.5	±0.5	0.6	24	1.20	6.95
ADC-20-4	5-1000	20.0±0.5	±0.8	0.5	21	1.1	6.95
ADC-6-10-75	20-1000	6.6±0.5	±0.5	2.1	15	1.3	6.95
ADC-8-4-75	5-1000	7.9±0.5	±0.5	1.60	17	1.20	6.95
ADC-10-4-75	5-1000	10.5±0.5	±0.5	0.9	18	1.20	6.95
ADC-12-4-75	20-1000	12.6±0.5	±0.5	0.9	23	1.2	6.95
ADC-15-4-75	5-1000	15.5±0.5	±0.5	0.7	20	1.20	6.95
ADC-16-4-75	5-1000	16.2±0.5	±0.5	0.7	30	1.15	6.95
ADC-18-4-75	20-1000	17.4±0.5	±0.5	0.4	18	1.15	6.95
ADC-20-4-75	5-1000	19.7±0.5	±0.5	0.5	23	1.15	6.95

Max. power input is 1W except ADC-6-1R and ADC-6-10-75, which are 0.5W.
Models with R suffix are equipped with internal resistor.

*Package and Circuit Patent Pending.

ADC Couplers...Innovations Without Traditional Limitations!



P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661 **INTERNET** <http://www.minicircuits.com>
For quick access to product information see MINI-CIRCUITS CATALOG & WEB SITE • EEM • MICROWAVE PRODUCT DATA DIRECTORY • WWW.RFGLOBAL.NET

ISO 9001 CERTIFIED

F 272 Rev. C

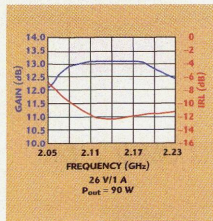
TECHNICAL FEATURE

W/12.1 dB gain/47.6 percent efficiency at 2.11 GHz and 118 W/12.1 dB gain/46.6 percent efficiency at 2.17 GHz. Gain and IRL are shown in **Figure 10**. As in the previous example, results are very similar to those obtained when measuring the impedances in a narrow band, which demonstrates that the method is valid and accurate.

For designers with access to a VNA with TRL calibration capability, an alternative solution consists of using the internal calibration routine of the VNA and extracting the error parameters corresponding to S_{eij} and S_{sij} . In this case, the calibration can be verified by measuring the thru.

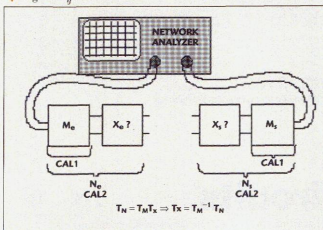
A NONINSERTABLE QUADRIPOLE

When a de-embedding solution is required, all parameters can be calculated with the presented method. However, a first calibration must be completed in the connector plane before the measurements are per-



▲ Fig. 10 The amplifier's gain and IRL vs. frequency at 90 W.

▼ Fig. 11 X_{ij} determination.



formed. The VNA routine also may be used and two successive calibrations performed: one in the connector plane (cal 1, error matrix M), and a second one (TRL) including the test fixture (cal 2, error matrix N). By using T parameters, the X_{ij} (S_{ij} parameters of the test fixture) may be calculated, as shown in **Figure 11**.

After some algebra, the input or output becomes

$$\begin{aligned} X_{11} &= \frac{N_{11} - M_{11}}{M_{22}N_{11} - \Delta M} \\ X_{12} &= \frac{M_{21}N_{12}}{M_{22}N_{11} - \Delta M} \\ X_{21} &= \frac{M_{12}N_{21}}{M_{22}N_{11} - \Delta M} \\ X_{22} &= \frac{M_{22}\Delta N - N_{22}\Delta M}{M_{22}N_{11} - \Delta M} \end{aligned}$$

In a calibration set, S_{12} and S_{21} of the different error matrices are not known independently; however, $X_{12}X_{21}$ can be calculated as a function of $M_{12}M_{21}$ and $N_{12}N_{21}$. If the quadri-pole is assumed reciprocal, that value is equal to X_{21}^2 and X_{12}^2 such that

$$\begin{aligned} X_{12} &= X_{21} \\ &= \pm \sqrt{\frac{(M_{12}M_{21}) \cdot (N_{12}N_{21})}{M_{22}N_{11} - \Delta M}} \end{aligned}$$

The sign then must be determined using an approximate value of X_{21} .

CONCLUSION

It has been shown that the TRL calibration technique can provide precise characterization of high power RF transistors, including impedances and board measurements for de-embedding. Examples show that this technique is much more accurate

than standard techniques using coaxial SOLT calibration because measurements are done without any coaxial-to-microstrip transition or width transition and can be performed in a low impedance system. The only calibration standard required to be built is a delay line that can be used over more

than two octaves. The use of the TRL method for impedance measurement allows the designer to build an optimized amplifier at the first pass, which drastically reduces the design's cost and cycle time. ■

APPENDIX A

S and T Parameters

$$\begin{aligned} \begin{pmatrix} b_1 \\ b_2 \end{pmatrix} &= [S] \cdot \begin{pmatrix} a_1 \\ a_2 \end{pmatrix} \\ \begin{pmatrix} b_1 \\ a_1 \end{pmatrix} &= [T] \cdot \begin{pmatrix} a_2 \\ b_2 \end{pmatrix} \end{aligned}$$

where

$$\begin{aligned} [S] &= \begin{pmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{pmatrix} \\ [T] &= \begin{pmatrix} T_{11} & T_{12} \\ T_{21} & T_{22} \end{pmatrix} \end{aligned}$$

Figure A1 shows the parameter orientations.

S to T Translation

$$[T] = \frac{1}{S_{21} - S_{22}} \begin{pmatrix} -\Delta S & S_{11} \\ 1 & 1 \end{pmatrix}$$

where

$$\Delta S = S_{11}S_{22} - S_{12}S_{21}$$

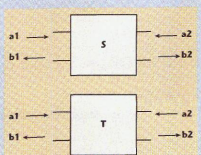
It should be noted that the expression for T_{11} as a function of S parameters is more complex than for T_{12} , T_{21} and T_{22} . For this reason, when there is a choice between two expressions, the one that does not contain T_{11} is chosen.

T to S Translation

$$[S] = \begin{pmatrix} \frac{T_{12}}{T_{22}} & \Delta T \\ \frac{1}{T_{22}} & -\frac{T_{21}}{T_{22}} \end{pmatrix}$$

where

$$\Delta T = T_{11}T_{22} - T_{12}T_{21}$$



▲ Fig. A1 S and T relationships.

[Continued on page 134]

5 W

MRF374

120W

INTRODUCING OUR 4TH GENERATION OF RF LDMOS

10x8

4x MRF374

4x MRF374

3300 WATTS

**SUPERIOR LINEARITY,
GAIN AND EFFICIENCY FROM MOTOROLA**

Device	Frequency	Operating Voltage	Output Power	Gain (Typ.)	Effic. (Typ.)	Package	Technology
MRF2120*	2170 MHz	28 Volts	120 Watts PEP	11.6 dB	36%	37SD/2	LDMOS
MRF2120S*	2170 MHz	28 Volts	120 Watts PEP	11.6 dB	36%	37SE/2	LDMOS
MRF19120*	1990 MHz	28 Volts	120 Watts PEP	11.5 dB	34%	37SD/2	LDMOS
MRF19120S*	1990 MHz	28 Volts	120 Watts PEP	11.5 dB	34%	37SE/2	LDMOS
MRF1800A*	1.8-2.0 GHz	26 Volts	90 Watts	12 dB	48%	36SD/1	LDMOS
MRF1800B*	1.8-2.0 GHz	26 Volts	90 Watts	12 dB	48%	36SE/1	LDMOS
MRF372*	470-860 MHz	28 Volts	180 Watts	14.5 dB	55%	37SD/2	LDMOS
MRF373	470-860 MHz	28 Volts	60 Watts	14.7 dB	55%	36SD/1	LDMOS
MRF373S	470-860 MHz	28 Volts	60 Watts	14.7 dB	55%	36SE/1	LDMOS
MRF374	470-860 MHz	28 Volts	100 Watts PEP	13.5 dB	36%	37SF/1	LDMOS
MRF1512T*	520 MHz	7.5 Volts	3 Watts	30.5 dB	55%	449T (P.D-1.5)	LDMOS
MRF1512T*	520 MHz	7.5 Volts	3 Watts	11 dB	55%	466T (P.D-1.5)	LDMOS
MRF1517T*	520 MHz	7.5 Volts	8 Watts	11 dB	55%	466T (P.D-1.5)	LDMOS
MRF1518T*	520 MHz	12.5 Volts	8 Watts	11 dB	55%	466T (P.D-1.5)	LDMOS
MRF166C*	500 MHz	28 Volts	20 Watts	16 dB	55%	318/3	MOSFET
MRF166W*	500 MHz	28 Volts	40 Watts	16 dB	55%	412/1	MOSFET
MRF141*	175 MHz	28 Volts	150 Watts	10 dB	45%	211/2	MOSFET
MRF141G*	175 MHz	28 Volts	300 Watts	14 dB	55%	375/2	MOSFET
MRF151*	175 MHz	50 Volts	150 Watts	13 dB	45%	211/2	MOSFET
MRF151G*	175 MHz	50 Volts	300 Watts	16 dB	55%	375/2	MOSFET
MRF171A*	150 MHz	28 Volts	45 Watts	19.5 dB	70%	211/2	MOSFET
MRF275L	500 MHz	28 Volts	100 Watts	8.8 dB	55%	333/2	MOSFET
MRF275S	500 MHz	28 Volts	150 Watts	11.2 dB	55%	375/2	MOSFET

*Internally Matched 4th Generation LDMOS

Device	Frequency	Operating Voltage	Output Power	Hybrid Gain (Typ.)	Chan. Load Capacity	Noise Figure Maximum	Package
MH-W7222A	750 MHz	24 Volts	+40 dBmV	22.3 dB	110	7.0 dB	714Y/1
MH-W8222B	860 MHz	24 Volts	+38 dBmV	22.7 dB	128	7.0 dB	714Y/1

DigitalDNA and the DigitalDNA logo are trademarks of Motorola, Inc.

As digital standards dominate wireless communications, Motorola technology dominates the marketplace. And Future Electronics sets the standards for worldwide distribution of the components you need.

Motorola RF LDMOS technology makes high power, high frequency amplifier designs simpler, easier and more cost effective. The enhanced Motorola RF portfolio combines world leadership in submicron VLSI MOS technology with high volume manufacturing. That means an even wider breadth of RF products, including discrete medium and high power devices, power modules and Class A, ultra-linear amplifiers...only from Motorola and Future Electronics.

Far more than a worldwide leader in electronic components distribution, Future Electronics provides leading edge e-commerce supply chain solutions, state-of-the-art design centers, and one of the largest technical support teams with qualified engineers around the world. With an advanced partner like Motorola, we enable you to be even more competitive for generations to come.



DigitalDNA™
from Motorola

THE HEART OF SMART.

For online data sheets and a free Motorola RF data package go to www.future.ca/motorolarf or call 1-888-680-5892



FUTURE ELECTRONICS

Microwave Journal Index on:



RFGlobalnet

www.rfglobalnet.com/mwindex.htm

Search an index
of all articles
published in
**Microwave
Journal**
since 1988.

Search
by author,
by technology,
by application,
by date,
or by keyword.

TECHNICAL FEATURE

APPENDIX B

Calculation Details

First, the 10 relations given by the measurements are

delay

$$S_d T_{d11} = T_{e11} T_{s11} S_d^2 + T_{e12} T_{s21} \quad (A1)$$

$$S_d T_{d12} = T_{e11} T_{s12} S_d^2 + T_{e12} T_{s22} \quad (A2)$$

$$S_d T_{d21} = T_{e21} T_{s11} S_d^2 + T_{e22} T_{s21} \quad (A3)$$

$$S_d T_{d22} = T_{e21} T_{s12} S_d^2 + T_{e22} T_{s22} \quad (A4)$$

thru

$$T_{t11} = T_{e11} T_{s11} + T_{e12} T_{s21} \quad (A5)$$

$$T_{t12} = T_{e11} T_{s12} + T_{e12} T_{s22} \quad (A6)$$

$$T_{t21} = T_{e21} T_{s11} + T_{e22} T_{s21} \quad (A7)$$

$$T_{t22} = T_{e21} T_{s12} + T_{e22} T_{s22} \quad (A8)$$

reflect

$$S_{r11} = \frac{T_{e12} + S_r T_{e11}}{T_{e22} + S_r T_{e21}} \quad (A9)$$

$$S_{r22} = \frac{-T_{e21} + S_r T_{t11}}{-T_{e22} + S_r T_{t12}} \quad (A10)$$

In addition, it is known that $S_{e22} = -T_{e21}/T_{e22}$ yields Z_{in}^* (conjugate of the transistor's input impedance), and $S_{d11} = +T_{s12}/T_{s22}$ produces Z_{out}^* .

Equations A11 to A20 are obtained by making some combinations between Equations A1 to A10 (for example, Equation A1 - Equation A5, Equation A1 - (S_d^2) Equation A5, Equation A2 - Equation A6, Equation A2 - (S_d^2) Equation A6, producing

$$S_d T_{d11} - T_{t11} = T_{e11} T_{s11} (S_d^2 - 1) \quad (A11)$$

$$S_d T_{d12} - T_{t12} = T_{e11} T_{s12} (S_d^2 - 1) \quad (A12)$$

$$S_d T_{d21} - T_{t21} = T_{e21} T_{s11} (S_d^2 - 1) \quad (A13)$$

$$S_d T_{d22} - T_{t22} = T_{e21} T_{s12} (S_d^2 - 1) \quad (A14)$$

$$S_d T_{d11} - S_d^2 T_{t11} = T_{e12} T_{s21} (1 - S_d^2) \quad (A15)$$

$$S_d T_{d12} - S_d^2 T_{t12} = T_{e12} T_{s22} (1 - S_d^2) \quad (A16)$$

$$S_d T_{d21} - S_d^2 T_{t21} = T_{e22} T_{s21} (1 - S_d^2) \quad (A17)$$

$$S_d T_{d22} - S_d^2 T_{t22} = T_{e22} T_{s22} (1 - S_d^2) \quad (A18)$$

$$S_{r11} \left(1 + S_r \frac{T_{e21}}{T_{e22}} \right) = \frac{T_{e12}}{T_{e22}} + S_r \frac{T_{e11}}{T_{e22}} \quad (A19)$$

$$S_{r22} \left(-1 + S_r \frac{T_{s12}}{T_{s22}} \right) = -\frac{T_{s21}}{T_{s22}} + S_r \frac{T_{t11}}{T_{s22}} \quad (A20)$$

Concerning the input, dividing Equation A15 by Equation A17 or Equation A16 by Equation A18, and Equation A11 by Equation A13 or Equation A12 by Equation A14

yields

$$\frac{T_{e12}}{T_{e22}} = \frac{T_{d11} - S_d T_{t11}}{T_{d21} - S_d T_{t21}} = \frac{T_{d12} - S_d T_{t12}}{T_{d22} - S_d T_{t22}} \quad (A21)$$

$$\Rightarrow \frac{T_{e11}}{T_{e22}} = \frac{S_d T_{d11} - T_{t11}}{S_d T_{d21} - T_{t21}} \cdot \frac{T_{e21}}{T_{e22}} = \frac{S_d T_{d12} - T_{t12}}{S_d T_{d22} - T_{t22}} \quad (A22)$$

Note that $S_{e11} = T_{e12}/T_{e22}$ is now calculated. These results are used in Equation A19 to obtain

$$S_r \frac{T_{e21}}{T_{e22}} \left(S_{r11} - \frac{S_d T_{d12} - T_{t12}}{S_d T_{d22} - T_{t22}} \right) = \frac{T_{d12} - S_d T_{t12}}{T_{d22} - S_d T_{t22}} - S_{r11} \quad (A23)$$

S_{e22} is now fully determined if it is assumed that S_d and S_r are known (same for S_{e11}). Applying the same method to the output yields

$$S_r \frac{T_{s12}}{T_{s22}} \left(S_{r22} - \frac{S_d T_{d21} - T_{t21}}{S_d T_{d22} - T_{t22}} \right) = \frac{T_{d21} - S_d T_{t21}}{T_{d22} - S_d T_{t22}} + S_{r22} \quad (A24)$$

where S_{d11} and S_{d22} are fully determined if S_d and S_r are known.

S_d Calculation

Equation A21 is used to extract S_d , and the second-order equation becomes

$$S_d^2 (T_{t11} T_{e22} - T_{t12} T_{e21}) + S_d \cdot (T_{d21} T_{t12} + T_{d12} T_{t21} - T_{d11} T_{t22} - T_{d22} T_{t11}) + (T_{d11} T_{d22} - T_{d12} T_{d21}) = 0$$

Only an indetermination remains to be solved (which root to choose) to obtain the value of S_d .

S_r Calculation

In fact, S_r will not be calculated, but a way to extract S_{e22} and S_{d11} without knowing it will be determined. By dividing Equation A23 by Equation A24 to obtain S_{e22}/S_{d11} (= A) and dividing Equation A14 by Equation A18 to obtain $S_{e22} \times S_{d11}$ (= B), S_{e22} and S_{d11} are now calculated as

$$S_{e22} = \pm \sqrt{AB} \quad S_{d11} = \pm \sqrt{\frac{A}{B}}$$

As before, the indetermination of the sign of the square root must be solved.

Repeatable Performance
Reduced Test Time
Low Return Loss
Long Life

PUSH-ONs

SMA & TNC & N & 7/16

The PUSH-ON Connectors and Connector Savers were developed to eliminate all the time consuming tightening, torquing and loosening of the connectors during test.

The PUSH-ON end slides directly onto any of the Standard female Connector of the same series, allowing quick and easy connection and disconnection.

You are not doing it the old-fashioned, time consuming way, do you?



Please ask for our other Products in the Frequency Range of DC to 50 GHz:

Adapters, ANA Test Cables, Antennas, Attenuators, Blind Mate Connectors, Circulators, CDM-Components, Coax Switches, Couplers, Custom Components, DC-Block Connectors & Adapters, Gain-Equalizers, Flexible Cable Assemblies, Isolators, Limiters, Mismatches, Multi Pin Connectors, Phase Shifters, Phase Stable Cable Assemblies, Precision Terminations, Push-On Connectors & Adapters, Semi Rigid Cable Assemblies, Waveguide Components, Waveguide to Coax Adapters, etc.



Spectrum
Elektrotechnik GmbH

80905 Munich, Germany

P.O. Box 45 05 33

Fax (89) 354-804-90

Telephone: (89) 354-804-0

push0996



ADAPTIVE FEEDFORWARD LINEARIZATION FOR RF POWER AMPLIFIERS

The design of RF power amplifiers has become increasingly complex. With modern radio communications systems focusing on ever-higher data rates and better spectral efficiencies, these challenges to amplifier design will continue. Modulation schemes such as multilevel linear quadrature amplitude modulation (QAM) increase spectral efficiency yet their

operating envelopes fluctuate, making this approach much more sensitive to the inherent nonlinear component of power amplifier behavior — the major source of nonlinear distortion in microwave transmitters. The traditional approach to the distortion problem is to back off the output power of a class A power amplifier until it

operates within a linear region and distortion is reduced to an acceptable level (that is, where average output power is much smaller than saturation power). Unfortunately, this course of action increases cost and reduces efficiency for amplifier design.

As supplementary stages are added to allow the amplifier to maintain transmitted power levels, more DC power is consumed. Further, with efficiency so critical for battery-operated systems and designs with limited enclosure space for heat dissipation, linearization of a

power-efficient class AB amplifier is a much more desirable alternative to backing off output power. Class AB power amplifiers provide approximately 25 percent efficiency and are more power efficient than class A amplifiers, which only attain approximately five percent efficiency. Class AB amplifiers also exhibit gain roll off at low input powers and at saturation.

The industry continues to embrace linear modulation techniques such as quadrature phase-shift keying (QPSK), 64-state QAM (64QAM) and multicarrier configurations. As this trend continues, active linearization of the power amplifier will remain a key technology for reducing nonlinear distortions. The transmitted signal from one of these modern linear modulation schemes may exhibit a fluctuating envelope, which generates intermodulation (IM) distortion in the power amplifier. Today's digital communication systems typically use very narrow channel spacing and require better distortion performance than analog systems. Since most of the IM power appears as interference in adjacent channels, it is critical that these systems utilize a highly linear power amplifier.

Unfortunately, power amplifiers are devices that exhibit both linear and nonlinear behavior, and these characteristics have a tendency to change over time due to repeated exposure to temperature changes, voltage variations,

[Continued on page 139]

"Adaptive feedforward linearization, while based on a concept developed many years ago, represents an optimized approach to solving the problem of IM distortion in multichannel, wideband applications."

SHAWN P. STAPLETON
Simon Fraser University,
School of Engineering Science
Burnaby, B.C., Canada

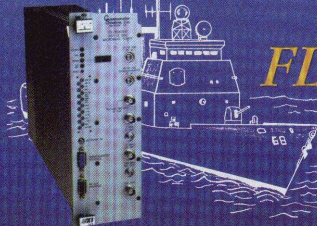
Does Your System

FLY...



CS-2000 VME
VHF/UHF Receiver

FLOAT...

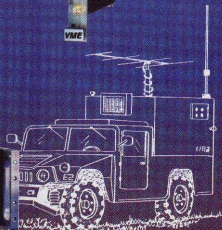


CS-5040 VXI
Microwave Tuner

or **ROLL?**



CS-5020C
Microwave Receiver



Then Look to COM-SOL for All Your Surveillance Equipment Requirements!

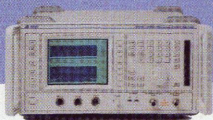
- Tuners and Receivers 5 kHz to 40 GHz
- Millimeter Wave Downconverters
- IF-to-Baseband Converters and Digitizers with Snap-Shot
- Custom Products - QRC Capability
- RF/IF Display Digitizers
- Demodulators and Multicouplers
- Up/Down Frequency Translators 20 MHz to 60 GHz
- Rack Mount, VXI, VME

**Communication
Solutions, Inc.**

(410) 574-4557 Fax (410) 574-4559 E-mail sales@comsol-inc.com

Visit our Web Site <http://www.comsol-inc.com> for the full COM-SOL Story and New Product Announcements

“I need to
test
microwave
sub-systems and
components.”



**You need the new IFR6840 series Microwave System Analyzer:
signal source, spectrum analyzer and scalar analyzer in one package.**

By combining the elements of a microwave test bench into a single unit, IFR has developed a unique product that allows more tests to be performed, faster and more precisely than ever before, including frequency conversion, gain compression and intermodulation.

Ideally suited to design and manufacturing applications, the 6840 series is available in a range of variants from 1 MHz to 24 GHz.

Tel: (316) 522-4981 • Toll Free: (800) 835-2352 • Fax: (316) 529-5575
info@ifrsys.com • www.ifrinternational.com

There's never been a single-instrument solution for testing RF and microwave components and subsystems - until now. To find out more, contact your local IFR office for more information.



microwave test • spectrum analyzers • signal generators • power meters
wireless communications test • ATE • avionics test • systems

test and measurement

CIRCLE 64 ON READER SERVICE CARD

channel changes and aging. Therefore, any robust linearization approach must incorporate the capacity for adaptability. Adaptive feedforward linearization represents just such an approach — one that has the distinct advantage of being able to handle wide bandwidths while continuously adjusting for component drift and power level changes.

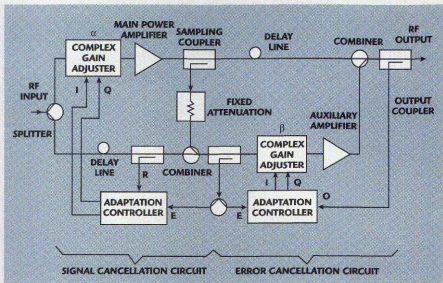
DESIGN CHALLENGES

Power amplifier nonlinearity is typically characterized by amplitude-dependent gain variation (AM/AM) and amplitude-dependent phase shift (AM/PM). However, in addition to nonlinearities, RF amplifiers also possess memory, that is, the output signal depends on the current value of the input signal as well as previous input values spanning the memory of the amplifier.

Other design constraints are the result of regulatory bodies, which specify power spectral density masks defining the maximum allowable adjacent-channel interference (ACI) levels. For example, **Figure 1** shows the application of a mask specified by the trans-European terrestrial trunked radio (TETRA) standard that uses a $\pi/4$ differential QPSK (DQPSK) modulation format with a symbol rate of 18 kHz and channel spacing of 25 kHz. A class AB power amplifier operating at a back-off power of 3 dB is shown superimposed on the mask to illustrate how the distorted output falls outside the specification.

FEEDFORWARD LINEARIZATION

The idea of using negative feedback for linearizing amplifiers is not



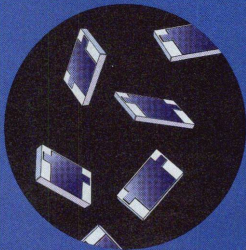
▲ Fig. 2 Key components of an adaptive feedforward linearizer.

new. First described in 1927 by H.S. Black of Bell Telephone Laboratories,¹ the concept of feedforward is simple. If the amplifier output is reduced to the same level as the input, the difference between the input and output is only the distortion generated by the amplifier. Further, if this resulting distortion is then amplified

using a different amplifier and subtracted from the original amplifier output, theoretically only a linear amplification of the input signal remains.

Figure 2 shows a schematic illustrating the key components of the feedforward linearizer circuit. Feed-

[Continued on page 141]



SPACE TESTED. SATELLITE APPROVED.

*It's a hard world up there.
What with shock vibrations. Continuous burn-in. Fungal invasions. It's a
wonder anything can survive.
So it's good to know that whatever the galaxies can dish out, we test our
attenuators to here on earth. Then send them up in spacecraft, just to make sure.
Think what all that reliability will mean to your wireless applications.*

EMC TECHNOLOGY LLC
Right Brain Components.
609-429-7800 www.emct.com



From Milliwatts to Megawatts

SPECIALIZED

Microwave Components

PRODUCT RANGE:

- TRAVELING WAVE TUBES
- MAGNETRONS
- PASSIVE COMPONENTS
- LOW NOISE AMPLIFIERS
- INTEGRATED MICROWAVE ASSEMBLIES
- COMPLETE FRONT ENDS

FOR:

- AVIONICS
 - DEFENSE
 - COMMUNICATIONS
 - MEDICAL
 - INDUSTRIAL
-
- CUSTOM DESIGN PRODUCT DEVELOPMENT
 - WORLD CLASS CUSTOMER & PRODUCT SUPPORT

Shopping for microwave products couldn't be easier. EEV is world renowned as **the** company with a wide range of components across the entire microwave spectrum. Now with the integration of solid-state activities EEV can offer even more innovative integrated solutions for your requirements.

USA: EEV, Inc.
Telephone: (914) 592-6050
Toll Free: 1800 DIAL EEV
Facsimile: (914) 682-8922
E-mail: info@eevinc.com

CANADA: EEV Canada Ltd.,
Telephone: (905) 678 9811
Facsimile: (905) 678 7726
E-mail: info@eevinc.com

UK: EEV Ltd.,
Telephone: +44 (0)1245 493493
Facsimile: +44 (0)1245 492492
E-mail: info@eev.com

www.eev.com

EEV

A SUBSIDIARY OF THE GENERAL ELECTRIC
CORPORATION PLC OF ENGLAND

CIRCLE 37 ON READER SERVICE CARD

forward linearization really utilizes two circuits: an input signal cancellation circuit and a distortion (or error) cancellation circuit. The incoming signal is split into two paths. The upper path, or signal-cancellation circuit, contains a complex gain adjuster and primary power amplifier. The signal-cancellation circuit's complex gain adjuster alters the amplitude and phase so that the input reference signal is cancelled from the primary power amplifier's output, leaving an error signal that contains both the linear and nonlinear components of the amplifier distortion.

The second path, or error-cancellation circuit, carries a replica of the primary output with the amplified signal plus distortion but with latency added to match the delay in the upper path. The distortion-only signal from the upper path is fed to the lower path. There the signal is amplitude and phase adjusted by a complex gain adjuster and combined with the delayed power amplifier's output, eliminating the distortion. The linear distortion component is due to deviations of the amplifier's frequency response from flat gain and linear phase.² Note that distortion from memory effects also can be compensated using the feedforward technique since these effects are included in the error signal.

Looking again at the diagram, the values for the sampling coupler and fixed attenuation should be chosen to match the gain of the primary amplifier. Variable attenuation is included in the circuit to enable the output level to be precisely adjusted to match the input reference, while the variable phase shifter adjusts the power amplifier output in an antiphase arrangement with the input reference. The delay line in the error-cancellation branch of the circuit is necessary for wide-bandwidth operation and compensates for the group delay of the primary amplifier by time aligning the power amplifier output and reference signals before they are combined. The error-cancellation circuit is used to suppress the distortion component of the power amplifier output, leaving only the linear-amplified component of its output signal. In order to suppress the distortion component of the signal, the gain of the power amplifier used

in the error-cancellation circuit must be carefully chosen to match the sum of the effects of the sampling coupler, fixed attenuator and output coupler. Thus, the error signal is amplified to approximately the same level as the distortion component in the power amplifier output signal.

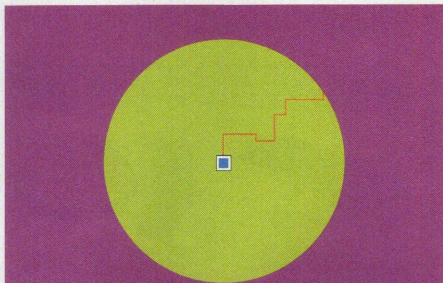
Since feedforward linearization is based on subtracting nearly equal quantities in the signal-cancellation loop, its major parameters must adapt to changes in the operating environment. In the mid-'80s and early '90s, many patents covering adaptive feedforward systems were filed. These patents encompass two general methods of adaptation, both with and without the use of pilot tones. The first is an adaptation based on power minimization;³ the second is an adaptation based on gradient signals.⁴

The control scheme for power minimization adaptation is based on trying to adjust the complex-vector modulator in the signal-cancellation circuit. Theoretically, this process minimizes the measured power of the error signal in the frequency band occupied by the

reference signal. The frequency range chosen for the error-cancellation circuit includes only the bands occupied by the distortion. Once the optimum parameters have been achieved, deliberate perturbations are required to continuously update the coefficients, which reduces the effects of IM distortion suppression.

Adaptive feedforward based on the use of gradient signals requires a continuous computation to estimate the gradient of a three-dimensional power surface. The surface for the signal-cancellation circuit consists of the power in the error signal. This power is minimized when the reference signal is completely suppressed, leaving only distortion. The surface for the error-cancellation circuit is the power in the linearizer-output signal, and the power is minimized when the distortion is completely suppressed from the primary power amplifier's output signal. Since the gradient is continually computed, no deliberate misadjustment is required.

(Continued on page 143)



COOLEST CHIP ON THE BOARD.

We've got the patent on the most heat-dissipating chip termination around. Asymmetrical wrap geometry means more solderable terminal area. And that leads to less thermal nasties and the need for heat sinks and tabs.

You can get production volumes of these cool babies in BeO and non-toxic AlN, on tape and reel, and in many sizes and configs.

EMC TECHNOLOGY LLC
Right Brain Components.
609-429-7800 www.emc.com





High Performance and Low Cost Electromagnetic Simulation and Optimization Tools

From: **Zeland Software, Inc.**, 39120 Argonaut Way, Suite 499, Fremont, CA 94538, U.S.A.,
Phone: 510-797-8109, Fax: 510-797-8241, E-mail: zeland@zeland.com, Web: <http://www.zeland.com>

Products:

IE3D Planar and 3D Electromagnetic Simulation and Optimization Package

FIDELITY Time-Domain FDTD Full 3D Electromagnetic Simulation Package

Applications:

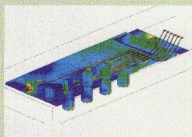
Microstrip, CPW, striplines, suspended-strip lines, coaxial lines, rectangular waveguides, high speed digital transmission lines, 3D interconnects, PCB, MCM, HTS circuits and filters, EMC/EMI, wire antennas, microstrip antennas, conical and cylindrical helix antennas, inverted-F antennas, antennas on finite ground planes, and other RF antennas.

Features:

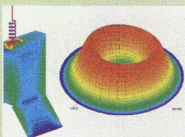
- MS-Windows graphic interface for interactive construction of geometry
- High efficiency and flexibility MOM and FDTD simulation engines
- Non-uniform automatic meshing and de-embedding
- Modeling 3D metallic and dielectric structures
- Built-in robust and efficient electromagnetic optimization
- Accurate modeling of metallic thickness, thin substrate and lossy dielectric materials
- Mixed electromagnetic simulation and nodal analysis for large scale simulation
- Cartesian and Smith Chart display of S-, Y- and Z-parameters, VSWR
- RLC parameter extraction compatible with SPICE
- 2D and 3D display of current distribution, radiation patterns and near field
- Calculation of antenna and scattering parameters including directivity, efficiency and RCS
- Current and near field animation

IE3D Simulation Examples and Display

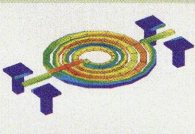
The current distribution on an AMKOR SuperBGA model at 1GHz created by the IE3D simulator



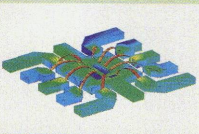
The current distribution and radiation pattern of a handset antenna modeled on IE3D



IE3D modeling of a circular spiral inductor with thick traces and vias

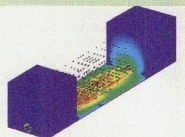


IE3D modeling of an IC Packaging with Leads and Wire Bonds

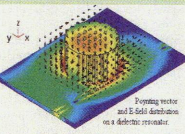


FIDELITY Examples

The near field and Poynting vector display on a packaged PCB structure with vias and connectors

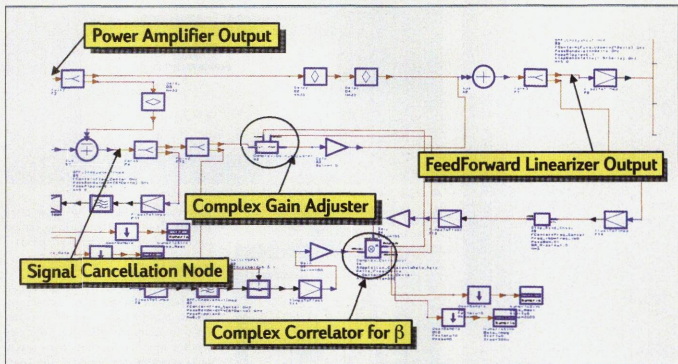


FIDELITY modeling of a cylindrical dielectric resonator and the Poynting vector display



Zeland Software, Inc. provides excellent technical support and services.

Zeland Software, Inc. is also the north American exclusive representative for the LINMIC product from Jansen Microwave GmbH



▲ Fig. 3 The feedforward error-cancellation loop based on the gradient-adaptation method created in HP ADS.

A GRADIENT ADAPTATION FEEDFORWARD LINEARIZER EXAMPLE

Figure 3 shows an example circuit schematic for the error-cancellation loop in a feedforward linearizer based on the gradient-adaptation method created by the Hewlett-Packard Advanced Design System (HP ADS). A rectangular implementation is used for the complex gain adjuster. The input is of a two-tone modulation with the following specifications: $K\alpha = -0.1$ adaptation rate and $K\beta = -0.01$ adaptation rate. A rectangular vector modulator is used, and the circuit operates at 5 dB back off from the 1 dB compression point. Ideal passive components are assumed.

When implementing this circuit, care must be taken in the choice of adaptation parameters. The best approach is to ensure that the signal-cancellation loop (α adaptation coefficient) has converged to within a small variance before the error-cancellation loop (β adaptation coefficient) begins to converge.

When gradient-based adaptation is used, delay must be added to the upper branch of the error-cancellation loop to ensure proper cancellation. If feasible, a bandstop filter may be incorporated after the output coupler to reduce the linear portion of the output signal. This configuration ef-

fectively speeds up the adaptation process. If the power minimization method is employed, then a bandpass

filter is used to sample the output IM distortion.

[Continued on page 144]

TAKE THE HEAT.

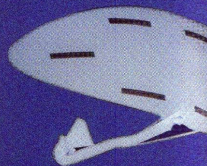
Between the four walls of this wafer-thin attenuator are near microscopic deposits of patented magic. Like climate control for your circuitry, the thick film-resistive technology in Thermopads® compensates for changing temperature and keeps power output flat.

EMC TECHNOLOGY LLC
Right Brain Components.
609-429-7800 www.emct.com

SPECIALTY ANTENNAS IS OUR MIDDLE NAME

Microwave Specialty Corporation

has been in the business of producing quality custom antennas for over 30 years. Our 50,000 square foot manufacturing facility is equipped to handle all phases of development including design, fabrication and testing. MSC is capable of producing a wide variety of antenna types for various commercial and military applications.



- Reflector Antennas
- Radomes
- Horn Antennas
- Omni Antennas
- Helix Antennas
- Log Periodic Antennas
- Arrays
(including microstrip)
- Auto-Tracking Antennas

For more information,
call or visit our website at:

www.microwavespecialty.com

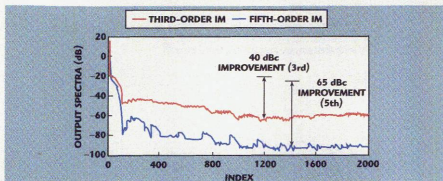


**MICROWAVE
SPECIALTY
CORPORATION**

*Designers and Manufacturers
of Microwave Antennas
and Related Components*

520 E. Carmel Street
San Marcos, CA 92069-4499
(760)744-1544
fax (760)744-1565

TUTORIAL



▲ Fig. 4 IM improvement at the feedforward linearizer output.

Fig. 5 The resulting output using 5 dB back off at (a) the initial state and (b) after the coefficients have adapted.

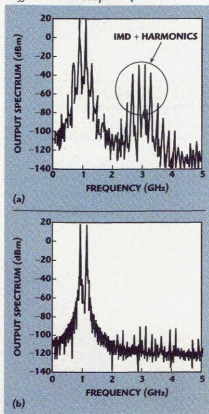


Figure 4 shows the level of improvement exhibited in both third- and fifth-order IM levels at the output of the feedforward linearizer in the first simulation. In the example, the signal-cancellation loop is allowed to converge before the error-cancellation loop is turned on to avoid instability. This condition can occur if close attention is not paid to the adaptation procedure. The error-cancellation loop takes more time to optimize than the signal-cancellation loop because of the order of magnitude difference in adaptation rates. Taking the example a step further, if the power amplifier is driven using 5 dB of back off, high levels of IM

power and harmonics are generated. Figure 5 shows the resulting output once the coefficients have adapted.

CONCLUSION

As the duties of RF power amplifiers become increasingly complex, innovative approaches must be developed to minimize distortion. Adaptive feedforward linearization, while based on a concept developed many years ago, represents an optimized approach to solving the problem of IM distortion in multichannel, wideband applications. The linearization example presented here demonstrates the kind of performance that can be achieved with feedforward linearization. System-level simulation provides a solid starting point for carrying out an implementation quickly since designed components can be integrated into the system to gauge the impact on overall performance. ■

References

1. H.S. Black, "Inventing the Negative Feedback Amplifier," *IEEE Spectrum*, December 1977, pp. 55-60.
2. H. Seidel, "A Microwave Feedforward Experiment," *Bell Systems Technical Journal*, Vol. 50, No. 9, November 1971, pp. 2879-2918.
3. M.G. Oberman and J.F. Long, "Feedforward Distortion Minimization Circuit," U.S. Patent 5,077,532, December 31, 1991.
4. J.K. Cavers, "Adaptation Behavior of a Feedforward Amplifier Linearizer," *IEEE Transactions on Vehicular Technology*, Vol. 44, No. 1, February 1995, pp. 31-40.

Shawn P. Stapleton has 17 years of experience in RF and microwave circuit and systems design. He is currently a professor of electrical engineering at Simon Fraser University in Burnaby, British Columbia, Canada, as well as a consultant for HP EEsof. He has developed GaAs MMIC components, including mixers, amplifiers, frequency dividers and oscillators. His most recent projects include digital signal processing, mobile communications and RF/microwave systems.

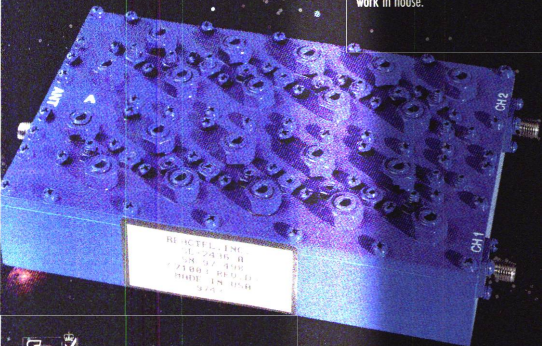
These new Diplexers deliver the performance required to achieve the full potential of your networks.

Performance Integrated with Production

Your operating parameters, such as >95 dB isolation and <2.5 dB loss, are incorporated in the passive circuit design. The circuit elements are then machined into metal blocks. Since all design and manufacturing is done at Reactel, the last unit you order will provide the same performance as the first.

Fast Response Time

for both evaluation prototypes and production units. Reactel maintains direct control over each step, from initial design to final production, by performing all work in house.



The Quality System in force at Reactel has been certified by FMRC of the US and SCS of the UK to ISO 9001 Standards.



REACTEL, INC.

e-mail: reactel@erols.com

CIRCLE 145 ON READER SERVICE CARD

687-K Lofstrand Lane • Rockville, MD 20850
Phone: (301)279-5535 Fax: (301)340-7304

MICROWAVE MCM-C UTILIZING LOW LOSS LTCC AND PHOTO-PATTERNING PROCESSES

Microwave applications at frequencies in excess of 1 GHz, such as wireless devices, are well suited to ceramic construction. Other circuit fabrication technologies do not exhibit the same balance of low loss, precise geometries, cost and reliability. In addition, ceramic technology has the ability to provide greatly enhanced functionality by integrating buried passive components. A further requirement stems from the increasing use of flip-chip technologies, which provide compact assemblies with good microwave characteristics suitable for volume production. Many alternative technologies fail to provide the appropriate interconnect density and, in the case of polymer circuits, require an expensive under fill process. This article describes a new low loss low temperature cofired ceramic (LTCC) technology that, when combined with a photo-patterned thick-film technology, offers outstanding interconnect density and microwave performance. The ability to combine the efficiency of cofired ceramic with multiple out photo processing leads to low cost systems solutions involving multichip module with cofired substrate (MCM-C) technology. Data are presented to show the outstanding performance available both as microstrip lines and other circuit components, extending the application of LTCC into the 30 GHz and higher range of frequencies.

As frequencies increase toward 40 GHz for many applications, circuit technology and performance become increasingly critical. Line loss rises with frequency, making the loss characteristics of the technology particularly important. At the same time, dimensions decrease, making geometrical properties critical. Conventional technologies, with the exception of thin-film circuitry, struggle to meet these needs. However, thin-film technology, which is expensive to manufacture, is not suited to the newer volume requirements.

Lower microwave frequency circuits are often manufactured using conventional FR4 or similar laminate materials. Unfortunately, these materials exhibit excessive loss, which

becomes particularly significant as frequencies rise. An additional problem is the poor dimensional stability of laminate materials, with both temperature and humidity having a significant effect on dimensions. Again, this problem be-

[Continued on page 148]

PETER BARNWELL,
MICHAEL P. O'NEILL
AND CHARLES SABO
*Heraeus Inc., Cermalloy Division
West Conshohocken, PA*
CHARLES FREE
*Middlesex University
London, UK*

Stellex Microwave Systems, Inc.

**Complete Solutions
to your**

RF and Microwave Applications

Stellex Microwave Systems is a proven industry leader in the design and manufacture of RF and Microwave components and subsystems. For over 40 years, Stellex products have been designed into sophisticated defense electronic systems, satellite communications systems, and high-end commercial applications.

The Stellex Advantage is dedication to design, advanced packaging and manufacturing processes. This balance between electrical, mechanical and process design is unique and offers our customers these benefits:

Cost-effective production

Highest quality and reliability

Rapid time-to-market

For more information, fax us at
650-813-2030 or call our 800 number:

1-800-321-8075

www.stellexms.com

The Stellex Advantage



RF & MICROWAVE MIXERS

- Frequency Range: DC to 26 GHz
- LO Drive Levels: +7 dBm to +27 dBm
- Packaging: Surface Mount, Microstrip, Open Carrier, TO & SMA Designs



RF & MICROWAVE FREQUENCY DOUBLERS

- Frequency Range: 0.005 to 12 GHz
- LO Drive Levels: +10 dBm to +23 dBm
- Packaging: Various Hermetic, Open Carrier & SMA



RF & MICROWAVE CASCADABLE AMPLIFIERS

- Frequency Range: 0.001 to 12 GHz
- Designs: Bipolar, GaAs FET/MMIC, & PHEMT
- Packaging: Surface Mount, TO & SMA Designs



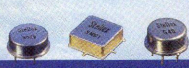
LIMITERS & LIMITING AMPLIFIERS

- Frequency Range: 0.005 to 4 GHz
- Designs: Bipolar, GaAs FET & MMIC
- Packaging: Surface Mount, TO & SMA Designs



COMMERCIAL YIG OSCILLATORS

- 2-10 GHz low cost, low noise TO-8 style YIG Oscillators. Ideal for DRO replacement
- 2-14 GHz low cost, low noise, broad tuning range YIG Oscillators



ATTENUATORS

- Frequency Range: 0.005 to 4 GHz
- Designs: PIN/IMP Diode Linearized & Non-linearized
- Packaging: Surface Mount, TO & SMA Designs



INTEGRATED MILLIMETER WAVE TRANSCIVERS/CONVERTERS

- Highly integrated custom military and commercial subsystems
- In-house metal injection molding and glass sealing for rapid low cost packaging



CUSTOM SUBSYSTEMS

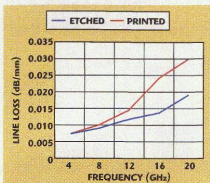
- Highly integrated custom military and commercial subsystems
- Advanced mixing technology for up and down conversion



AN ISO 9001 REGISTERED FIRM

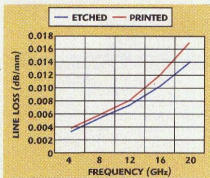


Stellex Microwave Systems, Inc.
3333 Hillview Avenue, Palo Alto, CA 94304-1223
email: sales@stellexms.com

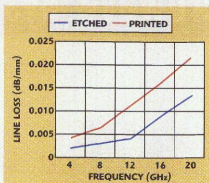


▲ Fig. 1 Line loss with 96 percent alumina, 0.635 mm line width.

Fig. 2 Line loss with 99.5 percent alumina, 0.635 mm line width. ▼

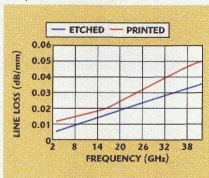


comes increasingly significant with increasing frequency. What is needed is a ceramic-based technology that can offer several advantages, including low dielectric loss; a precisely defined dielectric constant that is stable with frequency; precise, stable dimensions; excellent thermal management; integrated passive components;



▲ Fig. 3 Line loss with 99.6 percent alumina, 0.635 mm line width.

Fig. 4 Line loss for a 250 μ m line, 99.6 percent alumina. ▼



and low costs due to multiple out parallel processing.

Conventionally, ceramic technologies for high volume manufacture have used thick-film technology, sometimes in conjunction with LTCC. Unfortunately, the precision of the lines fabricated with thick-film technology, while capable of fabricating low loss lines,

does not allow the fabrication of precise geometries for devices such as filters and couplers. Furthermore, conventional LTCC technology is high in dielectric loss (10^{-2}) and relatively high in dielectric constant (typically 8). These problems are unfortunate since the parallel manufacturing technology and integrated components available with LTCC offer a very cost-competitive technology.

A family of photo-patterned thick-film materials has been developed to address the lack of precision in thick-film technology. These materials offer excellent microwave performance. In conjunction with this, a novel low dielectric constant, low loss LTCC material has been developed that offers outstanding capabilities when used with the photo-patterned materials.

PHOTO THICK-FILM MEASUREMENTS

Photo-processed thick-film technology has been discussed extensively elsewhere^{1,2} and will not be discussed in detail here. It consists of an etchable high density gold or silver conductor and a photo-sensitive, low loss dielectric. A full program of tests on microstrip lines using this technology on various substrates was performed recently and the results are presented.

It was decided to investigate microstrip lines using 96 percent, 99.5 percent and 99.6 percent alumina. The 96 percent alumina was (as fired)



Make Way For A Break

WIDE DYNA

w w w . m i t s u b i s h i

Coors ADS96F, the 99.5 percent alumina was Coors roll compacted as fired and the 99.6 percent alumina was Coors, lapped to a surface finish of 10 μm . It is particularly significant to compare the performance of these different materials because they vary significantly in cost: The 96 percent alumina is the least expensive with the 99.5 percent alumina being approximately twice the cost and the lapped 99.6 percent alumina at least 10-times the cost. The different performance of the materials on these different cost substrates is considered to be vital data for a microwave designer.

At the same time the loss of etched lines was measured, direct printed lines were measured to provide a performance comparison between the two technologies. All etched lines were fabricated using Heraeus KQ500 gold; printed lines were fabricated using KQ550 gold. Due to the fine line printing capability of the KQ550, it was possible to realize lines with widths very similar to those of the etched lines.

The majority of the work was carried out on 0.635 mm (25 mil) thick alumina with measurements up to 20 GHz. A microstrip line width of 0.635 mm was used to produce a 50 Ω impedance. Above this frequency, thinner substrates are needed to ensure correct microstrip propagation, therefore, a 0.25-mm (10 mil) substrate thickness and line width was adopted. Measure-

ments were made up to 40 GHz with these substrate dimensions. The measurements used both a direct pass through and a meander line on a 2 in² substrate. The substrate was then mounted in a Wiltron jig.

PHOTO THICK-FILM PERFORMANCE

The results obtained from the measurements described are shown as plots of loss in decibels per millimeter. **Figures 1, 2 and 3** show the results obtained with 96 percent alumina, 99.5 percent alumina and 99.6 percent lapped alumina, respectively. It can be seen immediately that, as expected, the etched lines show a significant performance advantage over the printed lines. However, this advantage is significant only above approximately 8 GHz and is relatively small for the 99.5 percent alumina. In all cases, the etched lines show excellent performance. Even on 96 percent alumina the etched lines show performance comparable with published figures for thin film.

These results could be interpreted as indicating that direct printed lines are acceptable as a general-purpose microstrip line technology at these frequencies. This capability is certainly the case for simple transmission lines. However, if these lines are used as part of a component, it is not just the loss that is significant, but also the geometrical precision. For example, if

an edge-coupled filter is being fabricated, it is likely to require line widths and spacing of 75 μm or better. Even though it may be possible to achieve this goal by direct printing, the tolerance on the dimensions is likely to be on the order of 25 μm . This tolerance makes the performance of the resulting component subject to wide variations in bandwidth and center frequency. The etched line, on the other hand, has an edge tolerance of 1 μm and produces a far more stable and reproducible component.

Further conclusions can be drawn from these three plots. First, it can be seen that loss reduces with the higher purity, higher cost substrates. However, this improvement is a small difference only, making the lower cost substrates suitable for circuit fabrication. Second, the difference between the printed and etched line on the 99.5 percent material is smaller than with the other materials. This result is believed to be due to the nature of the substrate surface allowing high quality printing, but will be the subject of further evaluation. **Figure 4** shows a plot of loss vs. frequency for the thin, 250 μm line on 0.25 mm thick, 99.6 percent lapped alumina. It can be seen immediately that the line loss rises steadily with increasing frequency but is linear, indicating no problems with dispersion. Again, the loss is higher in the printed line compared to the etched line. Finally, the

through In GaAs FETs.



MIC RANGE

Pass With Care

c h i p s . c o m

 **MITSUBISHI**
ELECTRONIC DEVICE GROUP

TECHNICAL FEATURE

loss at 20 GHz is only 20 percent higher than for the wider 0.635-mm line. These results indicate excellent low loss behavior of the microstrip line on a thin alumina substrate.

LOW LOSS LTCC

Although the classic microstrip line on alumina discussed previously is of great interest, it is somewhat limited in the fabrication of complex circuits. What is needed is the ability

to build multilayer patterns, incorporate resistors and other passive components and, hence, realize a complete structure. While this goal can be achieved using thick-film multilayer technology, the use of an LTCC process allows complex, low cost structures to be built in high volume. The reduction in processing steps with LTCC is significant and multiple out circuits can be fabricated readily. Unfortunately, as noted, LTCC tends

to offer a high loss, high dielectric constant material that is not suitable for microwave interconnect.

As a result of these limitations, a new low loss dielectric material has been developed based on the KQ dielectric material referenced earlier. This tape can be fabricated in various fired thicknesses from 75 μm . The material allows the ready fabrication of structures where the microstrip line can be fabricated on top of the tape to produce the thin dielectric material required for operation at higher microwave frequencies. The process can be taken a step further with the fabrication of lines buried within the tape to form stripline and similar structures. With the inclusion of general interconnect and passive components, a complex integrated high performance structure can be readily built.

The low loss tape has been measured at X-band (8 to 12 GHz), yielding a dielectric constant of 3.94 and a loss factor of 5×10^{-4} . It can be seen that the required low loss is achieved together with the advantage of a low dielectric constant.

LTCC IN COMBINATION WITH PHOTO THICK FILM

In order to realize the structures allowable with the low loss LTCC, compatible materials of appropriate performance are required. The photo-patterned KQ materials discussed earlier prove ideal for this task. Even with a low dielectric constant of 3.94, a 75 μm tape thickness requires a narrow 150 μm line width for a 50 Ω impedance. Conventional LTCC processes can realize such line widths, but with poor tolerance. KQ photo processing can readily achieve such dimensions with excellent edge acuity.

Structures combining low loss LTCC and KQ photo-processed conductors have been built, allowing the use of a thin tape material with good connection to the ground plane. Two alternative versions of the structure were fabricated — one with a fired tape thickness of 130 μm and one with a fired thickness of 260 μm . The line widths were designed to provide a 50 Ω impedance (using the 3.94 dielectric constant), resulting in line widths of 290 and 560 μm , respectively. Loss was measured using a comparison between a straight through line 50 mm long in

[Continued on page 152]

WEINSCHEL QUALITY COMPONENTS & SUBSYSTEMS

Products That Make a World of Difference

Whether it's standard off-the-shelf coaxial components or custom designs to meet your requirements, contact Weinschel for high quality products that make a world of difference in your wireless applications.

Variable & Step Attenuators

- Continuously Variable, dc-4.2
- Manual Step, dc-26.5 GHz
- Connector Choice: SMA, N, 2.92mm

Programmable Attenuators

- RF, Wireless, & Microwave Models (dc-1, 1.2, 2, 3, 4, 18, 26.5 GHz)
- New Solid-State Designs (PIN & GaAs FET)
- 75 Ω & Phase Compensated Designs

Phase Shifters

- dc-18 GHz
- Internal Self Locking Mechanism

Power Splitters & Dividers

- Resistive Models to 40 GHz
- Connector Choice: SMA, 2.92mm, N
- 2 & 4 Way Designs

Fixed Attenuators

- Models from dc-40 GHz
- High Power Models up to 1,000 W
- MIL & Space Qualified Models
- Low Intermodulation Design Options
- Connector Choice: SMA, 2.4mm, 2.92mm, 3.5mm, N, 7/16, BNC

Precision Adapters & Connectors

- Blind-mate Connector Systems
- "Plexus Connect" Connector System

Directional Couplers

- dc-4 GHz • Octave & Broadband

SmartStep[™] Components & Subsystems

- Plug & Go Programmable Attenuators and Relay Drivers
- IEEE-488 & Standard Serial Interfaces/Controllers
- Bus Controlled Programmable Attenuator Units
- Custom Subsystem Design for Specialized Applications

Terminations & Loads

- Models from dc-40 GHz
- High Power Models up to 1,000 W
- Low Intermodulation Design Options
- Connector Choice: SMA, 2.4mm, 2.92mm, 3.5mm, N, 7/16

Weinschel
CORPORATION

An MCE Company

5305 Spectrum Drive, Frederick, Maryland 21703-7362
800-638-2048 • Tel: 301-846-9222 • Fax: 301-846-9116
e-mail: sales@weinschel.com • Web: www.weinschel.com

EXPRESS
SHIPPING

VISA
MasterCard

CERTIFIED
ISO 9001
Certificate No. 94-0890

Limited Space?

Your solution is Dow-Key's line of miniature electro-mechanical switches

Do you need a miniature switch for your matrices, your microwave radio or to select an alternating antenna? Do you need a miniature switch to bypass a circuit element or to act as a direct input to output insertion? Do you need a miniature switch to provide simultaneous reception and transmission of signals?

If you do, then Dow-Key's low cost, miniature switches, operating to 3 GHz, are your solution. The product line includes a SPDT failsafe switch, a DPDT Bypass switch, and a DPDT Transfer switch. Designed to be PCB mounted, these 50 ohm impedance switches can be hot switched at 10W CW to 3 GHz without performance degradation and can handle up to 50W CW at 1 GHz.

If unprecedented customer service, on-time delivery, and the highest quality switch products with unsurpassed reliability at the right price are your requirements

DOW-KEY MICROWAVE is your solution.



Dow-Key® Microwave
CORPORATION

4822 McGrath Street
Ventura, CA 93003-5641

Tel: (805) 650-0260 • Fax: (805) 650-1734

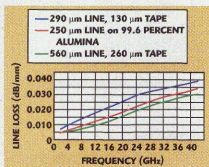
Visit us at www.dowkey.com

A **DOVER** TECHNOLOGIES COMPANY

CIRCLE 32 ON READER SERVICE CARD



TECHNICAL FEATURE



▲ Fig. 5 Line loss for a 50 Ω KQ line on tape and alumina.

comparison with a meander line of 110 mm. This procedure allowed for any losses in the interface with the Wiltron jig to be isolated.

Measurements of line loss are shown in **Figure 5**. It can be seen immediately that the 290 μ m line produces a loss of 0.039 dB/mm at 40 GHz, which is approximately 14 percent greater than the similar 250 μ m line on 99.6 percent lapped alumina. The wider line on the thicker material produces a loss of 0.03 dB/mm at 40 GHz, 12 percent lower than on 99.6 percent alumina. These results are considered to be excellent and

show the outstanding applicability of this technology to building microwave structures.

The small sizes that result allow the parts to be manufactured as multiple out circuits on a relatively large substrate. The photo-processing technique is also suitable for multiple out work, guaranteeing accurate alignment over a large surface area. These benefits offer mass production cost benefits similar to those found in integrated circuit and printed circuit board fabrication and make the technology ideal for economical high volume production as required by current telecommunications applications.

CONCLUSION

The performance of photo-processed thick-film conductors up to at least 40 GHz has been demonstrated and excellent results have been obtained. Using this knowledge, a low loss LTCC tape material with good microwave properties has been demonstrated. What is now needed is a fully integrated, cofireable LTCC system that allows the production of high performance components together with integrated passive components. The cost benefits resulting from such a structure will be considerable and research and development work is being directed into this area. The combination of these materials and processes will lead to the realization of compact, low cost, high performance microwave structures.

ACKNOWLEDGMENT

The authors would like to acknowledge Bill Lorelli and Jim Wood at Heraeus for their great assistance with LTCC structure fabrication. The support of Susan Munyon at Coors Ceramics has also been invaluable. Portions of this paper were presented at the International Conference and Exposition Exhibition on High Density Packaging and MCMs in Denver, CO, April 6-9, 1999. ■

References

1. P.G. Barnwell and J. Wood, "A Novel Thick-film on Ceramic MCM Technology Offering MCM-D Performance," *Proceedings of the Sixth International Conference on MCMs*, Denver, CO, April 1997, pp. 48-52.
2. P.G. Barnwell, C. Free, L. Chin and C. Aitchison, "A Novel Thick-film on Ceramic Microwave Technology," *Proceedings of the 1998 Asia Pacific Microwave Conference*, December 1998.



Peter Barnwell received his BS and PhD degrees in applied physics from City University, London, and has worked in the hybrid microelectronics industry for more than 30 years. His technical specialization has concentrated on RF and microwave properties of

thick-film technology. Barnwell has published more than 70 technical papers, including several at the annual International Microelectronics and Packaging Society (IMAPS) Conference in the US. He is currently president of IMAPS Europe. In addition, Barnwell is business manager for Advanced Materials and Telecommunications Applications at Heraeus Inc., Cernallony Division, where he has established new technologies in the marketplace and interfaced with both circuit manufacturers and systems companies.



Michael P. O'Neill received his BS degree in industrial engineering from Drexel University and has worked in the electronic materials industry for 14 years. He has held various positions in research and development, technical service,

market development and sales with DuPont Microcircuit Materials. Currently, he is sales and marketing manager for Thick Film and Advanced Materials with Heraeus Inc., Cernallony Division. O'Neill has authored or co-authored a number of papers on thick-film and LTCC materials and applications and is a member of IMAPS.

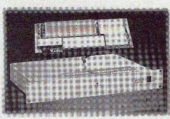


Charles Sabo received his BS and MS degrees in metallurgical engineering from Lafayette College and Purdue University, respectively. He spent three years as a member of the technical staff at the Microelectronics Circuits Division of

Hughes Aircraft Co., and has been with Heraeus Inc.'s Cernallony Division for the past 11 years in the position of senior quality assurance engineer and senior research metallurgist. Currently, he is technical service manager for Advanced Packaging responsible for the company's KQ and LTCC product lines. Sabo has co-authored eight papers dealing with material aspects of microelectronic packaging and is a member of IMAPS.

Charles Free is a principal lecturer and leader of the Communications Research Group at Middlesex University in the UK. He is the author of 50 technical and scientific papers and his current research interests are in dielectric measurements at microwave frequencies, microstrip antennas, high frequency MCM design, microstrip phase shifters and digitally controlled microwave oscillators.

STEL-9937



DDS SYNTHESIZER OFFERS OUTSTANDING COST BENEFITS

- Two Independently Tuneable Channels for Full Duplex Operation
- 2.7 to 2.86 GHz Tuning Range
- .06 Hz Tuning Resolution
- 5.5W Power Consumption at 5V
- Lightweight Design
- Customized to 18 GHz

See our website for complete details.
WWW.STELMSD.COM

STANFORD TELECOM

Microwave Systems

59 Technology Drive, Lowell, MA 01851
Phone: 978-441-0200 • Fax: 978-453-6299

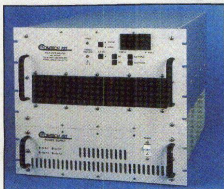
50 WATT GaAs FET POWER AMPLIFIER

Model ARD88258-50 operates over the 800 to 2500 MHz frequency band with 50 watts of output power (1 dB compression point). Gain is 47 dB minimum with a noise figure of 10 dB typical. An integral IEEE-488 interface provides full monitor and control of amplifier functions. Typical Intermodulation Distortion of <-30 dbc at 50 watts PEP. Size is 8.75"H x 19"W x 24"D.

Comtech PST Corp.
Melville, NY 11747 (516) 777-8900

CIRCLE 23 ON READER SERVICE CARD

250 WATT GaAs FET POWER AMPLIFIER SYSTEM



Model ARD1929-250 is a solid state, Class A RF power amplifier system operating in the 1000 to 2000 MHz frequency range with a power output of 250 watts (400 watts saturated) at the 1 dB compression point. It is broadband and laboratory-quality, with a gain of 53 dB min. and 12 dB max. noise.

Comtech PST Corp.
Melville, NY 11747 (516) 777-8900

CIRCLE 24

MODEL AM19258-50



Model AM19258-50 operates over the 1000 to 2500 MHz frequency band with 50 watts of output power. Gain is 54 dB nominal with a small signal gain flatness of ± 3.0 dB.

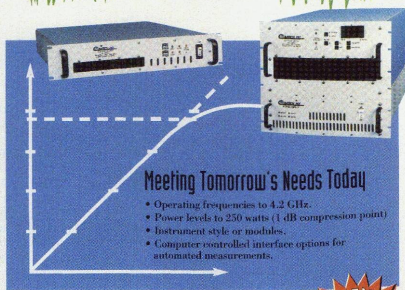
Size is 18"L x 12"W x 1"H and operates over the 0 to +71°C baseplate temperature range.

Comtech PST Corp.
Melville, NY 11747 (516) 777-8900

CIRCLE 25 ON READER SERVICE CARD

*Ultra Broadband
Linear Power Amplifiers*

*First & Still the Best for
IMD Testing*

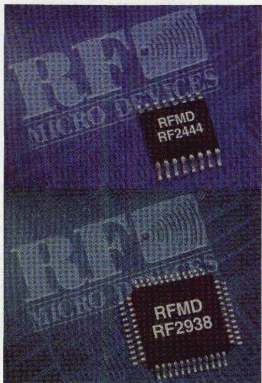


COMTECH PST

105 Baylis Road, Melville, NY 11747
Tel: 516-777-8900 Fax: 516-777-8877
E-mail: info@comtechpst.com
Web: www.comtechpst.com



CIRCLE 26 ON READER SERVICE CARD



A TRANSCEIVER CHIPSET FOR 2.4 GHz DIRECT SEQUENCE SPREAD SPECTRUM APPLICATIONS

The 2.4 GHz industrial, scientific and medical (ISM) band is coming of age, largely due to the coincidental emergence of three wireless local area network (LAN) standards. However, there are still relatively few products designed for this band that offer an attractive combination of performance, size and cost.

Wireless LAN systems have been hyped for many years with very limited success, but there are encouraging signs that this market will finally emerge. The segmentation of this market is still unclear since some of the standards appear to overlap. For example, the Home RF Working Group's shared wireless access protocol (SWAP) specification calls for 800 kbps and 1.6 Mbps data rates, while Bluetooth radios provide 1 Mbps with hopes to move to 2 Mbps later. The first IEEE802.11 wireless LAN specification was ratified in 1997 with a 2 Mbps maximum data rate but is quickly moving on to an 11 Mbps standard, a speed that clearly differentiates it from other alternatives. For the first time, a wireless LAN

offers performance competitive with existing wired systems.

What will finally enable the market is the right combination of data rate and price. The existence of the 11 Mbps IEEE standard is a key step; however, the cost of a wireless LAN radio is still too high and will inhibit market growth. While wireless LANs will remain more costly than Ethernet hardwire networking, it is clear that, in many applications, mobility has great value.

The model RF2938 RF/IF transceiver IC forms the core of the wireless LAN radio design and offers high performance, low power and high integration at a cost that makes discrete designs inefficient and other integrated approaches expensive by comparison. Other applications, such as wireless modems and wireless local loop (WLL), will also benefit from the versatility and integration level of the RF2938 IC.

[Continued on page 156]

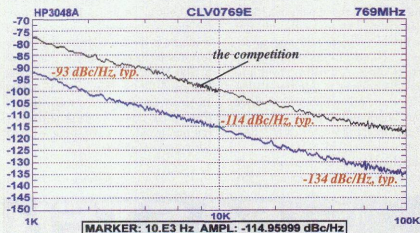
RF MICRO DEVICES
Greensboro, NC

All VCOs should be this good ...

Setting the standard for VCO performance.

Designing today's advanced radios is tough enough when you have VCOs that don't give you the margin you need. Our CLV line of patented ultra-low noise VCOs will give you that margin ... and more!

Part No:	Freq. Range:	V _{tune}	Φ _n at 10kHz	V _{supply}
CLV0769E	734-804	1-4	-112	5
CLV0815E	806-824	0.5-4.5	-113	5
CLV0945E	936-953	0.5-4.5	-114	5
CLV1320E	1295-1335	1-5	-113	5
CLV1525E	1500-1550	0.3-4.7	-110	5



Learn more about Z-COMM's CLV product line by visiting our web site at <http://www.zcomm.com/> for datasheets, outline drawings, tape and reel specifications, and application notes, as well as our complete product catalog and custom VCO inquiry form.

Come to the source ... **Z-COMM.**

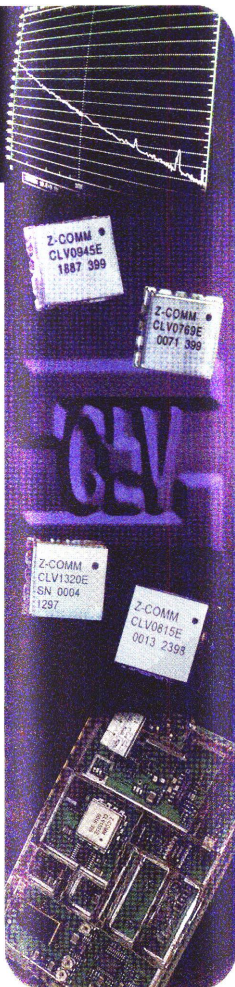


Z-Communications, Inc.

9939 Via Pasa • San Diego, CA 92126

(619) 621-2700 • Fax: (619) 621-2722

WWW: <http://www.zcomm.com/>



CIRCLE 188 ON READER SERVICE CARD

COVER FEATURE

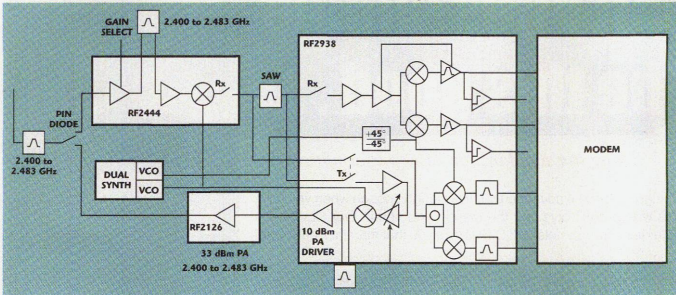


Fig. 1 A complete chipset for the 2.4 GHz ISM band.

AN IEEE802.11 CHIPSET

Figure 1 shows a high performance, low cost, IEEE802.11-compliant transceiver chipset designed for direct sequence spread spectrum (DSSS) communication in the 2.4 GHz ISM band. The RF2938 transceiver IC is designed using a state-of-the-art 24 GHz BiCMOS process and utilizes a single conversion architecture to optimize the system performance/cost trade-off. In half-duplex mode, the RF2938 IC saves the cost of one IF surface acoustic wave (SAW) filter by switching a single filter between RX and TX modes. Full-duplex mode is also available.

Linear amplifiers and 95 dB of gain control are used in the RX signal path to preserve signal amplitude, however, internal high speed comparators also offer data-sliced digital outputs. The TX signal path has 15 dB of gain control to make the chipset more flexible, allowing the system designer to choose filters with various insertion losses. A 6 dBm power amplifier (PA) driver is integrated that can drive an antenna directly or drive various highly efficient GaAs heterojunction bipolar transistor (HBT) PAs, which can deliver 1 W of power.

The chipset was designed specifically for an IEEE802.11-compliant DSSS

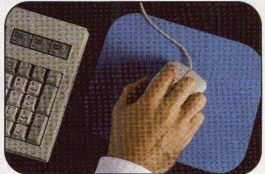
system using biphas-shift keying (BPSK), quadrature phase-shift keying (QPSK) or the complementary code keying (CCK) modulation scheme proposed for the 11 Mbps standard but, with built-in flexibility, it can be used for many other applications and is not confined to the 2.4 GHz band. Flexible features include a broad IF range (45 to 500 MHz) and user-programmable baseband filters (from 1 to 35 MHz). In short-range applications, the +6 dBm of RF power available at the output may avoid the need for an external RF power amplifier.

[Continued on page 158]

Get **FASTER**
Reader Service Response

Want more information from *Microwave Journal* advertisers? Now you can request it online. It's as easy as a click of a mouse! Here's all you have to do:

1. Simply log onto our Web site, www.mwjjournal.com.
2. Click on the **LEADnetSM** Reader Service icon.
3. Request your information (by advertiser name, circle number or product type).



www.mwjjournal.com

NEW ERA AMPLIFIERS

WOW! DC to 8GHz **\$1¹⁹**
(up to +18.5dBm output) From (1000 qty.)

Mini-Circuits ushers-in a new era of technology and economy with ERA monolithic GaAs amplifiers. Just check the specs! These surface mount and drop-in amplifiers cover your applications to 8GHz with higher gain, more output, and flatter response. Characterized with S-parameter data, these amplifiers are very easy to use. Simply sketch an interconnect layout, and the design is done. And ERA's are engineered with wider bandwidths to eliminate your need for costly compensation networks and extra gain stages. So, review your present design and replace with Mini-Circuits new ERA technology. Lower overall cost, wide bandwidth, and lots to...gain!

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

Model	*Freq. (MHz)	Gain. (dB)	Max. Power Out. (dBm, @ 1dB Comp)	Dynamic Range (dB)	IP3 (dBm)	@Device Current (mA)	@Price \$ ea. (10 Qty.)
ERA-1	DC-8000	11.8	11.7	5.3	26.0	40	1.80
ERA-1SM	DC-8000	11.8	11.3	5.5	26.0	40	1.95
ERA-2	DC-6000	15.6	12.8	4.7	26.0	40	1.95
ERA-2SM	DC-6000	15.2	12.4	4.6	26.0	40	2.00
ERA-3	DC-3000	20.8	12.1	3.8	23.0	35	2.10
ERA-3SM	DC-3000	20.2	11.5	3.8	23.0	35	2.15
ERA-4	DC-4000	13.5	▲17.0	5.5	▲32.5	65	4.15
ERA-4SM	DC-4000	13.5	▲16.8	5.2	▲33.0	65	4.20
ERA-5	DC-4000	18.8	▲18.4	4.5	▲33.0	65	4.15
ERA-5SM	DC-4000	18.5	▲18.4	4.3	▲32.5	65	4.20
ERA-6	DC-4000	11.3	▲18.5	8.4	▲36.5	70	4.15
ERA-6SM	DC-4000	11.3	▲17.9	8.4	▲36.0	70	4.20

Note: Specs typical at 2GHz, 25°C. Exception: ▲ indicates typ. numbers tested at 1GHz.

* Low frequency cutoff determined by external coupling capacitors.

① Price (ea) Qty 1000: ERA-1 \$1.19, -2 \$1.35, -3 \$1.48, -4, -5 or -6 \$2.95. SM option same price.

DESIGNER'S AMPLIFIER KITS

K1-ERA: 10 of each ERA-1, -2, -3 (30 pieces) only \$49.95

K1-ERASM: 10 of each ERA-1SM, -2SM, -3SM (30 pieces) only \$49.95

K2-ERA: 10 of each ERA-4, -5 (20 pieces) only \$69.95

K2-ERASM: 10 of each ERA-4SM, -5SM (20 pieces) only \$69.95

K3-ERA: 10 of each ERA-4SM, -5SM, -6SM (30 pieces) only \$99.95

Only Coupling Capacitors at 12e each (\$9 min.)

Size (mm) Value

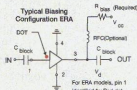
80x50 10, 22, 47, 68, 100, 220, 470, 680,

1000, 2200, 4700, 6800, 10,000 pf

.002, .047, .068, .1 pf



ERA-1 ERA-1SM
ACTUAL
SIZE



Free User Guide!
Packed with comprehensive technical support. Shipped with order, or call for your free copy today.

Mini-Circuits®

US INTL
CIRCLE READER SERVICE CARD

P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661 INTERNET <http://www.minicircuits.com>

For detailed specs on all Mini-Circuits products refer to • 760-pg. HANDBOOK • INTERNET • THOMAS REGISTER • MICROWAVE PRODUCT DATA DIRECTORY • EEM

ISO 9001 CERTIFIED

F 214 Rev F

XTENSIV

Delivering
Technology,
Innovation,
Quality
& Value



Space Saving Surface Mount EMI Filters

Square Design For Easy Handling

Small Size (8x2.1mm)

Reduces Component Count

Capacitance Up To 10,000pF

Insertion Loss Of 70dB At 1GHz

Attractively Priced

Taple And Reel Packaged

www.tusonix.com

TUSONIX

7741 North Business Park Dr.

Tucson, Arizona 85743

520-744-0400 FAX: 520-744-6155

email: sales@tusonix.com

Authorized Stocking Distributors:

- Avnet 1-800-332-8638
- PALtronics 1-800-387-7969
- Resco 1-800-638-1242
- RS Electronics 1-313-525-1155
- TTI 1-800-225-5884

COVER FEATURE

TABLE I

RF2444 LNA/MIXER
KEY SPECIFICATIONS

Noise figure (dB)	2.3
IF range (MHz)	45 to 500
Gain settings (dB)	25 or 10
Cascaded noise figure (high gain) (dB)	4
Supply voltage (V DC)	2.7 to 3.6
Current consumption (mA)	21
Package	16-pin SSOP

SIGNAL PATH

The front end of the receive signal path starts with a 2 dB noise figure low noise amplifier (LNA). An N-type MOS (NMOS) π -attenuator is placed directly after the LNA and either passes the signal or attenuates it by 15 dB. The signal moves off chip to the image filter then back on to the mixer, which is a double-balanced differential mixer with an additional pre-amplifier at its input that boosts gain and improves noise figure.

The choice of IF ranges from 45 to 500 MHz should allow the system designer to select from a wide range of available SAW filters. The IF automatic gain control (AGC) amplifiers have 50 dB of gain range and the baseband AGC amplifiers have another 30 dB of gain range, providing a total of 80 dB of gain range controlled by a single pin. Adding in the 15 dB gain step in the LNA yields 95 dB of total gain variation. Separating the gain between the IF and baseband frequencies adds frequency diversity to the system, which reduces the chance of instabilities and improves power supply rejection.

The baseband signal path also has four programmable lowpass filters (LPF) (I and Q in RX and TX). The internal LPFs are active gmCs, which realize a five-pole Bessel filter. A Bessel filter was chosen as the optimum filter type for data systems due to the flat passband group delay and excellent step response. The 3 dB corner for these four filters ranges from 1 to 35 MHz, and all are programmed simultaneously by a single external resistor.

The linear, filtered baseband outputs of the RX signal paths are also fed into a data slicer, which gives out

CMOS levels. These data slicers can be independently disabled if the analog outputs only are desired. The TX signal path starts by lowpass filtering the input bits with the five-pole gmC Bessel filter. The signal is then up-converted to IF and the I and Q channels are combined and moved off chip to the external SAW filter. The IF signal is then amplified prior to upconverting to RF. This amplifier provides 15 dB of variable gain to allow correction for all the various IF and RF filter losses. This gain also may be adjusted in real time if necessary. Finally, the RF signal is boosted to 6 dBm prior to going off chip to one of the GaAs HBT PAs.

THE RECEIVER

RX Front End

The RF2444 contains the RX front-end LNA/mixer for this chipset. The LNA comprises two stages: a common emitter amplifier stage with 13 dB power gain and an NMOS π -attenuator that has an insertion loss of 3 dB in the high gain mode and 17 dB in the low gain mode. The attenuator was placed after the LNA so that system noise figure degradation would be minimized. A single gain stage was used prior to the image filter to maximize the third-order intercept point (IP3), which minimizes the risk of large out-of-band signals jamming the desired signal. The LNA + attenuator noise figure is 2.3 dB and the input IP3 is -6 dBm in the high gain mode.

Table 1 lists key specifications for the RF2444 LNA/mixer.

The mixer on the RF2444 also comprises two stages. The first stage is a common emitter amplifier used to boost the total power gain prior to the lossy SAW filter. This stage also converts the single-ended signal to differential and improves the noise figure of the mixer. The second stage is a double-balanced mixer whose output is differential open collector. It is recommended that a current combiner is used (as shown in Figure 2) at the mixer output to maximize conversion gain, but other loads also can be used. The current combiner is used to perform a differential-to-single-ended conversion for the SAW filter. C1, C2 and L1 are used to tune the circuit for a specific IF. L2 is a choke to supply

[Continued on page 160]

CUSTOM DESIGNED HIGH POWER N-WAY COMBINERS

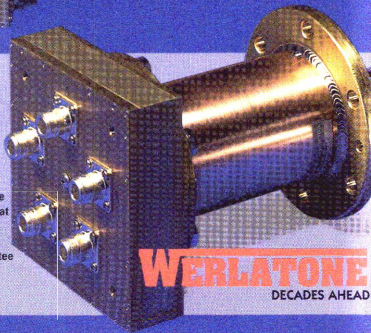
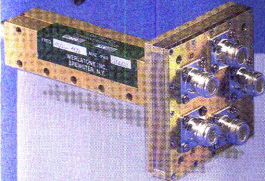
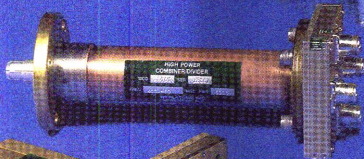
UP TO 20:1 BANDWIDTH CAPABILITY.

FREQUENCIES FROM 2 - 2000 MHz.

HIGH POWER EXPERIENCE TO 50 kW.

High Power Components
Since
1965

Let us design a solution to suit
your combining application.



Werlatone's high power custom N-Way Combiners are available with as few as 2 inputs to as many as 16. Combiners, operating at VHF frequencies and above, feature efficient air or teflon dielectric designs to assure low loss and high average / peak power performance. Our precision Combiner structures guarantee repeatability and high reliability, coupled with excellent phase and amplitude balance.

WERLATONE
DECADES AHEAD

COVER FEATURE

DC current to the mixer and also can be used as a tuning element, along with C3, if necessary. The conversion gain of this mixer is

$$\text{Power Conversion Gain (dB)} = 10 \log_{10}(R1) - 11 \text{ dB}$$

The mixer power conversion gain is +19 dB when R1 is set to 1 k Ω . The conversion gain can be adjusted up \approx 5 dB or down \approx 7 dB by changing the value of R1. Once R1 is chosen,

L2 and C3 can be used to tune the output for the SAW filter. The mixer cascade single-sideband (SSB) noise figure is 10 dB and IIP3 is -18 dBm.

The cascade power gain of the LNA/mixer is 29 dB. After the insertion loss in the image filter (\approx 3 dB) and IF SAW filter (\approx 10 dB), there is still 16 dB of gain prior to the IF amplifiers so the 5 dB noise figure of the IF amplifiers should not significantly degrade system noise figure.

RX IF AGC/Mixer

The front end of the IF AGC starts with a single-ended input and a constant gain amplifier of 15 dB. This first amplifier stage sets the noise figure and input impedance of the IF section, and its output is taken differentially. The rest of the signal path is differential until the final baseband output, which is converted back to single ended. Following the front-end amplifier are multiple stages of variable gain differential amplifiers giving the IF signal path a gain range of 0 to 50 dB. The noise figure (in maximum gain mode) of the IF amplifiers is 5 dB, which should minimally degrade the system noise figure. The IIP3 of the IF amplifiers is -68 dBm in maximum gain mode, and -8 dBm at minimum gain.

The IF-to-baseband mixers are double balanced, differential in, differential out types with 0 dB conversion gain. The LO for each of these mixers is shifted 90° so that the I and Q signals are separated in the mixers.

RX Baseband Amplifiers, Filters, Data Slicers and DC Feedback

At baseband frequency, multiple AGC amplifiers offer a gain range of 0 to 30 dB. Following these amplifiers are fully integrated gmC lowpass filters to further filter out-of-band signals and spurs that get through the SAW filter, anti-alias the signal prior to the analog-to-digital converter and band limit the signal and noise to achieve optimal signal-to-noise ratio. The 3 dB cutoff frequency of these LPPs is programmable with a single external resistor and continuously variable from 1 to 35 MHz. A five-pole, Bessel-type filter response was

Surface Mount High Performance Microwave Mixers

Choose REMEC Magnum as part of your Total Microwave Solution



Reaching high frequencies with low conversion loss and high isolations is now possible in a series of surface mount mixers from REMEC Magnum. Convert signals up to 20 GHz without connectors, and without manual installation of ribbon leads. These surface mount mixers can be placed atop your circuit and reflow soldered along with all the rest of your surface mount components.

Call us with your application information and we'll match a design to your requirements.

Typical Performance at 25°C

Frequency (GHz)			LO PWR NOM (1) dBm	CONV LOSS dB	ISOLATION		MODEL NUMBER
RF	LO	IF			LO/RF dB	LO/IF dB	
3.6-4.3	4.7-5.4	DC-1.5	+10	5.2	42	30	MC245MD-3
5.8-6.5	4.7-5.5	DC-2.0	+10	4.6	43	32	MC345MD-3
9.5-15.0	3.5-15.0	DC-4.0	+10	5.5	35	30	MC545MD-7
10.9-12.6	11.8-14.0	DC-2.0	+10	5.5	41	42	MC645MD-3
13.8-14.7	11.8-14.0	DC-2.0	+10	5.7	36	28	MC745MD-3

(1) Other LO power levels (+7, +13, +18 dBm) available.

The Total Microwave Solution

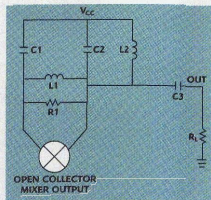
Email inquiries to sales@remecmagnum.com
Visit our website at www.remec.com

1-877-66-REMEC

REMEC Magnum, Inc.
1990 Concourse Drive
San Jose, CA 95131
Fax 408.432.1551

REMEC
Building solutions
through teamwork.

Fig. 2 Current combiner for the mixer load. ▼



[Continued on page 162]



INNOVATIVE MIXERS

WOW!

.smaller size .better performance .lower cost

200kHz to 4200MHz from **\$1.99** (10-49)



innovative technology

Searching high and low for a better frequency mixer? Then take a closer look at the Innovative Technology built into Mini-Circuits ADE mixers. **Smaller size** is achieved using an ultra-slim, patent pending package with a profile as low as 0.080 inches (2mm) in height. Electrically, ADE mixers deliver **better performance** than previous generation mixers through all welded connections and unique assembly construction which reduces parasitic inductance. The result is dramatically improved high frequency and IP2-IP3 performance. Plus, ADE's innovative package design allows water wash to drain and eliminates the possibility of residue entrapment. Another ADE high point is the **lower cost**...priced from only \$1.99 each (qty. 10-49). So, if you've been searching high and low for a mixer to exceed expectations...ADE is **it**™



ADE Mixers...Innovations Without Traditional Limitations!

ADE™ TYPICAL SPECIFICATIONS:

Model	Height (mm)	Freq. (MHz)	LO (dBm)	Conv. Loss (dB)	L-R Isol. (dB)	IP3 (dBm @ Midband)	Price (Qty. 10-49)
ADE-1L	3	2-500	+3	5.2	55**	16	3.95
ADE-3L	4	0.2-400	+3	5.3	47**	10	4.25
ADE-4	4	0.5-500	+7	5.3	55-	15	1.99
ADE-1ASK	3	2-800	+7	5.3	50-	16	3.95
ADE-2ASK	3	1-1000	+7	5.4	45-	12	4.25
ADE-1S	2	50-1000	+7	7.0	30	17	2.95
ADE-4	3	200-1000	+7	6.8	53**	15	4.25
ADE-14	2	800-1000	+7	7.4	32	17	3.25
ADE-4M1	3	800-1000	+7	5.9	32	13	2.95
ADE-5	3	5-1500	+7	6.5	40-	15	3.45
ADE-1S	2	50-1500	+7	8.1	40-	11	3.10
ADE-2S	3	1500-2000	+7	5.4	31	14	4.95
ADE-18	3	1700-2500	+7	4.9	27	10	3.45
ADE-90L	2	2100-2800	+7	6.0	34	17	4.05
ADE-90	3	2300-2700	+7	6.6	36	13	3.45
ADE-30	3	200-3000	+7	4.5	35	14	6.95
ADE-32	3	2500-3200	+7	5.4	29	15	6.95
ADE-33	3	1600-3500	+7	6.3	35	11	4.95
ADE-18W	3	1750-3500	+7	5.4	33	11	3.95
ADE-30W	3	300-4000	+7	6.8	35	12	8.95
ADE-1LH	4	0.5-500	+10	5.0	55-	15	2.99
ADE-1LHW	3	2-750	+10	5.3	52-	15	4.95
ADE-1MH	3	2-500	+13	5.2	50-	17	5.95
ADE-1MHW	4	0.5-500	+13	5.2	53-	17	6.45
ADE-15MH	3	10-1500	+13	6.3	45-	22	6.45
ADE-25MH	3	5-2500	+13	6.9	34-	18	6.95
ADE-35MH	3	5-3500	+13	6.9	33-	18	9.95
ADE-45MH	3	5-4000	+13	7.5	29+	17	14.95
ADE-1H	4	0.5-500	+17	6.3	52-	23	4.95
ADE-10H	3	400-1000	+17	7.0	38	30	7.95
ADE-12H	3	500-1200	+17	6.7	34	28	8.95
ADE-20H	3	1500-2000	+17	5.2	29	24	8.95

Component mounting area on customer PC board is 0.320" x 0.290".
 **Specified midband. *Patent Pending.

Mini-Circuits®

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

US 116 INTL 117
 CIRCLE READER SERVICE CARD

F 267 Rev I

COVER FEATURE

chosen because it is optimal for data systems due to its flat delay response and clean step response. Butterworth- and Chebyshev-type filters ring when given a step input, making them less ideal for data systems.

The filter outputs drive the linear 500 mV p-p signal off chip, but also connect internally to a data slicer that squares up the signal to CMOS levels and drives this data signal off chip. This data slicer is a high speed CMOS comparator with 30 mV of hysteresis and self-aligned input DC offset. It can be independently disabled if only the linear outputs are desired.

DC feedback is built into the baseband amplifier section to correct for input offsets. Large DC offsets can arise when a mixer LO leaks to the mixer input and then mixes with itself. DC offsets also can result from random transistor mismatches. A large external capacitor is needed for the DC feedback to set the highpass cutoff, and this capacitor is re-used to

set the DC input level for the self-aligned data slicer.

The receive signal path also has a received signal strength indicator (RSSI) output, which is the sum of both the I and Q channels. The RSSI has approximately 70 dB of dynamic range. **Table 2** lists key features of the RF2938 transceiver IC.

LO INPUT BUFFERS

RF LO Buffer

The RF LO input has a limiting amplifier before the mixer on both the RF2444 (RX) and RF2938 (TX). This limiting amplifier design and layout are identical on both ICs, which will make the input impedance the same as well. Having this amplifier located between the VCO and mixer minimizes any reverse effect the mixer has on the VCO, expands the range of acceptable LO input levels and holds the LO input impedance constant when switching between RX and TX. The LO input power range is -18 to +5 dBm, which should make it easy to interface to any VCO and frequency synthesizer.

IF LO Buffer

The IF LO input has a limiting amplifier before the phase-splitting network to amplify the signal and help isolate the VCO from the IC. In addition, the LO input signal must be twice the desired IF. This requirement simplifies the quadrature network and helps reduce the LO leakage onto the RX, IF input pin (since the LO input is now at a different frequency than the IF). The amplitude of this input must be between -15 and 0 dBm. **Figure 3** shows a block diagram of the RF2938 transceiver IC in half-duplex mode.

TRANSMITTER

TX LPF and Mixers

The transmit section starts with a pair of five-pole Bessel filters identical to the filters in the receive section and with the same 3 dB frequency. These filters pre-shape and band limit the digital or analog input signals

prior to the first upconversion to IF. These filters have a high input impedance and expect an input signal of 200 mV p-p (typ). Following these LPFs are the I/Q quadrature upconverter mixers. Each of these mixers is half the size and half the current of the RF-to-IF downconverter on the RF2444 IC. Recall that this upconverted signal may drive the same SAW filter (in half-duplex mode) as the RF2444 and, therefore, share the same load. Having the sum of the two baseband-to-IF mixers equal in size and DC current as the RF-to-IF mixer minimizes the time required to switch between RX and TX and facilitates the best impedance match to the filter.

TX Variable Gain Amplifier

The AGC after the SAW filter starts with a switch and a constant gain amplifier of 15 dB, which is identical to the circuitry on the receive IF AGC. This configuration was used (similar to the RX signal path) so that the input impedance remains constant for different TX gain control voltages. Following this 15 dB gain amplifier is a single stage of gain control offering 15 dB gain range. The main purpose of adding this variable gain is to give the system the flexibility to use different SAW filters and image filters with different insertion loss values. This gain also could be adjusted in real time if desired.

TX Upconverter

The IF-to-RF upconverter is a double-balanced differential mixer with a differential-to-single-ended converter on the output to supply 0 dBm peak linear power to the image filter. The upconverted SSB signal should have -6 dBm power at this point, and the image will have the same power. However, due to the correlated nature of the signal and image, the output must support 0 dBm of linear power to maintain linearity.

+6 dBm PA Driver

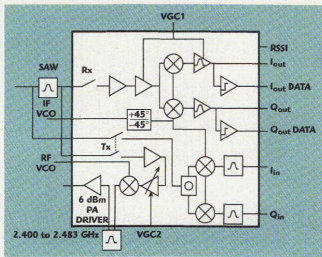
The SSB output of the upconverter is -6 dBm of linear power. The image filter has at most 4 dB of insertion loss while removing the image, LO, 2LO and any other spurs. The filter output supplies -10 dBm of input power to the PA driver.

TABLE II

RF2938 TRANSCEIVER IC KEY FEATURES

IF (MHz)	45 to 500
Programmable baseband filters (MHz)	1 to 35
Cascaded Rx gain (dB)	to 90
Package	small 48-pin
Supply voltage (V DC)	3
Single IF SAW filter for half-duplex mode	
RF amplifier to 6 dBm (linear)	

Fig. 3 The RF2938 transceiver IC in half-duplex mode.



[Continued on page 164]

PROVIDING
HIGH QUALITY,
LOW COST
COMPONENTS
FOR

TOMORROW'S DESIGNS...

State of the Art Wireless SOLUTIONS

300 MHz- 6 GHz

300 MHz- 6 GHz

GPS & ISM

PATCH ANTENNAS

BANDPASS FILTERS & DIPLEXERS

COAXIAL RESONATORS

ASK FOR OUR NEW BROCHURE

For additional information on Trans-Tech products visit
www.trans-techinc.com

tel: 301•695•9400 / fax: 301•695•7065 / e: transtech@alphaind.com



Trans-Tech
A Subsidiary of Alpha Industries

COVER FEATURE

The PA driver is a two-stage class A amplifier with 10 dB gain per stage, is capable of delivering 6 dBm of linear power to a 50 Ω load and has a 1 dB compression point of 12 dBm. For lower power applications, this PA driver can be used to drive a 50 Ω antenna directly.

THE POWER AMPLIFIERS

There are currently several PAs for the 2.4 GHz band designed in the

GaAs HBT fabrication facility. Since the RF2938 provides up to +10 dBm, not much more gain is required to achieve the +20 dBm for wireless LAN systems, and the RF2126 chip is a suitable choice. Offering 45 percent power-added efficiency at $V_{cc} = 3.6$ V, the RF2126 PA typically draws less than 200 mA at +20 dBm, though it can provide up to +30 dBm if required. The IC is supplied in a PSOP-8 package, which provides

good thermal characteristics as well as a low inductance ground.

IC PACKAGES

The RF2938, RF2444 and RF2126 ICs are supplied in new exposed dieflag packages. The dieflag is exposed on the bottom side of the package, which allows it to be soldered directly to the PCB. The use of this package has two major advantages: The thermal impedance of the package is greatly improved so that the junction temperature stays cooler. Thermal impedance improvements of 2x to 4x are not unusual. Though neither design needs this extra thermal conduction to operate properly, having more temperature control improves performance. In addition, the dieflag makes a very low inductance ground, which is very important for low power RF circuitry. The pads on the IC can be bonded directly to the dieflag, providing as many low impedance grounds as desired. Package pins are not required to be designated as grounds so they can be used for signals instead, thereby allowing more functionality in 16 pins than before. Each bondwire to ground has < 1 nH of inductance, and the common inductance from the top of the dieflag to the PCB ground is < 50 pH. Each common emitter amplifier (LNAs and PAs) and each section of circuitry has its own ground, thereby minimizing crosstalk between bondwires and circuit elements. This grounding capability is especially critical for 2.4 GHz signals, but is also important for the IFs since they can reach 500 MHz for this chipset.

CONCLUSION

The RF2938, RF2444 and RF2126 ICs provide a high performance solution to a 2.4 GHz design, reducing the cost significantly without sacrificing versatility. All devices are monolithic and manufactured on high volume lines, allowing a low cost solution (less than \$15 in high volume). Samples and evaluation boards for all products are available, and a complete 2.4 GHz transceiver reference design is expected to be available later this year.

**RF Micro Devices,
Greensboro, NC (336) 664-1233.**

Circle No. 302

high-reliability crystal-oscillators

- Quality
- Reliability
- Performance

y 2 k
compliant

dimensions: .550" x .350" x .115"

Product Range Includes:
TTL, HCMOS, ACMOS,
Low Voltage 3.3 V,
and ECL Clocks
• XOs • VCXOs
• Sine Wave
Frequency Range:
.01 Hz to 300 MHz



Q-TECH Corporation

10150 W. Jefferson Blvd.
Culver City, CA 90232

Telephone: 310.836.7900

www.q-tech.com

Facsimile: 310.836.2157

Don't go it alone.



HERLEY-MDI 

A HERLEY INDUSTRIES COMPANY



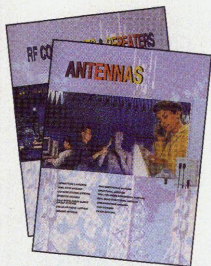
GENERAL MICROWAVE

A HERLEY INDUSTRIES COMPANY

When faced with your next microwave challenge, don't go it alone. Look for a powerful ally; one who has combined forces to offer you extensive engineering resources. The Herley Microwave Products Group designs and manufactures the broadest array of microwave control components, hybrid microcircuits, oscillators and subsystems. Whether your problem is military or commercial, we've got just the weapon you need. So visit our web site for complete details.

HERLEY Microwave Products Group

www.herleympg.com

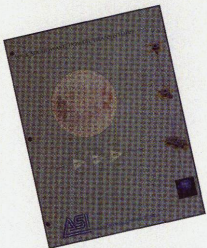


▲ Antenna and RF Component & Repeater Catalogs

The 104-page antenna catalog describes retractable, dual-band, inverted, cellular phone, ceramic, directional, reflector, yagi and patch antennas. The 106-page RF component and repeater catalog describes amplifiers, RF switches, attenuators, active mixers, bandpass filters, isolators, combiners, dividers and couplers.

Ace Technology Inc.,
Chatsworth, CA (818) 718-1534.

Circle No. 310

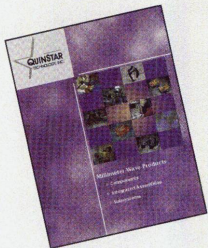


▲ RF & Microwave Power Transistor Catalog

This 30-page catalog details all of the company's standard silicon bipolar and MOSFET power transistors, including HF, VHF, UHF, pulsed avionics, pulsed radar, CW microwave, microwave oscillator and broadcast. Quality assurance and reliability standard information is included.

Advanced Semiconductor Inc. (ASI),
North Hollywood, CA (800) 423-2354
or (818) 952-1200.

Circle No. 311

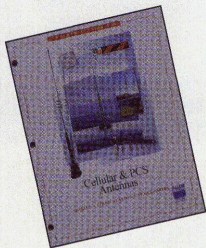


▲ Millimeter-wave Product Catalog

This 120-page catalog contains information on millimeter-wave products, including standard components, specialized RF signal generating, amplifying and conditioning components and fully integrated and customized assemblies and subsystems for digital and analog sensor, communications and test applications. Product photographs, specifications, outline drawings and model numbering information also are featured.

QuinStar, Torrance, CA (310) 320-1111.

Circle No. 345

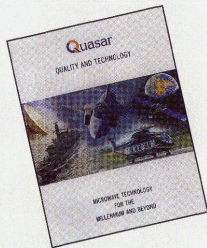


▲ Cellular/PCS Antenna Catalog

This 36-page catalog describes cellular, PCS and GPS products, including On-Glass® elevated feed, magnet and rooftop antennas as well as the fixed station Discreet™ planar, yagi, log periodic and omnidirectional antennas. Three new antennas, including a multiband omnidirectional indoor antenna, an enclosed coil cellular magnet-mount mobile antenna and a mini-magnet dual-band mobile antenna, are also featured.

Antenna Specialists,
a division of **Allen Telecom Inc.,**
Cleveland, OH (440) 349-8400.

Circle No. 313



▲ New Product Catalog

This 12-page catalog describes the company's full range of microwave waveguide products, including microwave attenuators, directional couplers, flexible/twistable waveguides, horns, load terminations, rigid waveguides, hybrid assemblies, tee junctions, coaxial and taper transitions, rotary vane attenuators, waveguide-tuned filters and diplexers.

Quasar Microwave Technology Ltd.,
Newton Abbot, Devon, UK
+44 (0) 1626 83 42 22.

Circle No. 334



▲ 1999-2000 Product Catalog

This product catalog describes state-of-the-art passive microwave components, including a variety of microwave adapters and connectors, flexible and semirigid microwave cable, three styles of coaxial contacts, precision phase shifters, terminations, shorts, caps, attenuators, and flexible and semirigid cable assemblies for test, commercial, space and military applications up to 50 GHz. Also featured are the patented mini-bend cable assemblies for use up to 40 GHz.

Astrolab Inc., Warren, NJ (732) 560-3800.

Circle No. 315

Mind Your Business.

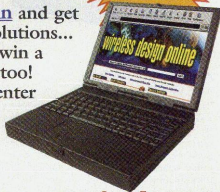
Online!

Everything you need to know about the wireless design industry is right on your desktop!

- late-breaking industry news, updated daily to keep you current
- original articles from experts, to help improve job performance
- instant links to thousands of vendors, for product knowledge and buying access
- classifieds and career information, to keep you aware of job opportunities
- daily and weekly auction opportunities, to help you buy and sell at great prices (including overruns and overstocks)
- one-of-a-kind online industry newsletter

Register now on www.wirelessdesignonline.com/win and get **FREE** access to complete industry information and solutions... and you'll be automatically registered for a chance to win a **FREE** state-of-the-art, blazingly fast IBM ThinkPad, too! We'll include a **FREE** laptop carrying case when you enter Prize Code A1104MJU in the appropriate box.

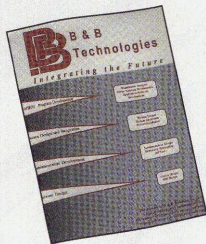
Win a
laptop!



It's e Business to Business

www.wirelessdesignonline.com/win

Another VerticalNet Community

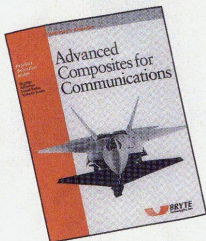


▲ Systems Integration Capability Brochure

This brochure contains information on the company's services, including research analysis, application software development, circuit and system design, and system integration as well as detailed descriptions of several products offered. A company history and client list also are provided.

B&B Technologies Inc.,
Albuquerque, NM (505) 345-9499.

Circle No. 316



▲ Advanced Composite Product Selection Guide

This four-page low dielectric composite product selection guide contains information on prepregs and liquid resins, film and paste adhesives, and bulk and film syntactic foams. Specified data include cure temperature, service temperature, glass transition temperature, neat resin moisture absorption, dielectric constant and loss tangent.

Bryte Technologies Inc.,
San Jose, CA (408) 776-0700.

Circle No. 317



▲ Quartz and Clock Oscillator Catalog

This 20-page catalog describes crystals and oscillators that are available in prototype-through-production quantities. Temperature and frequency tolerance and packaging are discussed. A part number guide and order forms are provided, and key specifications are listed.

Cal Crystal Lab Inc./Comelock Inc.,
Anaheim, CA (800) 333-9825
or (714) 991-1580.

Circle No. 318



▲ Microwave Isolator and Circulator Catalog

This eight-page catalog details single-junction and dual-junction isolators and circulators. Single-junction devices include octave/broadband, electronic warfare/broadband and high performance/narrowband; dual-junction devices include octave/broadband and high performance/narrowband. Key specifications are listed and outline drawings are provided.

DITOM Microwave Inc.,
San Jose, CA (408) 727-1201.

Circle No. 319

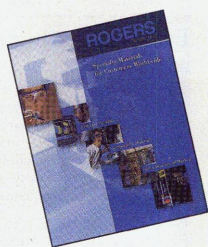


▲ Oscillator Catalog

This catalog contains information about a variety of oscillators including dielectric resonator oscillators, VCOs and voltage-controlled crystal oscillators as well as coaxial resonators and phase-locked oscillators. Frequency synthesizers, combine generators and special products are also detailed. Key specifications are listed and outline drawings are provided.

EMF Systems Inc.,
State College, PA (814) 237-5738.

Circle No. 320



▲ Specialty Material Catalog

This 16-page catalog contains information on a variety of specialty materials, including FORON® urethane foam and silicon material, R/bak® compressible printing plate mounting products, ENDUR® elastomer components, NITROPHYL® floats, MPC® and RX® moldable composites, RO3000™ and RO4000® high frequency circuit materials, RT/duriod® and TMM® high frequency circuit materials, R/flex® flexible circuit materials and Indurflex® laminates.

Rogers Corp., Rogers, CT (860) 774-9605.

Circle No. 336

SWITCHES

for RF/Microwave Applications



• PAGING • MW RADIO • GPS •
• TCAS • GSM • PCS • SATCOM •
• TEST EQUIPMENT • MEDICAL •
• PAGING • MW RADIO • GPS •
• TCAS • GSM • PCS • SATCOM •
• TEST EQUIPMENT • MEDICAL •

Introducing the New Commercial Series

- Switches for All Your Needs
- Up to 5 Million Cycle Life
- Over 35 Years of Experience
- Stock to 4-Week Delivery
- Low Cost, Volume Production
- Teledyne Reliability with a 2-Year Warranty

ISO-9001
CERTIFIED

Contact Teledyne today with your requirements!

 **TELEDYNE**
ELECTRONIC TECHNOLOGIES
Microwave Components

An Allegheny Teledyne Company

CIRCLE 174 ON READER SERVICE CARD

1274 Terra Bella Avenue
Mountain View, CA 94043
Phone: 650.962.6944 Fax: 650.962.6845
Web: www.teledynemicrowave.com
e-mail: switches@teledyne.com

CATALOG UPDATE



▲ Product Reference Guide

This eight-page brochure describes RF and microwave silicon power transistors, transponders, cellular base stations and emitters for PCS/cellular, broadcast, SATCOM and radar applications. The company's capabilities in product design, wafer fabrication, die fabrication, assembly and test are discussed. Key specifications are listed.

GHz Technology Inc.,
Santa Clara, CA (408) 986-8031.

Circle No. 322

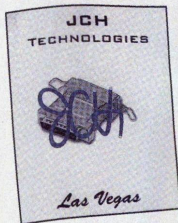


▲ 20/46 GHz Counter Power Meter Brochure

This six-page brochure describes the company's CPM 46 (46 GHz) and CPM 20 (20 GHz) counter power meters and their use in RF and microwave radio link installation and maintenance applications, including cellular network testing, local access radio, trunked radio and satellite communications. Key specifications and features are listed.

IFR Americas Inc.,
Wichita, KS (316) 522-4981.

Circle No. 323



▲ Cable Assembly Brochure

This four-page brochure describes a variety of cable assemblies, including coaxial, power, fiber-optic, patch, computer extension and Ethernet cables. Value-added services are listed and outline drawings are included.

JCH Technologies,
Las Vegas, NV (800) 773-2202
or (702) 639-4100.

Circle No. 324



▲ Commercial Filter and Selection Software Brochure

This six-page brochure describes the company's Kat-Com™ commercial filter selection software, which allows users to specify standard filters and submit requests for quotes directly to the factory. The software program generates response curves, outline drawings, tabular data and part numbers based upon user-defined filter parameters.

K&L Microwave Inc.,
Salisbury, MD (410) 749-2424.

Circle No. 325



▲ Hermetic Laser Sealing and Packaging Brochure

This four-page brochure contains information about hermetic laser welding, electromagnetic interference shielding, RF interference shielding and general-purpose welding capabilities, which include production slating and a typical 48-hour turnaround. The company's facilities and laser welding operations are also discussed.

Maryatt Technologies Inc. (MTI),
Sunnyvale, CA (800) 835-9353
or (408) 730-1907.

Circle No. 326



▲ Automated Tuner System Brochure

This 12-page brochure describes the newest features, options and applications available with the company's automated tuner system, including noise and power characterization, intermod/ACP measurements, swept-power load pull, harmonic source/load pull and on-wafer measurements. High matching range tuners specifically designed for the cellular/PCS frequency bands also are discussed.

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

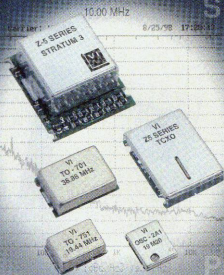
Circle No. 327

One

source TEMPERATURE COMPENSATED CRYSTAL OSCILLATORS

Complete Range Of TCXO's...

- Frequencies to 160 MHz
- Models From 2.5 ppm to 0.05 ppm
- Aging to 0.7 ppm for 10 Years
- Satcom TCXO's $\pm 1 \times 10^{-7}$ 0°C to + 70°C
- Phase Noise as low as -155 dBc offset @ 1 KHz offset
- Low Power Consumption
- Small Size, Low Profile Surface Mount Designs



STRATUM 3

SONET/SDH

SATCOM

ROUTERS

PICO CELLS

PCS

GSM

GPS

PCMCIA

New
Stratum 3
Design

We are the One!



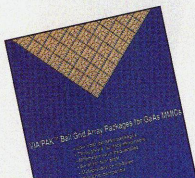
VECTRON
INTERNATIONAL

A **DOVER** TECHNOLOGIES COMPANY

166 Glover Avenue, Norwalk, CT 06856
Tel. 1-88-VECTRON-1 • Fax. 1-888-FAX-VECTRON
e-mail: vectron@vectron.com
www.tcxo.com www.vectron.com

CIRCLE 182 ON READER SERVICE CARD

CATALOG UPDATE



and technical and purchasing information.
Microwave Solutions Inc.,
 National City, CA (800) 967-4267
 or (619) 474-7500.

Circle No. 330

microwave mixers, triple-balanced mixers
 and frequency doublers is provided.
Mica Microwave,
 San Jose, CA (408) 363-9200.

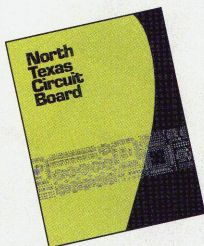
Circle No. 328

formation, specifications and outline drawings
 also are included.
Micro Substrates Corp. (MSC),
 Tempe, AZ (602) 731-6230.

Circle No. 329



▲ **ComponentWorks™ Brochure**



Practice is over...

it's time to perform.

In a modern era one company has been at the forefront of advanced electronics systems for the defense, aerospace, and communications industries: Zeta.

Doing business for over 30 years!

When your system calls for a level of performance that's beyond prevailing standards you need more than a product, you need a solution.

At Zeta we provide solutions that include a full range of microwave products and subsystems specifically designed for use in missile guidance, ground support equipment, radar, satellite communications, data links and other demanding applications. Our customers include United States government agencies, foreign governments, as well as major military and commercial contractors.

So, when you are called on to perform, place your trust in a name you know ... Zeta.

Crystal Stabilized Sources

Frequency Multipliers

Frequency Synthesizers

Comb Generators

Receivers

Frequency Converters

Microwave Subsystems

ZETA

2811 Orchard Parkway, San Jose, CA 95134 Tel 408.434.3600 Fax 408.433.0205 e-mail zeta@zeta-sni.com

CIRCLE 190 ON READER SERVICE CARD



Before Linux, software innovation from Finland scarcely commanded notice. Before Nokia, people scarcely knew we had telephones. Now it seems the RF community has discovered APLAC, our industrial-strength simulation technology that combines the functionality of Spice derivatives with the utility of advanced RF simulators.

In fact, many top RF engineers already use APLAC in their daily work, because APLAC, and only APLAC, provides them with accurate IC- and board-level models as well as precise methods to analyze non-linear circuit behavior. Wide-band CDMA, Bluetooth, and beyond – it's all being designed with APLAC.

We admit learning APLAC takes personal commitment. But it gives you something unique, the freedom to do things right.

To learn more about APLAC, why not download a student version from our website www.aplac.com and contact us at APLAC Solutions.



APLAC

The Freedom To Do Things Right. www.aplac.com

CATALOG UPDATE

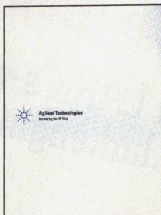


▲ Thin-film Fabrication Technology Brochure

This four-page brochure contains information about the company's photomask requirements, standard metallizations, and standard processes and features. Standard substrate types and sizes are listed.

Applied Thin-Film Products (ATP),
Fremont, CA (510) 661-4287.

Circle No. 314



▲ Company Background

This background describes the launch of Agilent Technologies, a diversified technology company launched as part of Hewlett-Packard Co.'s plan to strategically realign itself into two fully independent companies. A company profile, objective list and business overview are included.

Agilent Technologies,
Palo Alto, CA (650) 857-4752.

Circle No. 312



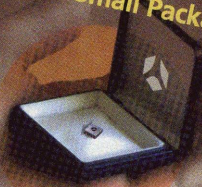
▲ Cable Assembly Catalog

This 32-page catalog lists approximately 4000 stock cable assemblies featuring the company's line of coaxial connectors, solid center conductors, dual-wall tubing for strain relief and fabrication with more than 650 variations of standard connector interfaces. Custom assembly forms are included.

RF Connectors, a division of RF Industries,
San Diego, CA (800) 253-1728
or (858) 549-6340.

Circle No. 335

Big* Surprises Come in Small Packages



*IF SAW Filter 3.8 x 3.8 mm
for wireless applications

THOMSON-MICROSONICS
<http://www.microsonics.thomson-csf.com>

399, route des Crêtes, BP 232 - 06904 Sophia-Antipolis, FRANCE
Tel (+33) 04 92 96 40 00 Fax (+33) 04 92 96 30 25

MICROWAVE JOURNAL • OCTOBER 1999

CIRCLE 176 ON READER SERVICE CARD

Step-by-step Filter Design At LARK we make it easy!

1

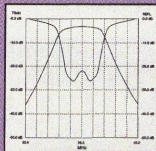
Go to LARK's web site,
www.larkengineering.com

2

Input specifications of your
filter requirements

3

Get



Instant gratification. That's what it's all about when you place your order using **Lark's** unique software and internet access. Just get on line with **Lark**. Click the **GO! Interactive Design** icon, just like the one shown below, and you will be guided one step at a time through the design process. Once the part number comes up you can select additional information such as performance plots, specification sheets, and outline drawings.

Select from one of the most extensive product lines in the filter industry. **Lark** provides RF/Microwave spectrum filters from 100 kHz to 18 GHz utilizing structures such as lumped constant, tubular, ceramic, interdigital, combline and cavity. **Lark's** mechanical packaging includes leadless surface mount and

connectorized units with solder pins to Type N Connectors.

Lark Engineering is ISO 9001 certified. We pride ourselves on being the leader in supplying RF and Microwave filters. We have coined the term **IMMEDIATE FILTER DESIGN** to describe how easy it is for you to get the optimum filter for your application. It's fast too! That's one good reason why major wireless communication systems worldwide use **Lark** filters.

Find out how easy it is. Link up with **Lark** at www.larkengineering.com and we'll do the rest. Your design, your specs, your exact filter, **EASY! ORDER NOW...** quantity, price, and delivery will be E-mailed or Faxed to you within 24 hours.



Lark Engineering Co.™

Div. Baier & Baier, Inc.
27282 Calle Arroyo ■ San Juan Capistrano, CA 92675
(949) 240-1233 ■ Fax: (949) 240-7910 ■ ISO 9001 Certified

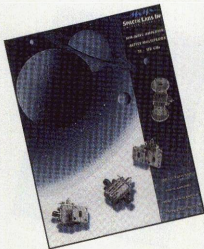




▲ Wireless Solution CD-ROM

This revised CD-ROM, "The Full Spectrum of Wireless Solutions" (revision 2.1), features complete information on filtronic semiconductor, wireless, component and ferretec products. **Filtronic Solid State,** Santa Clara, CA (408) 988-1331.

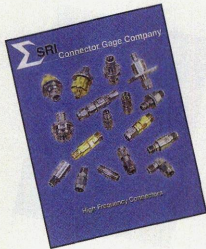
Circle No. 321



▲ mm-wave Amplifier Catalog

This six-page catalog details the company's capabilities in producing mm-wave amplifiers from 18 to 110 GHz and highlights low noise, power and general-purpose amplifiers as well as a full range of active frequency multipliers. Key specifications and photographs are provided. **Space Labs Inc.,** Santa Barbara, CA (805) 564-4404.

Circle No. 337



▲ High Frequency Connector Catalog

This 28-page catalog details the company's full line of custom and standard RF connectors and interface gages designed for a variety of microwave applications. Specifications and outline drawings are included. **SRI Connector Gage Co.,** Melbourne, FL (407) 259-9688.

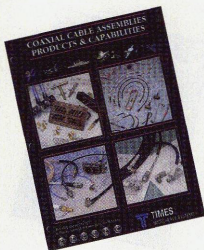
Circle No. 338

Allow us to Propose the Solution



THOMSON-MICROSONICS
http://www.microsonics.thomson-csf.com

399, route des Crêtes. BP 232 - 06904 Sophia-Antipolis. FRANCE
Tél (+33) 04 92 96 40 00 Fax (+33) 04 92 96 30 25

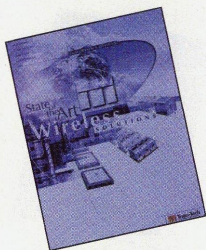


▲ Coaxial Cable Assembly Product and Capability Catalog

This 28-page catalog describes coaxial cable assemblies for military and aerospace applications. Miltech® hermetically sealed cable assemblies and multiport broadband microwave interconnect systems. Electrical performance, operating environment specifications, mechanical installation envelopes and military specification qualifications are highlighted.

Times Microwave Systems,
Wallingford, CT (203) 949-8427.

Circle No. 339

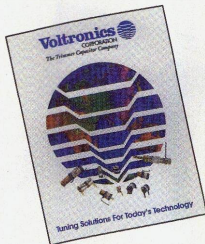


▲ RF and Microwave Ceramic Component Brochure

This brochure introduces the company's line of RF and microwave products for the wireless communication market. Design capabilities and current component technology for ceramic bandpass filters and diplexers, coaxial resonators and patch antennas are detailed. Specifications for typical products are also listed.

Trans-Tech,
a subsidiary of Alpha Industries,
Adamstown, MD (301) 695-9400.

Circle No. 340

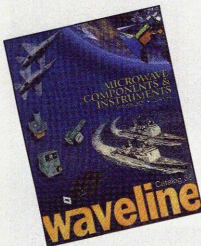


▲ Product Catalog

This 40-page catalog describes PTFE, glass, quartz, sapphire and air variable capacitors. Detailed information on the company's new line of solid dielectric trimmer capacitors designed for GHz frequencies with high Q, small size, low cost and high reliability is also included. Specifications are listed and outline drawings are provided.

Voltronics Corp.,
Denville, NJ (973) 586-8585.

Circle No. 341



▲ Microwave Component and Instrument Catalog

This 96-page catalog features a complete description of the company's waveguide and coaxial products, including adapters, attenuators, circulators, crystal mounts, directional couplers, phase shifters, switches, terminations, transitions and tuners. Specifications and outline drawings are provided.

Waveline, West Caldwell, NJ (973) 226-9100.

Circle No. 342



▲ 1999 Product Catalog

This 224-page catalog details wireless, RF and microwave products, including variable and step attenuators, programmable attenuators, resistive power splitters and dividers, fixed attenuators and terminations, precision adapters and connectors, blind-mate and Planar Crown® connector systems, directional couplers, phase shifters and SmartStep™ components and subsystems. Product photographs are included.

Weinschel Corp.,
Frederick, MD (800) 638-2048
or (301) 846-9222.

Circle No. 343



▲ Microwave Product and Capability Catalog

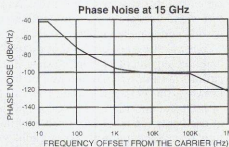
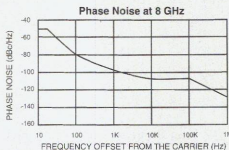
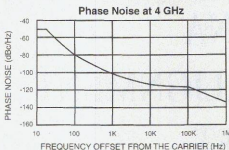
This 12-page catalog contains information on MICs, crystal-stabilized sources, multichannel sources, frequency multipliers, comb generators, frequency synthesizers, frequency converters, receivers and microwave subsystems, and other products specifically designed for use in missile guidance, ground support equipment, radar, satellite communications, data links and other applications.

Zeta, a division of Sierra Networks Inc.,
San Jose, CA (408) 434-3600.

Circle No. 344

Phase-Locked Coaxial Resonator OSCILLATORS

TYPICAL PHASE NOISE



ELECTRICAL SPECIFICATIONS

Output frequency (Fixed)	4 to 15 GHz
Output power	+13 dBm, minimum
Output power variation	±1 dB, maximum
Input reference frequency range	1 to 20 MHz
Input reference power range	-3 to +3 dBm
Output spurious signals	-65 dBc minimum
Output harmonics	-50 dBc minimum
Output impedance	50 Ohm nominal
Load VSWR	1.5:1 nominal
DC voltage (Customer specified)	15, 20 or 24 V
DC current	600 mA typical

FEATURES

- 4-15 GHz with 1-20 MHz Input Reference
- Superior Phase Noise
- Compact Loop Design
- Competitive Performance in a Smaller Package
- 100% Environmental Screening



For further information, please contact Al Annarumma at (516) 439-9172
or e-mail aannarumma@miteq.com.



100 Davids Drive, Hauppauge, NY 11788
TEL.: (516) 436-7400 • FAX: (516) 436-9219/436-7430
www.miteq.com



A MICROWAVE ANTENNA PATH-ALIGNMENT TEST SET

Microwave links require accurate path alignment to ensure proper operation. This process has traditionally required highly trained tower crews to physically align the antennas as well as ground technicians and complex and expensive test equipment to monitor the results. A new test set has been developed that simplifies this task at a low cost without compromising performance or accuracy. Tower installation crews now can perform the entire alignment process on the tower without the need for additional ground technicians or equipment. The associated system's radio equipment and waveguide feeds do not even need to be installed.

THE TRADITIONAL PROCESS

The traditional antenna alignment process requires the use of a transmitter and receiver located at each end of the microwave link. The transmitter generates the signal that passes through the transmission line to the antenna, which radiates the signal over free space to the receive antenna. If the antennas are optimally aligned,

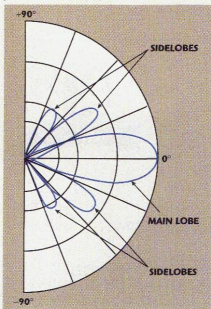
the largest concentration of signal (main beam) is emitted and received and maximum signal transfer is achieved. If the antennas are not aligned properly, the signal transfer is degraded and dynamic range is lost.

Several steps are involved in the process of antenna alignment in a microwave communications system. A voice communication link between the personnel inside the radio room of each site and the tower technicians located at each antenna is required using two-way radios or cellular phones. Some radio systems contain an order wire link for these communications; however, communications to each of the tower technicians still must be established.

Once this setup is completed the tower technicians may begin the adjustment of the azimuth (bearing) of the antennas (one at a time). Careful observation of the output power is necessary to distinguish each antenna's side-lobe to main-lobe response, as shown in **Figure 1**. Once the maximum signal is achieved, the antennas are aligned for optimum elevation. Throughout this process communications between the two sites and between the tower and receiver technicians must be continuous to ensure optimum antenna alignment.

[Continued on page 182]

Fig. 1 Azimuth radiation pattern for a typical parabolic antenna. ▼



XL MICROWAVE INC.
Oakland, CA

It's Time To Hang Up Your Old Technology.



Introducing the millimeter wave Vector Network Analyzer designed to take you into the 21st century: the Lightning™ 65 GHz VNA from Anritsu. Unlike those large, low-performance mmW dinosaurs of the past, the Lightning 65 GHz features a sleek bench-top design. High, fully-leveled, output power and a wide dynamic range. And, of course, the Lightning family's proven track record for speed, accuracy and ease of use.

The new 65 GHz Lightning VNA also brings uncompromising performance to your millimeter wave measurements. With four sampler architecture and a four-channel color LCD display.

Built-in hard and floppy drives. Gain compression software suites and an industry standard V-type coaxial connector, specified beyond 65 GHz.

Continuing the Lightning family's heritage for long-term reliability, the 65 GHz VNA also boasts Anritsu's unprecedented technical support. Featuring flexible on-site programs and complete upgrade plans.

To discover our entire line of newer, faster, leaner and meaner VNAs, call 1-800-ANRITSU or check out our website at www.global.anritsu.com.



Lightning 65 GHz Vector Network Analyzer

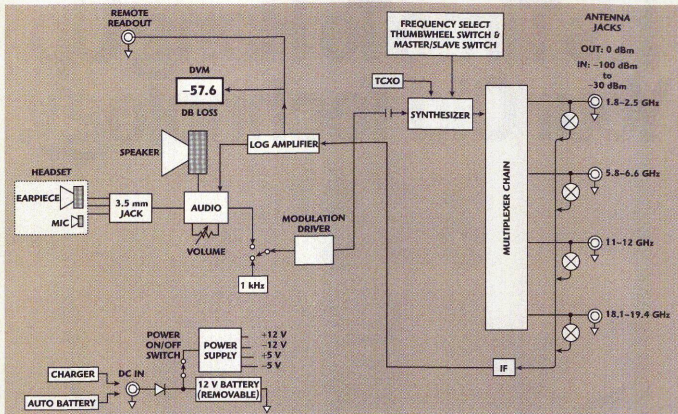
©1999 Anritsu Company Sales Offices: United States and Canada, 1-800-ANRITSU, Europe 44(0)1582433200, Japan 81(03)3446-1111, Asia-Pacific 65-2822400, South America 55(21)527-6922, <http://www.anritsu.com>

Anritsu

One world. One name. Anritsu.

CIRCLE 11 ON READER SERVICE CARD

PRODUCT FEATURE



▲ Fig. 2 The microwave antenna path alignment test set's block diagram.

TABLE I	
KEY SPECIFICATIONS	
Transmission	full duplex
Transmitter output power (dBm)	0 nominal
Transmitter stability (%)	0.005
Tunable operating bands (GHz)	
Band 1	1.8 to 2.5
Band 2	5.8 to 6.6
Band 3	11.0 to 12.0
Band 4	18.1 to 19.4
Modulation (1 kHz tone or voice)	FM
Transmit/receive offset (MHz)	39
Receiver sensitivity (dBm)	-100 nominal
Receiver bandwidth (kHz)	100 nominal
Receiver readout resolution (dB)	0.1
Operating temperature (°C)	-10 to +40
Input power	self-contained 12 V/2.3 Ah rechargeable lead-acid camcorder battery
Dimensions (H x W x D)	3.5" x 8.375" x 13.1"
Weight (lb)	7 each unit
Connectors	SMA-F

A NEW AND IMPROVED METHOD

A new method utilizing a recently developed high performance test set permits antenna alignment to be accomplished without the use or presence of the system's radio equipment. There are several good reasons for not utiliz-

ing the actual system radios to accomplish the antenna alignment process. First, the system radios may not be available at the time the antenna test has been scheduled or their reliability may be questionable. Also, Federal Communications Commission permits for the radios may not have been granted. In addition, if the anticipated path is questionable, a quick, cost-effective method is required to test the link prior to the significant investment of constructing permanent towers and purchasing radios and other equipment.

The Path Align-R™ model 2200 microwave antenna path alignment test set has been specifically designed to quickly and accurately optimize the transmission path between two microwave antenna sites. The process can be completed without the need for the individual site's system radios or other equipment. The battery-powered Path Align-R test set directly drives the site's antenna, providing an indispensable tool for antenna site installation and maintenance personnel. **Figure 2** shows a simplified block diagram of the test set. **Table 1** lists the model 2200 test set's key specifications.

The Path Align-R test set consists of two identical portable units in weather-resistant, instrument backpack measuring 3.5" x 8.375" x 13.1" and weighing only seven pounds each. Four tunable operating frequency bands are available, thus allowing the test technician to choose the appropriate frequency to match the antenna's required operating frequency. The antenna can be adjusted for minimum path loss by utilizing a test unit at each antenna site. The path loss is displayed on the test set's front-panel meter and/or an external instrument, such as a pocket digital

[Continued on page 184]



2 to 7GHz MIXERS ^{\$4⁹⁵} from ^{ea. (5000 qty.)}

They're here! Low profile, low cost level 7, 10, 13 and 17 (LO) frequency mixers offering high IP3 performance over the 2 to 7GHz frequency range. It's Mini-Circuits wide band SKY mixers typically featuring low 6dB conversion loss midband, and high 28dB isolation over the entire band. These miniature 0.10 inch high units are flat as a pancake for today's smaller, high density designs such as PCMCIA's, and are housed in a rugged, J leaded package built to withstand high temperature reflow. When your project demands a reliable surface mount mixer with high performance and value...*Reach For The SKY*, Mini-Circuits tough SKY mixers, with the 5 year Ultra-Rel[®] guarantee.

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

Model	Freq. MHz	LO PWR dBm	Midband Conv. Loss dB, typ.	Bandwidth MHz, typ.	Price \$ea.(1-9)
SKY-42	2000-4200	+7	5.0	31	14.95
SKY-5G	2000-5000	+7	5.8	26	14.95
SKY-7G	2000-7000	+7	7.0	26	16.95
SKY-80	2500-6000	+7	6.2	26	14.95
SKY-60LH	2500-6000	+10	6.2	26	16.95
SKY-60MH	2500-6000	+13	6.2	26	17.95
SKY-60H	2500-6000	+17	6.2	26	18.95
SKY-53R	2800-5300	+7	5.7	26	14.95
SKY-53LHR	2800-5300	+10	5.7	26	16.95
SKY-53MR	2800-5300	+13	5.7	26	17.95
SKY-53HR	2800-5300	+17	5.7	26	18.95



Mini-Circuits[®]

P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661 INTERNET <http://www.minicircuits.com>

For detailed specs on all Mini-Circuits products refer to • 760 -pg. HANDBOOK • INTERNET • THOMAS REGISTER • MICROWAVE PRODUCT DATA DIRECTORY • EEM

ISO 9001 CERTIFIED

US 118 INTL 119

CIRCLE READER SERVICE CARD

F 221 Rev A

PRODUCT FEATURE

voltmeter. The Path Align-R units enable test technicians to talk to each other during alignment over the antenna link in full-duplex FM using the included headset.

The Path Align-R test set provides 100 dB of effective dynamic range, the result of the -100 dBm sensitivity of the individual receivers and the 0 dBm output of the transmitter section. The four frequency bands provided in the standard test set are 1.8 to 2.5 GHz, 5.8 to 6.6 GHz, 11 to 12 GHz and 18.1 to 19.4 GHz. The operator can tune within these bands by means of thumbwheel switches to within 1 MHz of the required frequency. An antenna system with an operating frequency outside of the unit's frequency band edge (for example, 6.8 GHz) may still have its alignment correctly adjusted as long as the antenna system can operate at both the link frequency and a nearby frequency within the test set's operating bands (for example, 6.6 GHz).

A liquid-crystal display indication of direct path loss, within 0.1 dB resolution, is automatically updated

every 300 ms and can quickly detect subtle changes to the antenna response, thus permitting small adjustments to the antenna's azimuth or elevation for optimum signal transfer. Communications between sites and from the radio room to the tower top are significantly improved with a full-duplex FM voice channel. One tower technician can speak to the other using the included headset without having to key a radio. Also, voice communication is enabled immediately after setup and activation — the antennas do not need to be fully aligned for the voice channel to function.

The test set's output is from a synthesized internal signal source that provides an accurate and stable test signal. Comparisons to tests run using an HP 8360 synthesized source and a full-featured HP 8594E spectrum analyzer produced path loss agreement to within 1 dB. However, the Path Align-R test set is priced far below that of a separate synthesized signal source and spectrum analyzer combination. In addition, the cost of communicating between sites can be-

come considerably expensive when using cellular phones or other means. Additional savings are achieved because the required test personnel can be reduced to just two tower technicians and the cost of shipping bulky, expensive test equipment to the sites is eliminated.

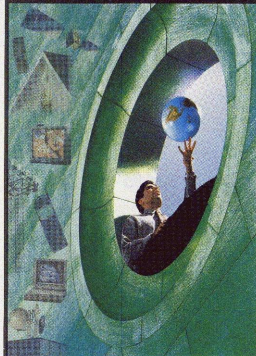
CONCLUSION

The difficulties of scheduling an antenna alignment with the system's radios can cause significant delays. Furthermore, traditional test methods can result in significant test costs. The Path Align-R model 2200 test set offers an accurate and cost-effective method of microwave antenna alignment that is easily performed by two technicians without the use of system radios. Additional information may be obtained from the company's Web site at www.xlmicrowave.com.

**XL Microwave Inc.,
Oakland, CA (510) 428-9488.**

Circle No. 301

SEMICONDUCTORS...ULTRA-SMALL SC-70 PACKAGE



VARIABLES

KEY SPECIFICATIONS	TUNING RATIO	CONFIGURATION	PART NUMBER	PRICING \$100,000
2.6pF@1V, 1.5pF@3V	$C_{11}/C_{12}=1.5$	Common Cathode	SMV1232-074	0.19
6.5pF@1V, 3.6pF@3V	$C_{11}/C_{12}=1.6$	Common Cathode	SMV1234-074	0.19
12.3pF@1V, 2.6pF@3V	$C_{11}/C_{12}=11$	Common Cathode	SMV1248-074	0.19

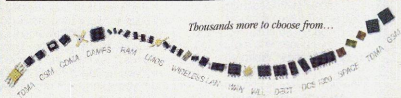
PIN DIODES

KEY SPECIFICATIONS	APPLICATIONS	CONFIGURATION	PART NUMBER	PRICING \$100,000
0.28pF, 0.81@10mA	Switch	Low Inductance	SMP1320-077	0.18
0.23pF, 1.1@10mA	Switch	Series Pair	SMP1321-075	0.19
0.25pF, 15@1mA	Attenuator	Common Cathode	SMP1302-074	0.21

SCHOTTKY DIODES

Low Barrier, 0.22pF	Mixer & Detector	Reverse Series Pair	SMS7621-076	0.26
ZBD, $R_s=3500\Omega$ (Typ.)	Detector	Series Pair	SMS7630-075	0.26

Thousands more to choose from...



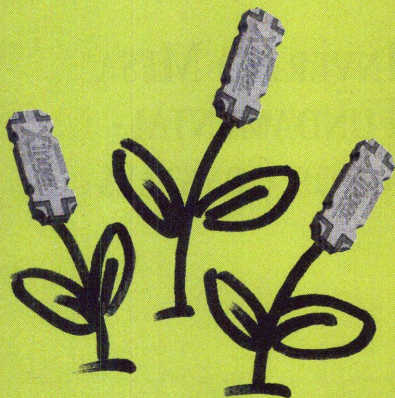
CALL OR SURF TODAY

508-894-1904 www.alphaind.com

20 Sylvan Road • Woburn, MA 01801 USA

Alpha
from concept to solution...your wireless source

Our smallest Xingers yet just cropped up.



Xinger

Just as farmers bump up their crop by working their fields — we've strengthened our line-up of Xinger® surface mounts by responding fast to what our Reps are hearing in the wireless field.

The consensus? "Xingers are cool, but can you make them even smaller so we can do more with them?"

You bet. Check out our 1.7 GHz PCS coupler. At only $0.56'' \times 0.20'' \times 0.075''$, it'll fit like a glove into wireless PBX terminals. Base station LNAs. Heck, a dozen of them will now fit on a multi-carrier PA board with room to spare for other components... No home-grown hassles. No performance tradeoffs on smaller, but lesser, solutions.

Or for wireless LAN designers, there's our equally tiny 2.4 GHz ISM band coupler — for use in WLAN access points, cellular boosters for wireless handsets, or any number of wireless devices finding their way into manufacturing, distribution, and healthcare these days.

We even offer 3.5 GHz hybrids for use in LNA, PA, vector modulator, and signal distribution applications.

Not just because innovation's our thing. But because innovation is your thing.

Xinger® surface mounts, exclusively from Anaren. **What'll we think of next?**

800-544-2414 • www.anaren.com
In Europe, call 44-1705-232392.
Visa/Mastercard accepted (except in Europe).

Anaren

1.7 - 2.0 GHz couplers,
at **half the size.**



Our Xinger® 1.7 - 2.0 GHz surface mount couplers measure up at a mere $0.56'' \times 0.20'' \times 0.075''$ — yet they offer big performance:

- > DCS, GSM, and PCS bands, LNA and PA applications
- > Low .20 dB max insertion loss; 2 degree phase balance; +/- .12 dB amplitude balance; 23 dB min isolation; and a max VSWR of 1.17:1
- > Performance is backed by our exclusive 100% OnSpec® guarantee
- > Cost-competitive
- > And our B-There® service commitment ensures on-time delivery — plus free samples in 24 hrs. for qualified prototype work

Xinger® surface mounts. **What'll we think of next?**

800-544-2414 • www.anaren.com
In Europe, call 44-1705-232392.
Visa/Mastercard accepted (except in Europe).

Anaren

2.4 GHz ISM-band coupler for
wireless LAN lovers.



If you design wireless LANS, you've got to try this $0.56'' \times 0.20'' \times 0.075''$ Xinger® surface mount on for size:

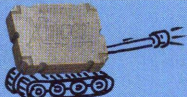
- > ISM and WLL bands, LNA and PA applications
- > Low .20 dB max insertion loss; 2 degree phase balance; +/- .12 dB amplitude balance; 23 dB min isolation; and a max VSWR of 1.18:1
- > Performance is backed by our exclusive 100% OnSpec® guarantee
- > A great price
- > Plus, our B-There® service commitment ensures on-time delivery — plus free samples in 24 hrs. for qualified prototype work

Xinger® surface mounts. **What'll we think of next?**

800-544-2414 • www.anaren.com
In Europe, call 44-1705-232392.
Visa/Mastercard accepted (except in Europe).

Anaren

High-power handling. In a
highly durable package.



Major power handling. Major physical integrity. That's the Xinger® high-power coupler, measuring in at a minuscule $0.65'' \times 0.48'' \times 0.14''$.

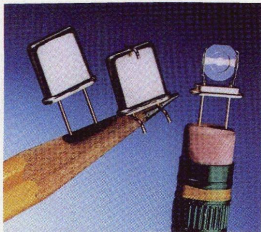
- > GSM, D-AMPS, NMT, PCS, UMTS, IMT 2000, and IS95 applications
- > Up to 200 watt power handling
- > Low .2 dB max insertion loss; +/- .3 dB amplitude balance
- > Performance is backed by our exclusive 100% OnSpec® guarantee
- > A surprisingly low price, in volume
- > Plus, our B-There® service commitment ensures on-time delivery — and free samples in 24 hrs. for qualified prototype work

Xinger® surface mounts. **What'll we think of next?**

800-544-2414 • www.anaren.com
In Europe, call 44-1705-232392.
Visa/Mastercard accepted (except in Europe).

Anaren

CIRCLE 9 ON READER SERVICE CARD



INVERTED MESA FUNDAMENTAL- MODE CRYSTALS

High frequency fundamental-mode crystals are increasingly in demand for applications such as precision high speed clocks, voltage-controlled crystal oscillators (VCXO) and voltage-controlled temperature-compensated crystal oscillators (VCTCXO). However, conventional crystal processing utilizing flat quartz blanks has limited the available frequency range to 55 MHz.

Using higher quality swept quartz, it has long been possible to produce inverted mesa fundamental-mode crystals with frequencies extending beyond 200 MHz. However, the higher cost of materials coupled with slower production throughput has made these resonators undesirable for use in large-volume applications. As telecommunications equipment designers continue to demand oscillators that operate at higher frequencies and still retain the smallest possible size and tightest stability, manufacturers have scrambled to fill this growing market.

Consequently, a means to produce high frequency inverted mesa fundamental-mode crystals without the need to start with swept quartz has been found. The CIM-32 series high frequency crystals were developed with a proprietary processing technology that produces crystals with low series resistance, high pulling ability

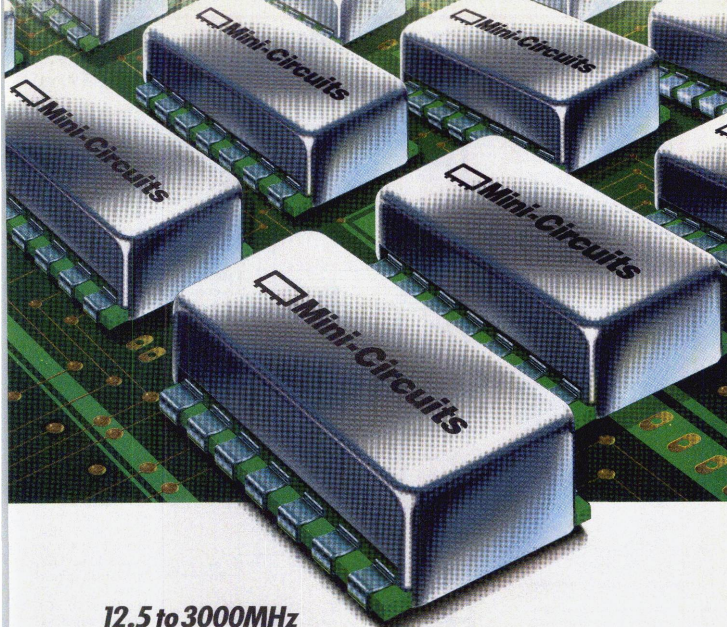
and excellent unit-to-unit and lot-to-lot repeatability at an affordable price. The new crystals are available in frequencies ranging from 51 to 155 MHz and are targeted for applications in precision high speed, low jitter clocks as well as VCXOs, VCTCXOs and low jitter hybrid modules for data communications.

THE NEW DESIGN

Several basic process steps are involved in manufacturing an inverted mesa-type quartz. A quartz wafer is metallized on both sides with a chromium gold masking mechanism in the shape of a doughnut. The plated wafer is then etched for the appropriate length of time depending on the desired frequency of operation using a proprietary etching process, and the metallization is removed from the inverted mesa wafer. At this point, the wafer thickness is 0.0030" to 0.0033" and the thickness of the middle active area for a 155.52 MHz fundamental-mode resonator is 0.00042". Finally, the resonator is enclosed in an HC-45 resistance-welded package that can be supplied for through hole or surface-mount applications.

[Continued on page 188]

CHAMPION TECHNOLOGIES INC.
Franklin Park, IL



12.5 to 3000MHz SURFACE MOUNT VCO's from \$13⁹⁵

Time after time, you'll find Mini-Circuits surface mount voltage controlled oscillators the tough, reliable, high performance solution for your wireless designs. JTOS wide band models span 12.5 to 3000MHz with linear tuning characteristics, low -120dBc/Hz phase noise (typ. at 100kHz offset), and excellent -25dBc (typ) harmonic suppression. JCOS low noise models typically exhibit -132dBc/Hz phase noise at 100kHz offset, and phase noise for all models is characterized up to 1MHz offset. Miniature J leaded surface mount packages occupy minimum board space, while tape and reel availability for high speed production can rocket your design from manufacturing to market with lightning speed. Soar to new heights...specify Mini-Circuits surface mount VCO's.



ACTUAL SIZE

JTOS/JCOS SPECIFICATIONS

Model	Freq. Range (MHz)	Phase Noise (dBc/Hz) SSB@ 10kHz Typ.	Harmonics (dBc) Typ.	V _{tune} TV In:	Current (mA) @+5V DC	Price See (5-49)*
NEW JTOS-25	12.5-25	-115	-26	11V	20	18.95
JTOS-50	25-47	-108	-19	15V	20	13.95
JTOS-75	37.5-75	-110	-27	16V	20	13.95
JTOS-100	50-100	-108	-35	16V	18	13.95
JTOS-150	75-150	-108	-23	16V	20	13.95
JTOS-200	100-200	-105	-25	16V	20	13.95
JTOS-300	150-300	-102	-28	16V	20	15.95
JTOS-400	200-380	-102	-25	16V	20	15.95
JTOS-535	300-525	-97	-28	16V	20	15.95
JTOS-765	455-765	-98	-30	16V	20	16.95
NEW JTOS-1000W	600-1000	-94	-26	19V	25	21.95
JTOS-1025	685-1025	-94	-28	16V	22	16.95
JTOS-1300	900-1300	-95	-28	20V	30	18.95
JTOS-1650	1200-1650	-95	-20	13V	30	19.95
JTOS-1910	1625-1910	-92	-13	12V	20	19.95
JTOS-2000	1370-2000	-96	-11	22V	30 (88V)	19.95
JTOS-3000	2300-3000	-90	-22	---	25 (88V)	20.95
JCOS-820BLN	790-880	-112	-13	---	25 (88V)	49.95
JCOS-820BLN	807-832	-112	-24	14V	25 (810V)	49.95
JCOS-1100LN	1079-1114	-110	-15	---	25 (88V)	49.95

Notes: *Prices for JCOS models are for 1 to 9 quantities. **Required to cover frequency range. ***Tuning Voltage for JTOS-3000 is 0.5 to 12V. JTOS-820WLN and JCOS-1100LN is 0 to 20V. For additional spec information, and details about SV tuning models available, consult RFIF Designer's Guide or call Mini-Circuits.

DESIGNER'S KITS AVAILABLE

K-JTOS1 \$146.00 (Contains 1ea. all JTOS models except JTOS-25, -1000W, -1300 to -3000).

K-JTOS2 \$99.95 (Contains 1ea. JTOS-50, -100, -200, -400, -535, -765, -1025).

K-JTOS3 \$114.95 (Contains 2ea. JTOS-1300, -1650, -1910).

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

Mini-Circuits®

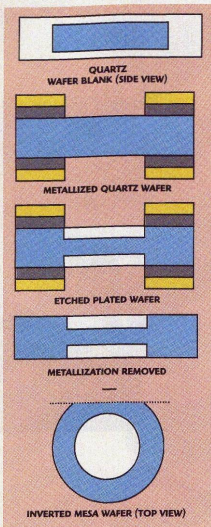
P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661 INTERNET <http://www.minicircuits.com>

For detailed specs on all Mini-Circuits products refer to • 760-pg. HANDBOOK • INTERNET • THOMAS REGISTER • MICROWAVE PRODUCT DATA DIRECTORY • EEM



CIRCLE READER SERVICE CARD

PRODUCT FEATURE



▲ Fig. 1 Basic steps for fabricating an inverted mesa-type quartz crystal blank.

Fig. 2 Frequency stability vs. temperature at 77.76 MHz. ▼

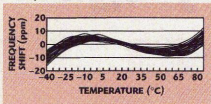
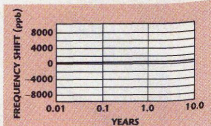
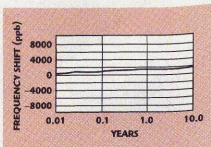


Figure 1 shows the steps involved in this process.

The general specifications for this type of crystal include a maximum series resistance of 25 Ω , a standard load capacitance of 32 pF (other options are available) and a typical frequency tunability of 105 ppm. The device is designed for operation over a -40° to $+85^{\circ}\text{C}$ temperature range. Individual specifications include a nominal operating frequency within the range of 51.84 to 155.52 MHz and a frequency tolerance at 25°C of ± 15 ppm. Temperature stability over a 0° to $+70^{\circ}\text{C}$ range is ± 10

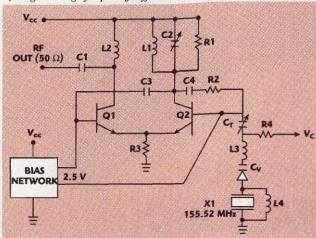


▲ Fig. 3 The inverted mesa crystal's aging at 77.76 MHz.



▲ Fig. 4 The inverted mesa crystal's aging at 155.52 MHz.

▼ Fig. 5 A high frequency differential VCXO example.



ppm referenced to 25°C , and aging for the first year at 25°C is typically 4 ppm. Figures 2 and 3 show typical temperature stability and aging performance, respectively, for a CIM-32-type crystal at 77.76 MHz. Figure 4 shows aging for a similar crystal at 155.52 MHz.

A TYPICAL VCXO APPLICATION

One of the more popular applications of this device is in high frequency VCXOs. The example described here illustrates the crystal in a differential pair topology, as shown in Figure 5. This type of circuit offers several advantages: The amplifier can operate at large-signal amplitudes without serious phase degradation due to the saturation and bias shift present in single transistor designs. Also, the differential pair has a broad

linear region with smooth and symmetrical limiting.

Using a proper design, the differential pair can be kept out of saturation to improve phase noise. In addition, the limiting function can eliminate the need for automatic level control. The differential pair configuration can be realized at very high frequencies. The circuit is noninverting and the collector of Q1 is AC grounded, thus eliminating the Miller effect at the base of Q1. The output is taken from the collector of Q2. In this example, R2 provides the negative feedback and the design uses a tank circuit at the collector of Q2, which removes undesired capacitance and permits higher frequency operation. It also constrains oscillation to the crystal's fundamental mode.

The oscillator's performance is typical of what can be achieved using

an inverted mesa-type crystal. This example operates at $155.52 \text{ MHz} \pm 20$ ppm over a temperature range of 0° to $+70^{\circ}\text{C}$ and produces $> -5 \text{ dBm}$ from a 5 V DC supply at $< 10 \text{ mA}$. The oscillator's phase noise is $< -130 \text{ dBc/Hz}$ at 10 kHz from the output frequency. The tuning deviation from center frequency is $> \pm 100$ ppm with a linearity of < 10 percent for a control voltage of 0.5 to 4.5 V applied to the varactor diode.

CONCLUSION

With the introduction of the CIM-32 series inverted mesa crystals, manufacturers of low cost, high volume electronic equipment can specify their VCXOs with higher frequencies, tighter stabilities and smaller packages without breaking their budgets. A full line of high frequency crystal oscillators using this technology is also available.

Champion Technologies Inc.,
Franklin Park, IL (800) 888-1499,
www.champtech.com.

Circle No. 300

The driving force in cellular and PCS components.



Move ahead of the competition with MECA standard and customized microwave and RF components.

When you're looking for the right components for your cellular or PCS application, you want a supplier with a proven track record—and a vision for the technology that's down the road.

MECA has been designing and manufacturing microwave and RF components since 1961. This experience gives us the power to offer a broad product line that addresses your passive coaxial component needs—whether it's a standard component or customized to meet your unique requirements. In fact, we've made significant contributions to cellular, wireless, and PCS technologies.

We also employ the highest possible product testing and quality-assurance techniques in the business. Our quality system is based on ISO 9002 standards.

In addition, MECA maintains many standard components in stock which are available for overnight delivery.

Put the driving force in cellular and PCS components into your systems today. Call (973) 625-0661 for your MECA product catalog, or visit our website at www.mecaelectronics.com.



Attenuators

- 1-50 watt
- Attenuation values (0-50 dB)
- N, SMA, BNC, TNC

Couplers

- Single/dual directional
- Hybrid
- High-power models (up to 500 watts)

Power Dividers

- High isolation
- 2-, 4-, 6-, 8-way
- N, SMA

Terminations

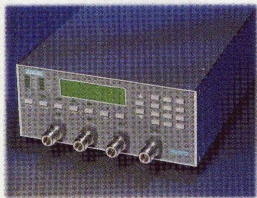
- 50-200 watts
- Low VSWR
- N, SMA, SMB, BNC, TNC



MECA ELECTRONICS, INC.

459 East Main Street, Denville, NJ 07834
Phone (973) 625-0661 • Fax (973) 625-1258
e-mail: mecasale@webspan.net
Website: www.mecaelectronics.com

CIRCLE 83 ON READER SERVICE CARD



PROGRAMMABLE ATTENUATOR SUBSYSTEMS

Finally there is a low cost, easy-to-use programmable attenuator for use on the test bench or in subsystem applications. The new 8310 series SmartStep™ attenuator units represent a new concept in programmable attenuation that is both flexible and easy to program. The standard 8310 series attenuator houses and controls various programmable attenuator models (for example, models 3200T and 150T and the 4200 series attenuators) via front-panel controls or standard communications interfaces such as the general-purpose interface bus (GPIB) IEEE-488, RS-232, RS-422 and RS485.

The programmable attenuator series provides a flexible, easy-to-program, low cost solution for benchtop test and calibration setups and subsystem applications. Additional features include multichannel attenuation paths (up to four inputs and outputs), relative vs. nominal attenuation step functions and a wide choice of frequency and attenuation ranges (DC to 1, 2, 3, 18 and 26 GHz and up to 127 dB). The units feature internal relay switched, GaAs FET or PIN solid-state attenuators, providing high accuracy and repeatability. The standard units are designed for 50 Ω input and output impedance operation, however, 75 Ω configurations are available.

The 8310 series attenuators are supplied in a 12.00" \times 8.38" \times 3.47" housing with front-panel control and readout. In addition, the units may be rack mounted either as a single unit using an available rack-mounting kit (part

no. 193-8033) or two model 8310 units may be mounted together using a slightly different mounting kit (part no. 193-8033-1). Both kits allow the unit to be easily installed into any rack or cabinet that is designed in accordance with EIA RS-310 or MIL-STD-189. The 8310 units combine the features of the model 8210A device controller with a front-panel user interface to form a flexible, easy-to-use solution.

Most 8310 series units are single-channel configurations where the RF signal is routed through either the front- or rear-mounted ports A and B. However, units may be configured for up to four channels of attenuation, RF switching or other functions. Multiple programmable attenuators may be used in conjunction with other coaxial devices such as switches, power combiners, directional couplers and filters, creating single- or multichannel subsystems.

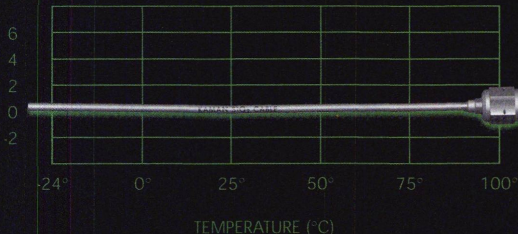
Applications for the 8310 series attenuators range from providing control of a single SmartStep attenuator in a bench test or lab environment using a PC and a terminal emulator to complex multichannel system applications where the 8310 unit is employed to control many devices to create custom subsystems to reduce design cost and increase flexibility. A variety of custom-designed driver interfaces for

[Continued on page 192]

WEINSCHTEL CORP.
Frederick, MD

Stable Cable™

PHASE CHANGE
(deg/ft)



PHASE CHANGE VS TEMPERATURE FOR A TYPICAL .141 DIAMETER CABLE



FOR SPACE

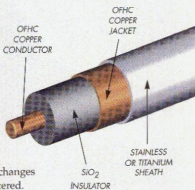


FOR EW/AVIONICS



FOR TEST

Not every application needs a cable this stable. But suppose stability is a big issue. Suppose you're designing the antenna farm for a commercial satellite. Or the avionics systems for a high-performance aircraft. Or a phased array radar. Or suppose you're installing a GPS or SATCOM system. Or upgrading your platform to a more advanced EW system. Or maybe you're performing critical thermal vacuum testing on an orbital platform. You simply can't afford phase or insertion loss changes when temperature fluctuations are encountered.



Your application may call for Kaman's SiO₂ insulated cable assemblies. At frequencies as high as 18GHz, the relative phase changes as little as 70 PPM over a 75°C temperature shift. This outstanding stability lowers design costs, because SiO₂ cable reduces the need for environmental conditioning, complex installations, power and space requirements, and the possibility of phase error in a matched system when different cables experience different temperatures.

All of Kaman's cables are sold as custom assemblies built to your specs, with connectors laser-welded as hermetic assemblies, making them ideal for hostile environments. And you have your choice of stainless steel or titanium jacketing, depending on your weight budget and how much of a weight problem you have. (SiO₂ stainless cable is significantly lighter than a comparable flexible Teflon assembly; SiO₂ titanium is even lighter than that.) Plus Kaman's cable reliability is outstanding: 1,000,000 hours MTBF.

We'd like to talk to you about the benefits of our stable cable. Please call to discuss your project, because SiO₂ is an alternative you should know about.

Kaman Instrumentation Corporation

1500 Garden of the Gods Rd., Colorado Springs, CO 80907
Voice 719-599-1821 Fax 719-599-1823 info-cos2@kaman.com
www.kamaninstrumentation.com

KAMAN

CIRCLE 74 ON READER SERVICE CARD

To see one's work in print is the rightful reward of every creative engineer and scientist. The editors of *Microwave Journal* invite you to submit your technical manuscripts for consideration to be published in one of our upcoming issues. Technical articles, application notes and tutorial articles based on the monthly editorial themes are encouraged. Editorial themes include wireless, radar and antennas; RF components and systems; test and measurement; amplifiers and oscillators; semiconductors and MMICs; commercial applications; IVHS and ITS; dual technologies; communications and PCN; passive components; and control devices, modulation and DSP.



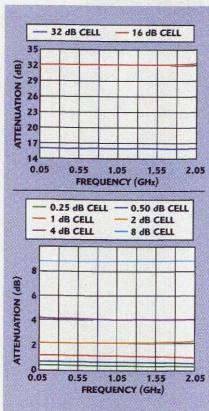
Design features should contain new and innovative technical ideas of practical use and interest to our predominantly engineering readers. Papers should be 14 to 16 double-spaced pages and contain 8 to 12 visual aids in the form of sketches, graphs, photographs or tables.

Papers should be submitted to the attention of the Technical Editor and will be reviewed promptly by our Editorial Review Board prior to acceptance. Articles outside of the monthly themes also will be considered.

SEND ALL MATERIAL TO:

Microwave Journal
685 Canton Street
Norwood, MA 02062
(781) 769-9750
Fax (781) 769-5037

PRODUCT FEATURE



▲ Fig. 1 Typical measured incremental attenuation performance.

▼ Fig. 2 Typical zero insertion loss.

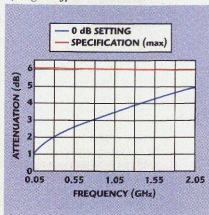
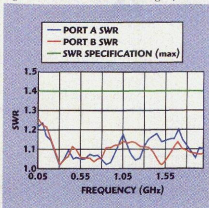


Fig. 3 The SWR at 0.25 dB setting. ▼



various devices, such as RF switches, relays, PIN attenuators, motorized step attenuators and displays, may be supplied.

SPECIFIC MODEL PERFORMANCES

The model 8310-37-2-F attenuator represents a typical example of the 8310 series units. It provides programmable attenuation in 0.25 dB steps to 63.75 dB over the DC to 2 GHz frequency range, as shown in **Figure 1**. Maximum insertion loss is 6 dB, and input and output SWR is 1.4 (max). **Figures 2** and **3** show the attenuator's typical insertion loss and input/output SWR performance vs. frequency, respectively. The unit features two channels and utilizes model 3200T-2 attenuators internally. N-type female connectors are mounted on both the front and rear panels.

The model 8310-38-3-T unit provides 63 dB of attenuation in 1 dB steps from DC to 2 GHz. This unit has three channels utilizing the model 3206T-1 attenuator and has N-type female connectors at both the front and rear panels. Insertion loss is 5.25 dB (max) and SWR is 1.4 (max).

The model 8310-202-R utilizes two 150T programmable attenuators to provide 121 dB of attenuation in 1 dB steps from DC to 18 GHz. Here, the connectors are SMA female on the rear panel. Insertion loss is 5.25 dB (max) and SWR is 1.95 (max).

Many additional models are available to provide different attenuation levels, resolutions, frequency ranges and configurations to suit the needs of a variety of applications. (A complete listing is provided in the 8310 series data sheet.) All models require 100 to 240 V AC at 50/60 Hz and 50 W and operate over a temperature range of 0° to +50°C. In addition, each unit features an IEEE-488 bus interface utilizing a 24-pin IEEE-488-1 connector and appropriate protocols, an RS-232 bus interface with a nine-pin male D connector, and RS-422 and RS-485 interfaces also utilizing a nine-pin male D connector. Additional information may be obtained from the company's Web site at www.weinschel.com.

Weinschel Corp.,
Frederick, MD (301) 846-9222.

Circle No. 303



Only **\$36⁹⁵**
ea. (qty. 1-49)

2W SMA DC to 18GHz ATTENUATORS

How can you buy attenuators that combine world renowned engineering expertise with high quality stainless steel construction, low cost, and off-the-shelf availability? Specify Mini-Circuits fixed attenuators! Built tough to handle 2 watts average with 125 watts peak power, this attenuator series supplies precision accurate 1dB to 40dB attenuation values with high temperature stability and excellent phase linearity in the wide DC to 18GHz band. Call Mini-Circuits and capture this next generation of value for your system integration today!

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



Mini-Circuits®
Celebrates Y2K!
**Buy 1
Get 1 Free!**

Buy Up To 25 Units Of Each Model At The Regular Price
Get An Equal Amount FREE!
Offer expires January 31, Year-2000

Model	Attenuation (dB)		Length (inches)
	Nominal	Accuracy*	
BW-S1W2	1	±0.40	.85
BW-S2W2	2	±0.40	.85
BW-S3W2	3	±0.40	.85
BW-S4W2	4	±0.40	.85
BW-S5W2	5	±0.40	.85
BW-S6W2	6	±0.40	.85
BW-S7W2	7	±0.60	.85
BW-S8W2	8	±0.60	.85
BW-S9W2	9	±0.60	.85
BW-S10W2	10	±0.60	.85
BW-S12W2	12	±0.60	.85
BW-S15W2	15	±0.60	.99
BW-S20W2	20	±0.60	.99
BW-S30W2	30	±0.85	.99
BW-S40W2	40	±0.85	.99

Equipped with SMA male and female connectors.

.312" across hex flats.

*At 26°C includes power and frequency variations up to 12.4GHz. Above 12.4GHz add 0.5dB typ. to accuracy.

ALL VALUES IN STOCK

Mini-Circuits®

US 122 INTL 123
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>

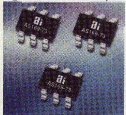
ISO 9001 CERTIFIED



COMPONENTS

■ DC - 2.5 GHz Integrated SPDT Switch

The model AS169-73 integrated pseudomorphic high electron mobility transistor (PHEMT)



SPDT switch delivers a broadband, low cost, integrated switching solution for transmit and receive chains operating from DC to 2.5 GHz. The AS169-73 features low loss

insertion loss of 0.4 dB at 2.5 GHz and positive voltage operation with low DC power consumption. Manufactured in the miniature SOT-6 plastic package, this general-purpose switch can be used in a variety of telecommunications applications. Price: \$2.70 each (100).

Alpha Industries,
Woburn, MA (800) 290-7200, ext. 306
or (308) 894-1904.

Circle No. 215

■ 100 dB High Isolation Switch

The model SWM-6000-IDTU-ECL-GB ultra-high speed, 20 ns balanced, low video trans-



ient, nonreflective, SPST solid-state switch offers 100 dB isolation. Insertion loss is 3 dB and SWR is 2 (max) between 10 MHz and 2 GHz. The switch operates from ± 5 V

DC at ± 100 mA (max) with emitter-coupled logic, but TTL is also available. The unit measures 1.5" \times 1.5" \times 0.4" with removable SMA connectors. Miniature sizes are also available.

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

Circle No. 216

■ Multiport RF Connector System

This flexible multiport RF connector system houses an array of microminiature blindmate



RF contacts, each providing a robust RF interface up to 18 GHz, within a chamfered light-weight aluminum shell. The system

is designed specifically for applications requiring reliable, high density RF signals where small size and weight characteristics are important, and will accommodate the increased bandwidth required for next-generation broadband communications services, including video conferencing, digital data transfer, audio/video distribution and Internet traffic. A full complement of electromagnetic interference/RF interference shielding features are included to protect signal integrity, and locking jack screws ensure reliability with protection from shock and vibration.

AMP Inc., Harrisburg, PA (717) 393-3831.

Circle No. 217

■ Analog-to-digital Converter

The model AD9288 eight-bit analog-to-digital converter operates at 3 V and contains



onboard track-and-hold circuits and separate encode clocks, allowing maximum design flexibility. Its low power require-

ment (110 mW with an input frequency of 10.3 MHz at 100 Msps per channel, single-supply operation and good dynamic performance make the AD9288 particularly well suited for dual-channel communications applications. The unit's two channels can be operated separately, making it useful for battery-powered applications such as hand-held wireless equipment and low cost digital oscilloscopes. Prices (1000): \$15.30 (100 Msps), \$9.99 (80 Msps) and \$5.40 (40 Msps). Delivery: stock.

Analog Devices Inc.,
Norwood, MA (800) 262-5643
or (781) 937-1428.

Circle No. 218

■ Dual B-band Preselector Shelf

The model 5000440 rack-mount shelf with two eight-pole cellular wireline receive filters protects B-band (wireline) base receivers from interference from most A-band (nonwireline) mobiles and portables. The unit's dual filters offer diversity receiver protection in a single 3.25" package, and combine bandpass filters feature steep skirts below 835 MHz and above 849 MHz. The dual B-band preselector shelf also protects against trunking base transmitter interference and provides extra filtering in the nonwireline receive band (824 to 835 MHz) and trunking transmit band (851 to 866 MHz).

Celwave, a division of Radio
Frequency Systems Inc.,
Marlboro, NJ (800) 235-9283.

Circle No. 219

■ Magnetic Coaxial Fail-safe Switch

The 601 series low cost, miniature, magnetic coaxial fail-safe switches operate from DC to



18 GHz. Standard with SMA connectors, these 50 Ω impedance switches with actuating voltage of 12 or 25 V DC can handle up to 100 W CW. Insertion loss is

0.50 dB (max), SWR is 1.5 (max) and isolation is 60 dB (min) with a switching time of 20 ms. Intended for test equipment applications, including switch matrices, microwave radios and selection of alternating antennas that are connected to a transmitter or receiver, these switches offer up to five million operations without performance degradation and can be used to alter the path of an incoming signal to one of the two outputs or one of the two inputs for an output.

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

Circle No. 221

NEW PRODUCTS

■ 300 W UHF Drop-in Isolator

The model EU332 drop-in isolator is designed specifically to operate in the UHF telecommu-



nication frequency bands and isolate the linear-amplifier output stage from its load. Operating over the 0.8 to 1.0 GHz frequency band, the isolator provides typical insertion loss of 0.08 to 0.10 dB

between 836 and 881 MHz, isolation of 23 dB (min) and output power of 300 W. Operating temperature range is 0° to +85°C and SWR is 1.17 (max). The integral termination can absorb 100 W of reverse power continuously. Size: 1.25" \times 1.69" \times 0.310".

Channel Microwave Corp.,
Camarillo, CA (805) 482-7280.

Circle No. 220

■ DC - 18.2 GHz TNC Connectors

These high power, hermetically sealed TNC connectors cover the DC to 18.2 GHz band



with a maximum SWR of 1.1 and can handle 1 kW CW. Designed for use in the company's hybrid cou-

plers and filters as well as other microwave components, these connectors feature very low loss and superior mechanical rigidity as compared to the conventional connector design, protecting the component's internal circuit. This in turn allows for use in extremely harsh environments. These connectors are available in screw-in type (spark plug) or flange-mounted style, and the design can be adapted to a type-N and -SC.

Microwave Engineering Corp. (MEC),
North Andover, MA (978) 685-2776.

Circle No. 230

■ Filters and Diplexers

These millimeter filters and diplexers in a suspended substrate operate from DC to 40 GHz



over the passbands of DC to 18, 18 to 26 and 26 to 40 GHz. Crossovers are 18, 23, 26 and 30 GHz, and rejection/

isolation is 50 dB (min) at crossovers of ± 15 percent. Connectors are K female/male. The filters and diplexers offer insertion loss of 2 dB (min), SWR of 2 and crossover tolerance of ± 0.25 percent.

ES Microwave LLC,
Gaithersburg, MD (301) 519-9407.

Circle No. 222

■ Tunable Bandpass and Bandreject Filters

The BT and TNF series tunable filters are designed for cellular, PCS, PCN and VLL applications and include octave range tuning that

replaces the need for several fixed tuned filters. The BT bandpass series filters operate from 500 to 3000 MHz and feature impedance of 50 Ω , nominal 3 dB bandwidth of five percent, SWR of 1.5 and power handling up to 5 W. The TNF bandreject series filters operate from 100 to 2000 MHz and offer passband insertion loss of < 0.5 dB (max) passband, SWR of 1.5 and impedance of 50 Ω . Delivery: stock.

K&L Microwave Inc.,
Salisbury, MD (410) 749-2424.

Circle No. 258

5.8 - 18.4 GHz Waveguide

The model WRD 584 waveguide is offered in a new size that allows transmission of C, X and



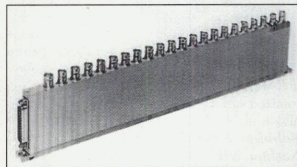
Ku SAT-COM bands as well as the extended DBS band and covers the 5.8 to 18.4 GHz frequency band. WRD 584

directional couplers, terminations, adapters and related components also are available.

Microwave Development Co. Inc.,
Salem, NH (603) 870-6280.

Circle No. 289

Triaxial-to-coaxial Converters



The model 12740 triaxial-to-coaxial converter and/or coaxial-to-triaxial converter and distribution modules feature nine converters in one module, adjustable gain and DC offset, and unity plus gain. Input/output impedance is 50 or 75 Ω over the DC to 200 MHz bandwidth. Typical applications include converter modules and distribution amplifier modules. Special configurations are available.

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

Circle No. 227

High Ratio Isolators

This complete line of low cost, high performance high ratio isolators features isolation up to 60 dB,



SWR of 1.15, insertion loss of < 0.5 dB through the double pass and a 30 dB \pm 1 dB flat attenuator port for reverse power monitoring. Designed for cellular, PCS and DCS applications, these isolators

can handle up to 300 W CW power in the forward direction and 200 W CW in the reverse direction. Delivery: less than 30 days.

Mica Microwave Corp.,
San Jose, CA (408) 363-9200.

Circle No. 228

GaAs Switches

The model ITT501AJ SPDT high power transmit/receive (T/R) switch operates from +3 to +10 V and features positive control with a 1 dB compression point of 35 dBm at +5 V. Pack-

aged in an MSOP-8 plastic package, the switch is compatible with standard T/R switches. The ITT5159AB \sim 5 V, high isolation, SPST reflective switch operates over the 0 to 5 GHz frequency range. Provided in an SO-8 package, the switches exhibit 49 dB of isolation at 1.0 GHz. These switches, along with six others introduced by the company, are designed for use in wireless handsets, local area networks, data, base stations and other wireless applications.

CaAsTEK, a unit of ITT Industries,
Roanoke, VA (888) 563-3949
or (540) 563-3949.

Circle No. 224

Bandpass Filters

The MMFM-FBGW series bandpass filters feature center frequencies from 500 MHz to

40 GHz, a nominal 10.1 MHz 1 dB operating bandwidth, typical insertion loss of 3.9 dB and nominal input/output impedance of 50 Ω . These narrowband filters offer unique properties that make them well suited for applications in which extremely narrow bandwidths, small size, low insertion loss, moderate power levels and easy integration with other components are critical. The filters are manufactured using the company's Multi-Mix™ multilayer manufacturing process that typically results in a filter that is significantly smaller, lighter and less expensive than conventional counterparts. Operating temperature range is \sim 55° to +125°C. Size: 0.80" \times 0.24" \times 0.24".

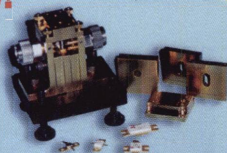
Merrimac Industries Inc.,
West Caldwell, NJ (888) 434-6636.

Circle No. 233

'Measurement Solutions are our Business'

Focus Microwaves' line of superior, high quality products make your critical measurement solutions possible.

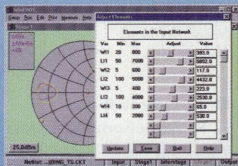
NEW!



MLTF, a Minimum Loss Transistor Test Fixture for Sub 1 Ω Load Pull Measurements

Insertion loss <0.04 dB to 5 GHz
Return loss >30 dB
Includes DC bias networks

NEW!



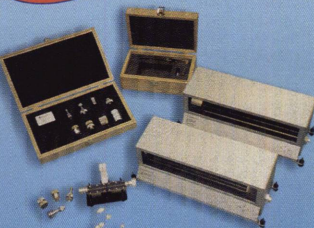
WinPADS, 2 stage Power Amplifier Design Software using Load Pull Contours with schematic capture, interactive manual tuning and extremely fast optimizers

COMPLETE SET OF COMPONENTS ALL IN 7/16 FOR HIGH POWER LOAD PULL.

Includes:

- Two **Programmable Tuners** (0.2/0.4 - 3 GHz)
- One or two selective **Harmonic Tuners**
- High Power **Test Fixture** with TRL calibration and water cooling capability
- **Complete Calibration, Measurement and Graphics Software** in Windows 95/98 or NT

THE EXPERT'S CHOICE



Take advantage of our latest innovations in load pull & noise measurement technology.

Visit our Website at:
<http://www.focus-microwaves.com>
or Contact us directly for our latest catalogue



Focus microwaves

970 Montee-de-Liesse, Suite 308, Ville St-Laurent, Quebec, H4T 1W7

Tel: (514) 335-6227 • Fax: (514) 335-6287

Email: info@focus-microwaves.com

NEW PRODUCTS

■ RF Preselector Bandpass Filter

The model 3275RF(3) bandpass filter is a cavity type, fully tunable filter used in UHF applications. The filter offers three high Q cavities, providing less than 2 dB insertion loss over a 6 MHz operating bandwidth and > 15 dB rejection at ± 5 MHz from center frequency, > 25 dB rejection at ± 13 MHz from center frequency and > 40 dB rejection at ± 22 MHz from center frequency. Return loss is 14 dB (min) in the passband, and the filter can be retuned to any 6 MHz channel in the 470 to 890 MHz frequency range. The unit is available in two- or four- cavity configurations to provide more or less selectivity as required, and 50 or 75 Ω configurations as specified.

Microwave Filter Co. Inc. (MFC),
East Syracuse, NY (800) 448-1666
or (315) 438-4747.

Circle No. 231

■ 800 - 1000 MHz Frequency Mixer

The model ADM-10DH frequency mixer is a low noise, high performance solution for airborne and cellular applications, and has a typical conversion loss of 6.0 dB and 30 dBm IP3 (typ at midband). Operating over the 800 to 1000 MHz frequency band, these level 17 surface-mount mixers typically provide L-R and L-I isolation of 35 and 37 dB, respectively, and have a maximum 200 mW RF power rating. Operating temperature range is -20° to $+85^\circ\text{C}$. Price: \$15.95 (1-9 units).

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

Circle No. 232

■ Lightning and EMP Protection Products

These coaxial lightning protection products for use in base stations are integrated into an antenna feed line and designed specifically to protect expensive equipment from lightning and electromagnetic pulse (EMP)-induced energy. A variety of interfaces are available, including type-N and 7/16 DIN connectors. All parts are designed to handle the high induced current as-

sociated with lightning and EMP as well as deliver superior 1M performance.

Narda Microwave-East,
Hauppauge, NY (516) 231-1700.

Circle No. 234

■ Radiation-resistant RF Coaxial Connectors

These 50 Ω radiation-resistant RF coaxial connectors are designed with special insulators and constructed for use in nuclear environments. The devices have brass or beryllium-copper bodies with silver or nickel plating (or stainless steel) and aluminum

construction. Featuring insulators machined from Rexolite® or other radiation-resistant materials and beryllium-copper center contacts, the connectors are capable of withstanding neutron and gamma irradiation. Available with N, HN, LC, BNC and twin interfaces per MIL-STD-348, the connectors can be supplied as straight plugs, jacks, and tee- or angle adapters, and are ideally suited for use with RG-8A, 9B, 213 and 214/U cable types.

Tru-Connector Corp.,
Peabody, MA (800) 262-9875
or (978) 532-0775.

Circle No. 242

■ Drop-in Isolator

The model 04701ED drop-in isolator provides 20 dB isolation and has low insertion loss of 0.4 dB over the frequency bandwidth of 4.4 to 5.0 GHz with an SWR of 1.25. The circuit tabs are designed to provide excellent yield during circuit assembly.

Operating temperature range is -20° to $+85^\circ\text{C}$. (Storage temperature range is -50° to $+125^\circ\text{C}$.) The package size is: $0.5" \times 0.5" \times 0.25"$. Delivery: stock. (Isolators and circulators in other frequency bands are available in a similar package.)

Nova Microwave,
Morgan Hill, CA (408) 778-2746.

Circle No. 235

■ 75 Ω Broadband RF Directional Couplers

These 75 Ω surface-mount broadband RF directional couplers have an operating bandwidth of 5 to 900 MHz, are rugged enough to withstand IR reflow manufacturing techniques and operate in an environment within a temperature range of -40° to $+85^\circ\text{C}$. Designed specifically for use in high volume cable applications such as set-top boxes, line amplifiers and headend equipment, these directional couplers separate an input signal into two unequal output signals, and the stronger signal appears at the main output port with little degradation. The highly isolated smaller signal allows network designers to sample the main line signal without affecting it. Price: \$1.36 (25,000). Delivery: six weeks.

Pulse, a Technitrol company,
San Diego, CA (858) 674-5100.

Circle No. 236

■ Surface-mount Hybrids and Couplers

These high power, surface-mount quadrature hybrids and surface-mount 3 dB couplers cover the 1.5 to 2.4 GHz and the 20 MHz to 20 GHz bands, respectively. Both series have superior match and repeatability, and cross reference to any size and frequency up to over

20 GHz. While most of the company's products are an octave wide, some can be optimized for 1° phase match and 0.1 dB amplitude match in narrower-band cases, such as cellular and PCS.

RADITEK, San Jose, CA (408) 266-7404.

Circle No. 237

■ PIN Diode Switches

These SPST, SP2T, SP3T and SP4T ultraminiature switches operate over the frequency range

of 2 to 18 GHz with a 100 ns switching speed. The switches are designed to operate over the -55° to $+100^\circ\text{C}$ temperature range and have removable connectors for drop-in applications. Customized variants of these standard switches are also available. Delivery: two weeks.

Robinson Laboratories Inc.,
Nashua, NH (603) 880-7880.

Circle No. 238

■ Wideband, Load-insensitive Mixers

The models SM5T, SM5T17 and SM5TH wideband, load-insensitive mixers are available in hermetic, surface-mount packages for high reliability applications. Frequency coverage is 50 to 5000 MHz, LO and RF

(F), with availability in +10, +17 and +23 dBm LO drive levels. Typical performance includes 7.2 dB conversion loss and 35 dB isolation.

Stellax Electronics Inc.,
Palo Alto, CA (800) 321-8075.

Circle No. 239

■ Miniature, Tight-tolerance Chip Inductors

The PTL1005-F series photo-etched chip inductors offer reliability and superior performance to a variety of mobile communication designs and have a 0402 footprint (1.0 mm \times 0.5 mm) with a low profile of 0.5 mm. Designed for use in GaAs FET

matching circuits such as low noise amplifiers and voltage-controlled oscillators, these highly

[Continued on page 202]

Phase Locked Sources

Operational, Deployed, Field Proven



FEATURES:

- DRO Compatible Size
- Excellent Phase Noise
- Ruggedized for Microphonics
- 2-20 GHz Frequency Coverage

Micro Lambda, Inc. a leader in the development of next-generation YIG devices now offer YIG-Based Phase Locked Sources covering the 2-20 GHz frequency range. Designed specifically for harsh commercial environments, these oscillators offer 3 to 10 dB better phase noise performance than DRO's. Applications include LMDS, MVDS, VSAT, Tele-Comm and a multitude of general applications.

MLPE-SERIES PHASE LOCKED OSCILLATORS:

Utilize external reference oscillators from 50-200 MHz to generate fixed frequencies covering 2-20 GHz.

MLPI-SERIES PHASE LOCKED OSCILLATORS:

Utilize internal reference oscillators to generate fixed frequencies covering 2-20 GHz.

MLTP-SERIES TUNEABLE PHASE LOCKED OSCILLATORS:

Utilize external reference oscillators with the capability of coarse tuning the output frequency via the oscillators main coil or with integrated digital interface in step sizes equal to the external reference frequency.



**MICRO
LAMBDA, INC.**

48041 Fremont Blvd.
Fremont, CA 94538
Phone (510) 770-9221
Fax (510) 770-9213
Email: microlambda@aol.com
Internet: www.micro-lambda.com



NEW PRODUCTS

stable chip inductors have a ± 0.2 nH or two percent inductance tolerance over the full temperature range and a 100 ppm/°C temperature coefficient. Self-resonant frequency is controlled within ± 10 percent and inductance is specified at 800 MHz as well as 100 MHz. The PTL1005 devices are available in 1.0 to 12.0 nH inductance values and are packaged on tape and reel in 1000-piece quantities.

Toko America Inc.,
Mount Prospect, IL (847) 297-0070.

Circle No. 240

■ Integrated VCO and Mixer Assembly

The model VDM1900-260L combined VCO, mixer, filter and amplifier is integrated and positioned on one circuit board. Primarily designed for wireless applications in PCS base stations, the combination eliminates tuning mismatch errors and reduces tuning and testing time. The integration of these components provides conservation of board space with dimensions of $1.20" \times 1.20" \times 0.28"$ and conserves power with a typical current draw of 100 mA.

Trak Communications Inc.,
a Tech-Sym company,
Tampa, FL (813) 884-1411.

Circle No. 241

■ Power Switches



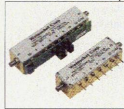
The model SM2001 16 A power switch and SM7001 terminated microwave switch are designed for high density signal switching systems that require fast switching speeds. The SMIP family of switches provide more than 30 different switch configurations from DC to light, and can be controlled via a general-purpose interface bus, RS-232, Firewire, Ethernet or PCI. Delivery: stock to four weeks (ARO).

VXI Technology Inc. (VTI),
Irvine, CA (949) 955-1894.

Circle No. 243

■ 1000 W Coaxial Attenuators & Terminations

The model S2 coaxial attenuators and model 1456 terminations are capable of handling up to 1000 W average (unidirectional) and 10 kW peak power over the frequency range of DC to 3 GHz. The attenuators are available in 20, 30 and 40 dB versions. Others feature of the attenuators



and terminations include a maximum SWR of 1.25 and operating temperature range of -55° to $+125^{\circ}$ C. Type-N or 7/16 connectors are available.

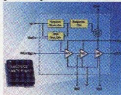
Weinisch Corp.,
Frederick, MD (800) 638-2048
or (301) 831-4701.

Circle No. 244

AMPLIFIERS

■ CDMA Power Amplifier

The model AWT6101 MIC CDMA power amplifier operates across the 1850 to 1910 MHz



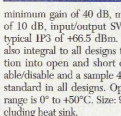
frequency range and has a low leakage of less than 10 μ A, allowing extended standby times. Designed to minimize cycle time, save board space and reduce cost, the self-contained amplifier delivers linear operation up to +29 dBm with high efficiency of 32 percent and manages voltage turn-on and turn-off synchronization with a single interface pin. The amplifier is one of the first parts that incorporates the company's integrated DC-to-DC converter technology, which allows all of the benefits of GaAs devices without the need to supply negative voltage and additional supporting components in system designs. Size: 7 mm \times 7 mm.

ANADIGICS Inc.,
Warren, NJ (908) 668-5000.

Circle No. 245

■ 2.6 GHz 180 W Broadband Amplifier

The 180 W class A broadband wireless GaAs FET power amplifier, with a removable heat sink, operates from 2.4 to 2.7 GHz over any 200 MHz bandwidth. All units include over-voltage, reverse polarity and over-temperature protection. The amplifier provides

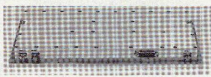


minimum gain of 40 dB, maximum noise figure of 10 dB, input/output SWR of 1.5 (max) and typical IP3 of +66.5 dBm. An output isolator is also integral to all designs to ensure safe operation into open and short circuits, and RF enable/disable and a sample 40 dBc RF output are standard in all designs. Operating temperature range is 0° to $+50^{\circ}$ C. Size: $9.0" \times 13.0" \times 1.5"$, excluding heat sink.

Chesapeake Microwave Technologies Inc.,
Glen Rock, PA (717) 235-1655, ext. 112.

Circle No. 246

■ 13 W CDMA High Power Amplifier



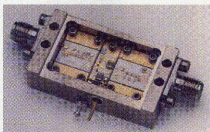
The model HPA1920-13 highly linear 13 W CDMA high power amplifier is fully compliant to J-Std-005 specifications and covers the en-

tire PCS transmit band of 1930 to 1990 MHz with a gain of 30 dB. This solid-state amplifier designed for single-channel tower-top or base station applications meets all specifications over a DC input range of 26 to 29 V DC with an operational current of < 5.5 A. Operational baseplate temperature range is -30° to $+85^{\circ}$ C. Monitor lines are provided for over-temperature, over-current and over/under supply voltage fault status. Size: $12.0" \times 5.8" \times 1.1"$.

MPD Technologies Inc.,
Hauppauge, NY (516) 231-1400, ext. 452.

Circle No. 248

■ Multi-octave Band LNA



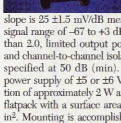
The model JCA26-300P low noise amplifier (LNA) has been designed to provide a low noise figure over multi-octave bands. The amplifier covers a frequency of 2 to 6 GHz with a minimum gain of 30 dB and gain flatness of ± 1.5 (max). Noise figure is 2.0 dB (typ), input/output SWR is 2.0 and output power is +10 dBm. Amplifiers can be customized to provide optimal performance for the customer's individual specification requirements. Delivery: two to three weeks (ARO).

JCA Technology Inc.,
Camarillo, CA (805) 445-9888.

Circle No. 247

■ Miniature Dual Log Amplifier

The model MCWL-4-4538 is a pair of matched miniature logarithmic amplifiers featuring log linearity of ± 0.75 dB (typ) and a standard center frequency of 200 MHz with an operating bandwidth of at least 20 MHz.



The log video slope is $\pm 25 \pm 1.5$ mV/dB measured over the input signal range of -67 to $+3$ dBm (typ). SWR is less than 2.0, limited output power is 0 dBm (nom) and channel-to-channel isolation between pairs is specified at 50 dB (min). The unit requires a power supply of ± 5 or ± 6 V with total consumption of approximately 2 W and is housed in a dual flatpack with a surface area of approximately 1.3 in². Mounting is accomplished via four through-hole threaded flanges. Price: \$2950 (5-9).

Signal Technology Corp.,
Elektron Operation,
Beverly, MA (978) 524-7444.

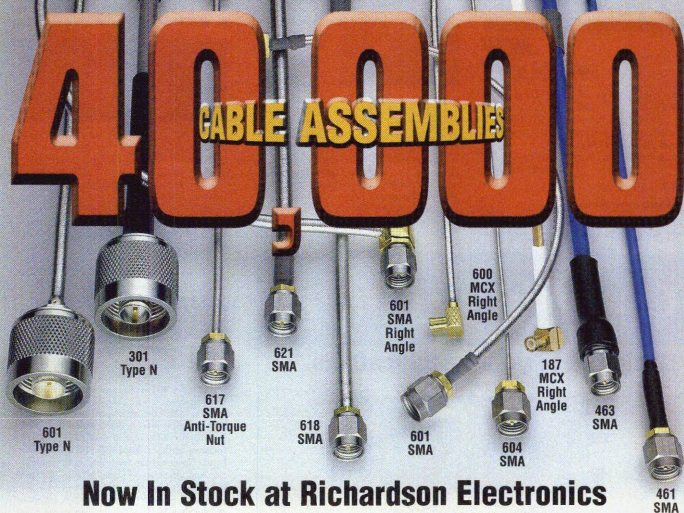
Circle No. 250

■ Solid-state Power Amplifier

The model SPA-5964-200-26200 solid-state power amplifier covers the frequency band of 5.850 to 6.425 GHz and is designed for satellite communication terminals, travelling-wave-tube amplifier retrofits and very small aperture terminal hub applications. The amplifier features class A linearity, gain and temperature compensation, an integral thermal management system, and control and monitoring function.

[Continued on page 204]

40000 CABLE ASSEMBLIES



Now In Stock at Richardson Electronics



MCX Straight



MCX Right Angle



SMA



SMA Right Angle



Type N

Cable Code	Flexible Low Loss 301	Semi-Flex 600	Semi-Flex Plus 620	Semi-Flex II 617	Semi-Flex 601	Semi-Flex Plus 621	Semi-Flex II 618	Q-Flex 461	Q-Flex 463	Semi-Flex 604	RG316 187
Diameter	.195	.086	.115	.086	.141	.180	.141	.110	.170	.047	.102
MCX Straight		✓								✓	✓
MCX Right Angle		✓								✓	✓
SMA	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
SMA Right Angle		✓			✓					✓	
Type N	✓				✓						

In stock, fully specified cable assemblies with selected lengths and connector combinations.

Data sheets available at www.qmiinc.com



MADE IN THE USA

Tensolite
QMI® Microwave Interconnects
 A CARLISLE Company



"Do it Yourself" - call QMI for cable and connector price and availability. Selected options and lengths in stock for immediate delivery from QMI's Worldwide Distributor:

Richardson Electronics
 Engineered Solutions
 1-800-RF-POWER

301 Ballardvale St. Wilmington, MA 01887

1-800-362-FLEX

FAX: (978) 988-9393

www.qmiinc.com Email: sales@qmiinc.com

CIRCLE 142 ON READER SERVICE CARD



NEW PRODUCTS

tions. Output power is 52 dBm (min) at -1 dB GCP (53 dBm typ), small-signal gain is 70 dB (min) at 25°C and input/output SWR is 1.25. Operating ambient temperature is 0° to +50°C. **Pascal Electronics Ltd., Ryde, Isle of Wight, UK +44 0 1983 817425.**

Circle No. 249

17 - 19 GHz Microwave Amplifier

The model PAN-19001 microwave amplifier covers the 17 to 19 GHz frequency range and



provides a five percent bandwidth (900 MHz midband) centered between the overall frequency limits. Output power is 30 dBm (min) at a 1 dB compression point over the full band, input SWR is 1.5 (max), output SWR is 1.3 (max), small-signal gain is 40 dB (min) and operating temperature is between 0° and +55°C. In-band spurious is < -60 dBm and noise figure is 10 dB (max). Size (excluding connectors): 172 mm x 72 mm x 31 mm.

Wessex Electronics Ltd., Dornand, Bristol, UK +44 117 957-1404.

Circle No. 252

W-CDMA Amplifier

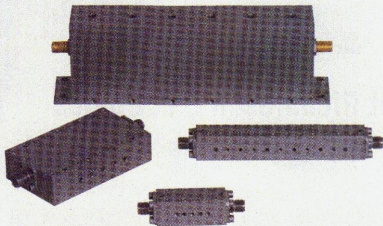


The 25 W wideband CDMA (W-CDMA) broadband single-carrier amplifier covers the 2.11 to 2.17 GHz bandwidth and meets the needs of the data-intensive 5 MHz bandwidth third-generation wireless markets. The IMT-2000 amplifier features low cost, small size, high reliability and hot swap field-replaceable modules and is available in a standard rack configuration with up to four 25 W amplifiers per shelf. **Spectrian, Sunnyvale, CA (408) 745-5400.**

Circle No. 251

Combine Filters

Designed to your specifications.



- For Frequencies of 500 MHz to 26.5 GHz
- 2 to 17 Resonant Sections
- Bandwidths of 3 to 50%.

Foreign Distributors Sought.

MFC

MICROWAVE FILTER COMPANY, INC.
6743 KINNE STREET • EAST SYRACUSE, NY 13057
800-448-1666 • 315-438-4700 • FAX: 315-463-1467
<http://www.microwavefilter.com>
e-mail: mfcsales@microwavefilter.com

ANTENNAS

MMDs Antenna Range

The DataMaster™ antenna range for two-way multichannel, multipoint distribution service (MMDs) systems is available in three versions, including a 90° sector transmit antenna for two-way systems with 18 dBi gain in the 2500 to 2700 MHz frequency band, and receive antennas for two-way systems with a gain of either 18 dBi (90° sector size) or 22 dBi (30° sector size) in the 2150 to 2360 MHz frequency band. Designed for sectorized data transmission and efficient use of the MMDs spectrum for data applications, the antenna pattern performance provides front-to-back ratios of greater than 30 dB and minimizes sector interference. The antennas are available in horizontal and vertical polarization, weigh approximately 20 lb, can survive winds of up to 150 mph and will continue to operate in temperatures between -40° and +70°C.

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

Circle No. 253

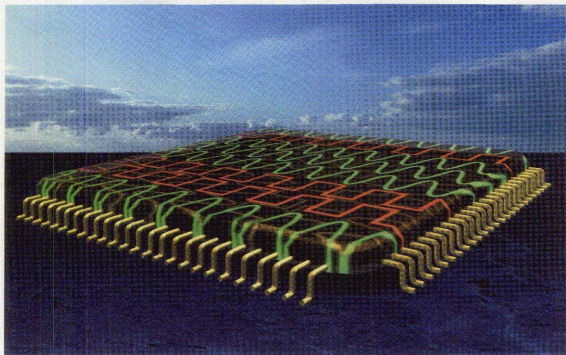
Distributed Antenna System



The RadWire™ distributed antenna system is designed to provide in-building wireless coverage at a low cost and offers an affordable solution to the problem of enhancing wireless coverage inside high-rise buildings, transportation terminals, shopping malls, campuses, warehouses and manufacturing facilities. RadWire replaces radiating coaxial cable, standard coaxial cable and individual antennas with a single-wire transmission line that serves as a high efficiency distributed antenna. Wireless signals are transformed into a surface wave that is simultaneously guided and radiated by the wire. The open system is band specific, entirely passive, rated for plenum environments and available in four versions that cover the cellular/SMR/

[Continued on page 206]

MIXED SIGNALS



Get wireless devices that speak both analog and digital.

When your products have to do analog and digital on a single chip, Sarnoff IC design expertise can keep everything clear. No crosstalk, no misunderstandings, just open lines of communication.

Look to Sarnoff's 50 years of innovation in wireless for

- A/D, D/A, DSP, and ASP macroblocks
- System-on-a-chip approaches
- High-density IC design

Choose macroblocks to embed in your own circuits or have us do a complete, fab-ready IC design. We'll support you from concept to foundry and beyond. Our ESD protection know-how will help you keep yields up and failures down.

We can supplement your in-house skills or execute the complete project. Look to Sarnoff for superior technology, fast turnaround, and a track record for designs that work on the first cut.

Get straight talk on mixed signals at **609-734-2507**. Or check out our web site at www.sarnoff.com/ad/wireless.

NEW PRODUCTS

pagings, DCS, PCS and 2.4 GHz industrial, scientific and medical (ISM) wireless bands.

Rubyttron, White Plains, NY (914) 697-7655.

Circle No. 255

Internal Planar Antenna

The Splatch internal planar antenna for use in compact applications such as remote controls,



paggers and alert devices covers the 902 to 928 MHz frequency band. Designed for direct PCB mounting, the antenna eliminates the mechanical and

cosmetic concerns of traditional external antennas. The stable groundline design results in excellent pattern and polarization characteristics and minimizes proximity detuning. The antenna exhibits a 50 Ω characteristic impedance and an SWR of < 1.9 and measures $1.100'' \times 0.500'' \times .062''$. Price: less than \$1 (production quantities).

Linux Technologies,

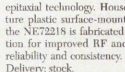
Grants Pass, OR (800) 736-6677.

Circle No. 254

DEVICES

GaAs MESFETs

The model NE72218 miniature GaAs MESFET delivers high output power of 15.0 dBm at 12 GHz and low phase noise of -90 dBc/Hz at 10 kHz offset. The MESFETs are best suited for oscillator and amplifier applications and feature a 0.8 μ m recessed gate and triple



epitaxial technology. Housed in an ultraminiature plastic surface-mount SOT-343 package, the NE72218 is fabricated using ion implantation for improved RF and DC performance, reliability and consistency. Price: \$1.57 (3000).

California Eastern Laboratories,

Santa Clara, CA (408) 988-3500.

Circle No. 256

2 GHz RF Transistors

The models PTF 10120, 10043, 10035 and 10112 high power RF transistors are optimized



for amplification of PCS signals. These 2 GHz wideband RF transistors are highly linear, gold metallized, silicon

LDMOS FETs. Designed for amplifying either CDMA or TDMA signals, these devices support new digital modulations as well as traditional analog applications. The highest power device in the family is the PTF 10120. This GOLD-

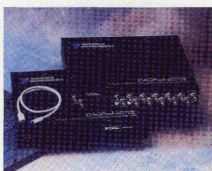
MOS™ device is in a wideband push-pull configuration and displays an intermodulation distortion level of greater than -30 dB for peak envelope power levels up to 120 W. The device has 11 dB of linear gain and a saturated power capability of more than 150 W. The highly reliable, field-proven, full gold metal system used on all of the devices in this family extends the mean time to failure to well over 6000 years.

Ericsson Components,

Morgan Hill, CA (408) 778-9434.

Circle No. 257

Data Acquisition Device



The DAQPad™ -6070E multifunction data acquisition device (DAQ) features eight digital input/output lines, two 24-bit counter timers, 12-bit analog/digital resolution and a 1.25 Msps sampling rate. Available with mass termination or a BNC-equipped option, the device features a 68-pin shielded connector to connect signals and includes an AC-to-DC power adapter and an optional rechargeable battery pack or 9 to 25 V DC supply. The DAQ connects directly to Windows 95 PCs equipped with an IEEE1394 serial port or PCI-to-1394 adapter and offers engineers and scientists a portable, easily installed and configured solution for computer-based measurement applications. As a Fire-Wire product, the unit is hot pluggable and delivers an easy plug-and-play configuration. Price: starting at \$1995.

National Instruments,
Austin, TX (800) 258-7022.

Circle No. 260

RF LDMOS Devices

The MRF21000 series RF LDMOS devices are fully characterized and internally tuned



to operate at frequencies from 2.0 to 2.4 GHz, and are suitable for all linear transmitter formats. The RF LDMOS devices include the model MRF21060, the first ever RF LDMOS single-ended and 60 W device operating at 2170 MHz, which uses the company's fourth-generation RF LDMOS process to



support designs for the emerging third-generation (3G) market, including W-CDMA and UMTS base stations. The complete characterization of the devices makes them easier to use in applications where matched device performance is important. The 30 W MRF21030, the 90 W MRF21090 and the flagship MRF21120

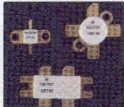
internal impedance-matched push-pull transistor that provides 120 W power (peak) and 14 W power while meeting the W-CDMA mask also are included in the family. Price: \$140 for the MRF21060 (10,000).

Motorola Semiconductor Products Sector,
Phoenix, AZ (602) 244-7108.

Circle No. 259

RF Power MOSFET Transistors

The models SA741 (35 W), SM746 (175 W) and SR746 (300 W) 50 V RF power MOS-



FET transistors exhibit low capacitance, which makes them easier to broadband and use at frequencies from less than 1 MHz to 500 MHz. The

modular design allows combinations of the same die to produce output power ranging from 35 to 300 W. This modular die concept reduces delivery time and extends the product availability lifetime.

Polyflex RF Devices,
Cammarillo, CA (805) 484-4210.

Circle No. 261

SiGe Transistors

The HBT30 series low phase noise silicon-germanium (SiGe) transistors are designed for WLAN, 3G, W-CDMA, LDMOS, point-to-point radio satellite, cable modem and fiber-optic systems achieving higher data transfer rates. At 10 GHz, these transistors exhibit typical residual phase noise of -142 dBc/Hz at 100 MHz and -160 dBc/Hz at 10 kHz offsets. Nominally rated at 5, 10 or 20 mA, the transistors provide a maximum output power of +1, +7 or +13 dBm, respectively, and are capable of operating at supply voltages as low as 1 V. Versions are available as die and in SC-70 (SOT-343) and Micro-X packages.

SiGe Microsystems Inc.,
Ottawa, Ontario, Canada
(613) 748-1334.

Circle No. 262

Power MOSFETs

The models Si4880DY, Si4800DY and Si4890DY pulse-width-modulation-optimized



Little Foot™ power MOSFETs combine lower on resistance and gate charge specifications with record switching speeds, which together ensure maximum efficiency in power conversion circuits across all

typical load ranges and are designed specifically for notebook computer and central processing unit point-of-use DC-to-DC conversion applications. The Si4880DY offers on resistance of 8.5 m Ω at a 10 V gate drive with a gate charge of 19.5 nC and turn-off times of 46 ns. The Si4800DY provides turn-off times of 22 ns with on resistance of 18.5 m Ω and a gate charge of 8.7 nC. The Si4890DY features on resistance of 12 m Ω , gate charge of 14 nC and turn-off times of 35 ns. Price: 71¢ (100,000).

[Continued on page 208]

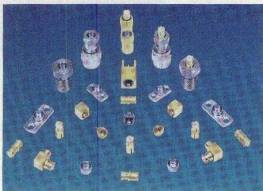
INTRODUCING A BETTER SOURCE FOR SMP CONNECTORS.

US.

You know us for the highest quality cable assemblies for RF and Microwave. Now there's a reason to fall in love: a complete line of DSCC SMP connectors that are **fully compatible with all SMP connectors and the Gilbert GPO™**. Our new SMP Series features a broad range of connectors that include cable types, flange types, field replaceable, float types, hermetic, and adaptors.

Another reason to love us is that Dynawave SMP's are designed to minimize space and allow axial (0.010) and radial (0.020) misalignment while sustaining electrical performance (DC to 40 GHz). They feature **an easy interface** with an insertion force that can vary, depending on your application, and provide the most efficient packaging for both RF and Microwave systems.

Lastly, now **you can order both your cable assemblies and SMP connectors from one trusted company**. Contact us today for more information and our SMP brochure.



dynawave
INCORPORATED®

135 Ward Hill Avenue • P.O. Box 8224 • Haverhill, MA 01835 / TEL: 978-469-0555 / FAX: 978-521-4589

Dynawave is an ISO 9001 UL Registered Company
www.dynawave.com

CIRCLE 35 ON READER SERVICE CARD

NEW PRODUCTS

Delivery: eight to ten weeks.

Vishay Siliconix,
Santa Clara, CA (800) 554-5565, ext. 10
or (408) 567-8220, ext. 10.

Circle No. 263

INTEGRATED CIRCUITS

■ CDMA Single-chip Modem Solution

The model MSM3100™ sixth-generation single-chip Mobile Station Modem™ baseband



processing solution features a 50 percent reduction in chip size and up to 300 hours of standby time. Other features include enhanced

voice recognition, such as continuous digit dialing and support for large speaker independent libraries and on-chip acoustic echo cancellation. The MSM3100 chipset and software enable design of a new generation of CDMA handsets and data devices with rich feature sets and industry-leading performance and will be the first baseband modem to offer on-chip hardware support for in-phone GPS-based CDMA position and location services, providing manufacturers with a cost-effective and integrated solution for the upcoming Federal Communications Commission mandate for emergency location tracking.

QUALCOMM Inc.,
San Diego, CA (619) 651-7942.

Circle No. 264

MATERIALS

■ Irradiated Polyolefin Microwave Substrates

POLYGUIDE™ clad laminates and dielectrics, made from irradiated polyolefin, feature a dielectric constant of 2.32, dissipation factor of .0005 at 10 GHz, peel strength of 8 lb/in and water absorption of < 0.01 percent. Operating temperature range is -55° to +85°C. The substrates are recommended for microwave and UHF applications where optimum low loss operation is a primary requirement, and provide a combination of electrical, physical and chemical characteristics most suitable for microstrip, coplanar waveguide and other demanding uses. Manufactured under the strictest production and quality control conditions, thickness variation for each sheet of the material is held within ±0.002".

Polyflon Co., Norwalk, CT (203) 840-7555.
Circle No. 265

■ Urethane Foam

PORON® urethane foam is specifically directed to gasket materials that are used to seal or protect electrical enclosures (UL-50) and in-

dustrial control equipment (UL-508). The gasket materials withstand rigorous mechanical testing, including age acceleration and oil immersion, and the urethane foam offers low fogging, low outgassing, high resistance to compression set, resistance to ozone, UV light and other environmental stressors and chemicals. PORON materials are available in a firmness and thickness for nearly any high performance application.

Rogers Corp., Rogers, CT (800) 755-6766.

Circle No. 266

SOFTWARE

■ Spectrum Analyzer Software

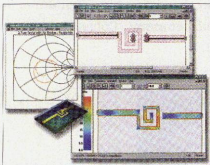


Spectrum Capture custom software dramatically expands the analysis capability of the company's MS2650/MS2660 series spectrum analyzers. The software enables engineers to capture, analyze, store and recall data on a PC with extreme ease, making signal analysis more precise as well as functional, and creates trace markers to display the power level at various frequency points along the signal trace. The software also has the ability to categorize similar data by frequency, create and display upper and lower limit lines and conduct simple pass/fail tests. Multiple sets of limit lines can be saved in the software and recalled later for comparison. Price: \$500. Delivery: stock.

Anritsu Co.,
Richardson, TX (800) 267-4878.

Circle No. 269

■ Electromagnetic Analysis Software



Sonnet® Lite is a free three-dimensional planar electromagnetic (EM) analysis software suite that is suitable for microstrip, stripline and two-layer circuits, including interlayer vias and vias to ground planes. Users can enter circuit layouts in an easy-to-use drawing editor, perform EM analyses, plot and print output results, export output data (S, Y and Z parameters) to other high frequency simulators, and display and animate circuit current density. The software also includes EM analysis combined with lumped elements, as well as the ca-

pability to incorporate active devices through external S-parameter data blocks. SPICE model extractions also may be derived for arbitrary circuits and interconnects that are electrically small compared to a wavelength.

Sonnet Software Inc.,
Liverpool, NY (315) 453-3096.

Circle No. 271

■ Power Amplifier Design Software

Microwave WinPADS is a design and optimization software tool that uses measure load pull contours as starting data to optimize a wide-band, single-stage amplifier stage. The software uses very fast optimizers and a standard netlist file description for the source and load matching networks. In addition, lumped and distributed microstrip circuit elements with accurate models are included.

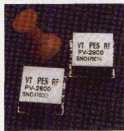
Focus Microwaves Inc.,
St-Laurent, Quebec, Canada
(514) 335-6227.

Circle No. 270

SOURCES

■ 2600 - 2750 MHz VCO

The model PV-2600 VCO for wireless local area networks and radios operates over the



2600 to 2750 MHz frequency range with a tuning voltage of 0.5 to 5 V. The device has a supply voltage of 5 V and draws 25 mA. Phase noise is -103 dBc/Hz at 100 kHz offset.

Operating temperature range is -30° to +85°C. Size: 0.500" x 0.500" x 0.205".

Princeton Electronic Systems Inc. (PES),
Princeton, NJ (609) 275-6500.

Circle No. 272

■ Synthesized Digital Paging Systems



The PagePro series synthesized digital paging transmitters with built-in PCSAG paging encoder are fully synthesized and can be field programmed in 10 or 12.5 kHz increments via a built-in RS 232 port. The systems can generate numeric, alphanumeric and tone pages and are designed to handle the demands of wide area paging as well as in-house and local area paging. Output power is adjustable with nominal output of 5 W (max) in the 136 to 174 MHz range and 2 W in the 218 to 230 MHz range. Several models are available covering the

[Continued on page 210]

DUCOMMUN TECHNOLOGIES, INC.

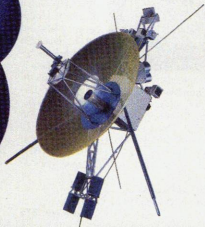
now Includes
DMT, Jay-El and AEI
Product Lines



AIR TRANSPORT CORPORATE REGIONAL MILITARY



COMMERCIAL WIRELESS MILITARY



SATELLITE LAUNCH VEHICLE GROUND SUPPORT SYSTEM



1999 150th Anniversary of
DUCOMMUN INCORPORATED



DMT

• RF/Microwave Products

- Wireless and Hi-Rel Applications
- Single Pole Double Throw, Multi Throw, Transfer, T-Switch and ATE Matrix
- TCAS Coaxial Antenna Switches
- Military Notch Filter and Switch Filters



Jay-El

• Illuminated Switch Panel Products

- Engineered Lighting, Panel and Switch Solutions
- COTS and Military Components
- Military NVIS Compatible
- Primary Displays and Control Display Unit Bezel and Front End Assemblies
- Cockpit Switches
- Switch Assemblies/Annunciator Panel Assemblies



• Electromagnetic Products

- Custom Designed, Space Qualified Components
- Stepper Motors
- Resolvers for Extreme Environment
- Actuators

CIRCLE 33 ON READER SERVICE CARD

For more information, please call (310) 513-7215

23301 Wilmington Avenue • Carson, California 90745

Fax: 310-522-8994 • www.ductech.com • e-mail: sales@ductech.com

NEW PRODUCTS

134-174, 218-230 and 260-280 MHz frequency ranges.

RF Neulink, a division of RF Industries, San Diego, CA (800) 233-1728 or (858) 549-6340.

Circle No. 273

Low Cost VCO

The model V607TE01 VCO features low noise characteristics, minimal power requirements and a compact size. This VCO generates frequencies between 1279 and 1313 MHz with a tuning voltage between 0.4 and 2.8 DC, making it ideal for quick integration into any PLL where the error voltage can be taken directly from the IC's charge pump circuitry. Developed for the satellite hand-held phone market, the VCO provides output power of -3.5 dBm ± 2.5 dB, phase noise of -99 dBc/Hz at 10 kHz offset, supply voltage of 3 V DC and supply current of 6 mA. Size: 0.375" x 0.375" x 0.124". Price: \$15.95 (5). Delivery: stock to six weeks.

Z-Communications Inc., San Diego, CA (858) 621-2700.

Circle No. 275

Clock Oscillators

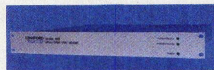
The VCA3-100 and -200 series tight stability clock oscillators are capable of 20 ppm stability, including initial stability, frequency over operating temperature, power variation, power variation and aging. Supply voltage is 5.0 V DC at ± 10 percent or 3.3 V DC at ± 10 percent, and the devices operate over the temperature range of 0° to +70°C or -40° to +85°C. Packaged in an industry-standard 14-pin DIP, the clock oscillators are most suitable for use in telecommunication and networking applications.

VITE, a Vectron International company, Norwalk, CT (888) 835-8483.

Circle No. 274

SUBSYSTEMS

VSAT Modem

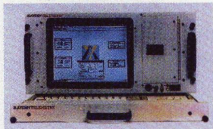


The STEL-9261 very small aperture terminal (VSAT) modem is programmable for coverage over the full 52 to 88 MHz IF output range. Power level is programmable over the -5 to -25 dBm range. The unit includes integral forward error correction using constraint length K = 7 with rate 1/2, 3/4 or 7/8 Viterbi decoding to reduce overhead and assure the highest signal integrity. A programmable FIR filter allows the modem to match system requirements. The unit includes an AGC value monitor and alarm, C/N (Eb/No) value monitor and alarm, signal quality monitor and bit error rate value and is packaged in a 1RU rack-mounted case. The STEL-9261 transmit and receive functions can be remotely and independently programmed and monitored via a user-selectable EIA 232-E or EIA-485 interface. The data interface is EIA-485.

Stanford Telecom, Sunnyvale, CA (408) 745-2660.

Circle No. 282

20 Mbps PCI Bit Synchronizers



The model 5200 multichannel bit synchronizer subsystems are fully integrated rugged units with installed cards that receive multiple independent baseband data streams and simultaneously process them to provide clean serial output data streams with synchronous clocks. Each unit also includes an optional onboard Viterbi decoder that operates with three-bit soft decision for maximum coding gain, PCI/ISA bus, 300 W power supply and 10-inch diagonal active matrix color liquid crystal display (LCD) VGA display. Designed specifically for preflight system checkout, aircraft flight testing, satellite system checkout, and monitoring and launch vehicle qualification, the unit operates on 110 or 220 V (switch controlled). All storage devices are shock and vibration isolated, and rack-mount slides are included. Operating temperature range is 0° to +45°C.

AYDIN Telemetry, a division of AYDIN Corp., Neutown, PA (215) 497-8000.

Circle No. 279

Dual-input Base Station Receiver Unit

The INTERWAVE 99 dual input base station receiver unit consists of downconverters, baseband amplifiers and an optional control and monitoring interface module. Designed to operate in any 12 MHz segment of the 2100 to 2700 MHz

MMDS band, the unit includes a diversity switch to select the stronger of two input signals. The base station receiver unit architecture is implemented to minimize the spectral regrowth, adjacent-channel power and error vector magnitude critical to QPSK, QAM, DQPSK modulations used with CDMA, and other wireless voice and data network architectures. Gain is 40 dB, noise figure is < 4 dB, SWR is 2 and power supply is -45 V at 0.4 A through the input coax. Operating temperature range is -40° to +65°C.

Size: 9.0" x 10.0" x 1.6".
ITS Electronics Inc., Concord, Ontario, Canada (905) 660-0405.

Circle No. 281

High Frequency PLL Synthesizer Module

The model PLL800-5800 PLL synthesizer module generates frequencies from 5700 to 5900 MHz in 500 kHz steps with a typical settling time of 12 ms. The unit typically requires 53 mA of current from a 5 V supply voltage. Phase noise at 1 kHz offset is -61 dBc/Hz (typ), phase noise at 100 kHz offset is -105 dBc/Hz (typ) and phase detector spurious suppression is -75 dBc (typ). Output power is 0 dBm (typ) and second- and third-harmonic suppression is -15 and -20 dBc, respectively. The unit is housed in a 15.25 mm x 15.25 mm x 3.50 mm surface-mount, pick-and-place/reflow-compatible package.

Vari-L Co. Inc., Dener, CO (303) 371-1560.

Circle No. 283

SYSTEMS

Multiple Output 350 W Power Supply

The model NT350 compact, multiple output 350 W power supply provides a 3.3 V high current main output and active input power factor correction (PFC). The PFC input stage is followed by a two-transistor forward converter, which provides a proven architecture for high reliability requirements. The NT350's output configurations were developed to support applications in which the circuitry has largely migrated from 5 to 3.3 V. All outputs are fully isolated and regulated and active current sharing is standard to simplify N+1 redundant requirements in fault-tolerant applications. Auxiliary outputs are designed to sustain high surge current demands to support fan and disk drive spin-up requirements. Other features include power fail warning, remote inhibit and remote sense. Price: from \$370 (100).

C&D Technologies, Power Electronics Division, Tucson, AZ (800) 547-2537.

Circle No. 276

Redundant Relay Fed LMDS Transmitter

The model TR280120RR local multipoint distribution system (LMDS) transmitter features multichannel block conversion operation, fully redundant throughput and synthesized local oscillators. The transmitter is designed to operate in the 27.5 to 28.5 GHz frequency range and consists of all necessary signal conditioning equipment to upconvert two blocks of video or data channels to the LMDS band and transmit

[Continued on page 212]

NEW PRODUCTS

RF/IF MICROWAVE COMPONENTS

NO.63



FROM
\$11.95

DC TO 6GHz TERMINATION HAS N-TYPE MALE CONNECTOR

Mini-Circuits KARN-50 is a 50 ohm DC to 6GHz wideband termination usable to 9GHz. The unit is ruggedly constructed to withstand severe mechanical vibration and shock, and has a 2 watt rating to 70°C ambient. Minimum return loss DC to 500MHz is 36dB, DC to 1GHz is 32dB, DC to 2GHz is 28dB, DC to 4GHz is 20dB, and minimum return loss band wide is 18dB. Applications include cellular and satellite communications and test set-up. Value priced and shipped from stock.

FEATURED PRODUCT



FROM
\$29.95

LEVEL 23 (LO) 10 TO 1500MHz MIXER HAS HIGH IP3

Mini-Circuits has started to ship the new SYM-15VH frequency mixer operating in the 10MHz to 1500MHz band. Typically, this unit provides high 31dBm IP3 at center band and a 1dB compression point of +16dBm typical with low 6.5dB midband conversion loss, good 40dB L-R/35dB L-I isolation, and can handle maximum 350mW RF power, 40mA IF current. 5 year Ultra-Rel® guarantee.



FROM
\$12.95

12V VCO PROVIDES 75 TO 150MHz OCTAVE BAND TUNING

Mini-Circuits has introduced the ROS-150, a compact, low cost voltage controlled oscillator providing 75 to 150MHz octave band tuning, low -103dBc/Hz SSB phase noise typical at 10kHz offset, and excellent -23dBc (typ) harmonic suppression. With 9.5dBm typical power output, this miniature 12V, 20mA (max. current) VCO measures only 0.5"x0.5"x0.18" and is ideal for test instruments such as signal generators. Operating temperature range is -55°C to +85°C (max.).



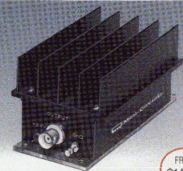
FROM
\$3.95

9 TO 625MHz TRANSFORMER HAS UP TO 1W POWER RATING

Standing only 0.108 inches high.

4WAY SPLITTER/COMBINER FOR CATV APPLICATIONS

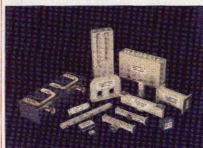
Designers requiring a 4way-0° power splitter or combiner for 75 ohm systems operating in the 50 to 860MHz band can specify Mini-Circuits new JS4PS-9-75. Equipped with solder plated J leads for excellent solderability and strain relief, this surface mount unit exhibits typically high 25dB isolation, excellent input matching and very good output matching with VSWR typically 1.20:1 in/1.3:1 out. Amplitude unbalance is excellent at 0.15dB typical. Maximum power input is 50W.



FROM
\$149.95

50MHz TO 1000MHz AMPLIFIER HAS HIGH IP2 AND IP3

FILTA MICROWAVE INC.
The RF and Microwave Solution



FILTERS AND DIPLEXERS

UP TO 40 GHz

High Performance, High Quality
at Low Cost

FILTA MICROWAVE INC.

342 Alamo Vincent, Anaheim, California, 92705
TEL: (408) 425-6032 FAX: (408) 424-6079

CIRCLE 42



250-290 Mhz
Coaxial
25dB Isolation
0.4dB ins loss

2.0-2.3 GHz
Drop-in w/
Internal Load
20dB Isolation
0.5dB ins loss

**100 MHz-19.5 GHz COAX/DROP-IN
ISOLATOR / CIRCULATOR**

Aerocomm Thailand

89 Intamara 41, Sutthisaran Rd. Dindang

Bangkok 10320 THAILAND

Tel (662) 693-8300 Fax: (662) 693-8304

WWW.aerocommthailand.com E-mail aerocomm@ksc.th.com

UK: Datron Ltd., Tel 44 1582 605278

CIRCLE 2

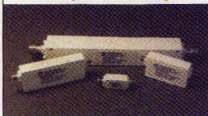
**RF
and
Microwave
Components**

Salisbury Engineering Inc.
PO Box 480
Delmar, DE 19940
www.Salisbury-Engineering.com
800-958-2141

FILTERS

High Performance Filters and Diplexers
DC - 40 GHz

Surface Mount • Combine • Miniature • Custom Ceramic
Low Pass • High Pass • Band Pass • Band Stop
Call for your free filter catalog!

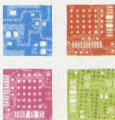


**MICROWAVE
CIRCUITS, INC.**

6856 Eastern Avenue NW Phone: 202 829 3630
Washington, DC 20012 Fax: 202 829 2639
e-mail: filters@micckts.com
Website: www.micckts.com
© 1998 MICROWAVE CIRCUITS, INC. ALL RIGHTS RESERVED

CIRCLE 89

LABTECH
www.labtechcircuits.com



leaders in high
technology microwave PCBs
email: sales@labtechcircuits.com

CIRCLE 78

**SPECIALISTS IN
CUSTOM DESIGNED
SATELLITE SWITCHES**

SPACE WAVEGUIDE SWITCHES



WR137

WR112

WR75



**SECTOR MICROWAVE
INDUSTRIES, INC.**

999 Grand Blvd., Deer Park, New York 11729
(516) 242-2300 • FAX: (516) 242-8158 • Telex: 673-2151

• Coax & Matrix Switch Assemblies Available

CIRCLE 150

NEW PRODUCTS

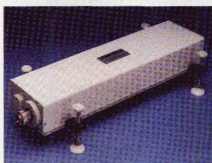
The 1 GHz block at power levels that will provide a range of 5 to 8 km with 0.999 availability, depending upon the rain zone and required carrier-to-noise ratio. Superior performance is achieved by using field-proven RF circuitry and synthesized oscillators phase locked to a rubidium master reference. Optional antennas are available with patterns ranging from 30° to 360° azimuth coverage in either vertical or horizontal polarization.

mm-Tech Inc.,

Eatontown, NJ (732) 935-7150.

Circle No. 278

Automated Harmonic Tuner



The model MT999 precision automated harmonic tuner designed for harmonic load pull or tuning measurements is capable of presenting a high mismatch over a broad frequency range of 0.8 to 7.5 GHz. The tuner also provides a highly accurate and cost-effective method for device characterization where harmonic tuning is required. SWR matching range is 50 (min), carriage step size is 625 micrometers and position accuracy is ± 1 step. The tuner works with the company's MT996B24/26 harmonic tuner controllers and features power handling of 10 W CW (0.5 kW peak). The high isolation between the fundamental and harmonic frequencies provided by multiplexers assures the accuracy of the harmonic measurements.

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

Circle No. 277

TEST EQUIPMENT

Precision Current Pulse Generator

The model 507 precision current pulse generator offers digitally controlled current pulses with currents from 0 to 10 A and pulse widths from 0.1 to 100 ms. Precise current control and time-domain resolution allow for complete characterization of electronic systems. Offered in two, four and eight channels, the generator is suitable for automobile airbag squib testing, industrial fuse breakdown testing and precision laser triggering and driving applications. TTL-sync outputs are ideal for video capture or other related test parameters. Price: \$3295 (two channels). Delivery: 30 days (ARO).

Berkeley Nucleonics Corp.,
San Rafael, CA (800) 234-7858.

Circle No. 285

[Continued on page 214]

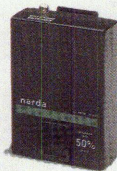
Before you buy an RF personal monitor, monitor their performance.

When you look at what our competition isn't offering, alarms go off in your head. Relax.

Just consider everything you *will* get with Narda's personal radiation monitors. Things like guarantees. Ease of use. And performance you can count on.

So no matter what the conditions—even in the most complex, multi-signal environments—you'll get all the protection you need with Narda.

For more information, call today
516-231-1700.





narda
microwave-east

an **L3** communications company



© 1999 L-3 Communications, Inc.
www.nardamicrowave.com

		
	Narda	Competition
Frequency Range	300 kHz-45 GHz	3MHz-40 GHz
Frequency Response Error	<i>Guaranteed</i> Max. ± 2 dB	Not Guaranteed Typical ± 3 dB
Responds equally to all field polarizations	<i>Guaranteed</i> Max. ± 0.75 dB	Not Guaranteed Typical ± 2 dB
Accurate at all temperatures	<i>Guaranteed</i>	No
Immune to static	<i>Guaranteed</i>	No
RMS detection under all conditions	<i>Guaranteed</i>	No
Functions near power lines	Yes	No
LED Indicator visible when worn on body	Yes	No
Unit cost	\$	\$\$\$
2 Year factory calibration & checkup included*	Free (No calibration costs for 4 years)	\$
Calibration within 10 business days	<i>Guaranteed</i> (or calibration is Free)	No

*Two-year recommended calibration cycle. No additional costs for four years with first two-year checkup and calibration included.



...Your Career

Staff Design Engineer: Responsible for designing and evaluating RF circuits and technologies for high volume consumer applications. Participating actively in a team for package, device and assembly development may be required on projects. Developing customer application/evaluation requirements. Use CAD software for design, development and verification. Minimum requirements include BSCE with eight years experience; MSCE with five years experience; PhD EE with two years experience; two years RF/MCM or MCM design and design experience with SPICE and TOUCHSTONE or equivalent required (UBRA simulation experience desired).

Applications Engineers: Responsible for providing customers with RF technical product support at the RF system and component level; participating with new standard and custom RFIC product development; developing application notes and data sheets. Requires BS/EE/MSCE with minimum 3 years RF design/product experience, strong RF/MCM/CMOS measurement skills; design experience with analog and digital modulation schemes (AMPS, GSM, TDMA, CDMA); strong written and customer relation skills.

Product Marketing Engineer: Responsible for new product development, coordinating the contributions of many departments including Design Engineering, Manufacturing, Marketing and Quality Assurance. Will prepare marketing plans for product objectives, competitive analysis, main user benefits, customer profiles and primary selling points. Requires BS degree in Engineering-related discipline and related experience, technical sales and marketing experience in RF/Wireless industry preferred.

Key Account Manager: This position will work closely with key customers to implement standard product designs and custom IC development projects. Individual will manage all phases of project development, schedules, forecasts, resources and technical goals. Requires engineering degree and experience with project management methods and tools. Account management or sales management experience is also a plus.

Power Amplifier IC Design Engineer: Responsible for carrying a design from concept through manufacturing and providing sufficient engineering documentation to fully describe the circuit, specifications and performance. Requires BS/EE/MSCE with 5 to 10 years commercial design experience, preferably design with power amplifiers; experience with Silicon Bipolar, GaAs MESFET, or GaAs HBT integrated circuits; familiarity with test equipment required for amplifier test and characterization; and experience in wireless systems such as cellular, cordless or ISM-band equipment.

Filter Design Engineer: MS. Minimum 3 years experience in the design and development of Broad Band, comb-line, strip line, interdigital, low pass and high pass filters, multiplexers, diode switches (phase shifters) at microwave and millimeter wave systems desirable.

Commercial Project Manager: Microwave hybrid and monolithic IC design experience is required. This person must be experienced in computer aided design, analysis and measurement techniques. Responsibilities will include analysis of existing MMIC designs for RF portions of digital cellular radios and modifications to designs.

Sr. MMIC Design Engineer: Design highly integrated GaAs MMICs for advanced cellular products. Circuits to be designed include power amplifiers, driver amplifiers, LNAs, mixers, IF amplifiers, buffer amplifiers. RF frequencies are 900 and 1800 MHz. Circuitry will be designed for advanced MMIC wave process technologies.

Regional Field Sales: Aggressive individuals to create and serve new accounts. Positions are located throughout the U.S.A. An engineer who wants to enter sales world is acceptable. Base salary, commission and car.

Advanced Technology Development: Design and optimization of RFICs for high performance low-power wireless communications applications in a 60 GHz SiGe BiCMOS technology. Includes transistors for cellular and PCS handsets and wireless communications devices at 900 MHz-1.8 GHz. Ph.D./MS.

With experience with one of the following: LNAs, VCOs, power amps, mixers and frequency synthesizers.

CMOS/BiCMOS Analog IC Design: Design of analog or mixed signal ICs in SiGe BiCMOS for cellular/PCS handsets and wireless communication devices at 900 MHz and 1.8 GHz. BS/MS/Ph.D.

Sr. Staff T/R Modules: You will join a development team designing microwave monolithic transmitter/receiver modules. Qualified applicants will have experience in microwave receiver technology, specifically in GaAs FET MMIC applications. Requires a BSCE (MSCE preferred), and 5+ years directly related experience.

RF Wireless Engineers: Requires design experience in RF circuits for low cost, battery-powered portable systems, including RF amplifiers, mixers, oscillators and synthesizers in the range of DC to 5 GHz. Experience in the latest RF CAD tools essential. Strong knowledge in communication theory, digital modulation and TDMA/CDMA standards a plus.

Packaging Engineer: At least 3 years of relevant packaging experience. Experience with plastic packages or modules. Experience with PA specific problems an obvious plus. Job responsibilities to include: team with IC designers to develop optimal packaging solution for specific requirements; manage package qualification of any non-qualified package and manage/review any packaging related failure analyses specific to the product line.

Sr. R&D Engineer: More than 5 years of cellular PA related work. Special interest in research projects focusing on new technologies and design concepts that are 3 to 5 years away from production. Job responsibilities to include: present research updates at quarterly technology exchange meetings with the customer and work closely with customer research groups throughout the year.

Regional Sales Managers: Excellent opportunity for articulate, personable professionals to take on key, high visibility role at the world's fastest growing manufacturer of RF integrated circuits. Positions require knowledge of RF technology and the ability to develop and maintain relationships with a customer's RF design, management and purchasing organizations. The Regional Manager will have responsibility for winning new design-ins, maintaining customer satisfaction and training/managing Sales Representative Network in the assigned territory.

Positions are available for candidates with 4+ years of relevant sales and/or technical experience. Experience in RF design, applications engineering and/or electronics manufacturing is a plus. Experienced, people-oriented engineers looking to move into sales are encouraged to apply.

VISIT OUR WEBSITE AT WWW.MICSSEARCH.COM

MICRO COMMUNICATIONS EXECUTIVE SEARCH

We specialize in the placement of wireless, RF, microwave communications professionals both nationally and internationally

800 Turnpike St. • North Andover, MA 01845

Call Collect: Tel: (978) 685-2272 • Fax: (978) 794-JOBS

NEW PRODUCTS

■ VXI RF Power/Volt Meters

The 5730 series RF power/volt meters for measuring power and voltage measurements in VXI configurations have the ability to sample up to 200 readings per second. The units measure power levels from -70 to +44 dBm with a 90 dB dynamic range, measure RF voltage from 10 Hz to 2.5 GHz and cover 10 kHz to 100 GHz when measuring power. The dual-channel meters also allow readings in different units (such as dB and mW) to be displayed simultaneously on different channels. Sensor calibration data, resident in the data adapter, are automatically downloaded to the meter when the sensor is connected, which eliminates the need to re-enter the calibration if a sensor is changed. A zero correction function stores the zero offsets of each range and automatically corrects all subsequent readings.

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

Circle No. 284

■ RF/Microwave Radiation Badge

The model H600A RF/microwave radiation badge is intended to be ultrasonifying RF and microwave radiation. Designed to monitor the telecommunications frequency range of 50 MHz to 2.5 GHz, the badge provides real-time power density (mW/cm^2) information via its LCD. Measurement modes include a choice of instantaneous or six-minute average. The H600A provides a user-adjustable alarm level setting from 0.2 to $20 \text{ mW}/\text{cm}^2$ to satisfy diverse environments. The unit carries a two-year warranty. Standard accessories include a carrying case and earphone for high noise environments. Size: $3.70" \times 2.75" \times 1.10"$. Weight: 5 oz.

General Microace Corp.,

Amityville, NY (516) 226-8900, ext. 236.

Circle No. 286

■ RF Spectrum Analyzer

The model P9116 spectrum analyzer is designed for use in production automatic test equipment systems and covers the frequency range of 100 kHz to 1600 MHz. It is packaged in a 2RU industrial PC chassis and can be operated like any other conventional RF spectrum analyzer when used in conjunction with a VGA monitor and supplied graphical user interface. Since the unit's local oscillator is digitally tuned, the precise number of steps and the span between steps are fully controllable with a resolution of 2 Hz across the entire spectrum. This feature, coupled with the synthesizer step of < 150 μs , makes the unit ideal for test applications where increased production throughput is critical. Absolute level accuracy is $\pm 0.5 \text{ dB}$ over the -120 to +20 dBm amplitude range and frequency accuracy is 0.5 ppm.

Morrow Technologies Corp. (MTC), Largo, FL (813) 531-4000.

Circle No. 287

■ SMP Calibration Kit

This surface-mount package calibration kit from Rosenberger Hochfrequenztechnik GmbH & Co. consists of an open, load and short — all in a male and female interface for use in calibrating various types of test equipment. The calibration kit ensures the reliability of the test results for SMP connectors up to 18 GHz. Also included are two 60 cm precision cables (SMP and SMA) to interface with the test port. The SMP interface is per DESC 94007/94008 and compatible with the GPO™ connector series.

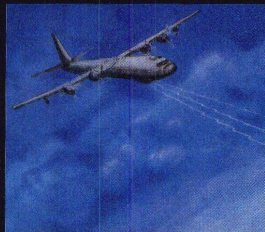
Rosenberger of North America LLC, Lancaster, PA (717) 290-8000.

Circle No. 288



Positions are available for candidates with 4+ years of relevant sales and/or technical experience. Experience in RF design, applications engineering and/or electronics manufacturing is a plus. Experienced, people-oriented engineers looking to move into sales are encouraged to apply.

The more demanding your requirements, the more you'll appreciate



an MPD Solid State Power Amplifier.



Whether the application is mobile, airborne, ground or shipboard, you can depend on MPD, a leader in the field of RF/Microwave amplifiers.

These rugged amplifiers, built in conformance with ISO 9001, are geared to meet the challenge of the most severe environments.

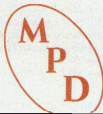
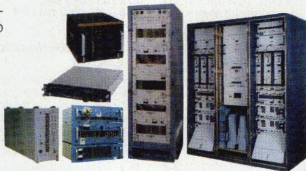
Our solid-state amplifiers provide extraordinary performance and exceptional reliability over operating frequencies of 1 MHz to 14 GHz and power up to 100kW, supporting a wide range of military and commercial requirements.

MPD has maintained leadership in advancing technology by breaking crucial frequency/power barriers to reach higher performance levels.

Our areas of expertise include:

- COMMUNICATIONS
- AIRCRAFT/SATELLITE
- COMMUNICATION
- EW/ECM
- EMI/EMC TESTING
- RADAR
- NAVIGATION AND GUIDANCE
- LABORATORY AND MEDICAL APPLICATIONS

Contact MPD today for information on a wide variety of solid-state RF/Microwave power amplifier products.



MPD AND REPUBLIC PRODUCTS

MPD TECHNOLOGIES, INC. A Subsidiary of Microwave Power Devices, Inc.

49 WIRELESS BLVD, HAUPPAUGE, NEW YORK 11788-3935 (516) 231-1400 Fax: (516) 231-8081





NEW LITERATURE

■ FLEXIBLE FOAM BROCHURE

This new brochure, *Flexible Foams: State-of-the-art Designs*, Precision Cut, describes the company's offerings and capabilities with polyethylene foams, polyurethane foams and extruded profiles. New products, including aircraft accessories, electronic components, pharmaceuticals, gaskets and displays, are also discussed.

Polyfoam Packers Corp.,
Wheeling, IL (800) 323-7442.

Circle No. 212

■ AIR FILTER ENGINEERING BROCHURE

This six-page application brochure provides prototype information helpful for designing sophisticated equipment that requires electromagnetic interference or RF interference shielding and is a quick reference for design considerations, including Bellcore, CE and UL requirements.

Universal Air Filter Co.,
Sauget, IL (800) 541-3478.

Circle No. 213

■ DC PARAMETRIC MEASUREMENT APPLICATION NOTE

This application note explores the recent advances in DC parametric measurements, including new parametric testers and new parametric wafer probes that reduce system capacitance and noise levels and resolve common measurement problems such as low measurement resolution and high noise. Methods to ensure fast and accurate low level measurements are also discussed.

Cascade Microtech Inc.,
Beaverton, OR (800) 550-3279
or (503) 601-1000.

Circle No. 201

■ LOGIC ANALYZER APPLICATION NOTE

This 13-page application note provides hardware engineers, firmware designers and systems integrators with information about acquiring data from a multiplexed address or data bus, using offsets to avoid false triggers, reducing security risks on networked logic analyzers, capturing data before a system crash and analyzing serial data with a logic analyzer.

Heute-Packard Co.,
Palo Alto, CA (800) 452-4844, ext. 6570.

Circle No. 202

■ RADAR TECHNOLOGY COMPENDIUM

This comprehensive compendium, *Radar Essentials*, discusses a variety of topics on radar technology, including the history of radar, recent advances in radar technology, new and proposed radar systems, radar simulation and modeling, new radar components and insight into select foreign radar systems.

The Institute of Electrical and Electronics Engineers Inc. (IEEE),
Piscataway, NJ (800) 678-4333
or (732) 981-0060.

Circle No. 203

■ CD-ROM LIBRARY

Back issues of the *LabView™ Technical Resource*, a quarterly technical journal, are available via a CD-ROM that features articles about real-world problems and solutions when working with LabView software. The CD-ROM holds the contents of the resource disc published in each issue as well as virtual instrument software examples, utilities, source code and documentation.

LTR Publishing Inc.,
Dallas, TX (214) 706-0587.

Circle No. 204

■ PROBE STATION NAVIGATION SOFTWARE BROCHURE

This brochure details pcSetup™ software designed specifically for infrequent users of analytical test stations. The software is also useful to engineers who develop routines that involve testing of samples that are repetitive. Samples of the function icons and toolbars and unique dialog boxes that provide additional information about individual sequence steps are illustrated.

The Micromanipulator Co. Inc.,
Carson City, NV (800) 967-2426
or (775) 882-2400.

Circle No. 206

■ CARRIER-TO-NOISE GENERATOR BROCHURE

This four-color brochure provides a thorough overview of the company's carrier-to-noise (C/N) generator designed to evaluate the performance of today's digital communication systems, including PCS, wideband CDMA and satellite systems. A replica of the C/N generator's unique front screen display as well as ordering information are also provided.

Micronetics,
Hudson, NH (603) 883-2900, ext. 312.

Circle No. 205

■ TECHNICAL NOTE

This 18-page technical note, *Advances in Low Noise Receiver Front Ends and Developments in AFC Circuitry for MTI Magnetron-based Radars*, describes special mixer products designed for the radar market. The limitations in dynamic range of Schottky and MESFET mixers are discussed and front end specifications utilizing each mixer are outlined. In addition, several state-of-the-art analog and digital radar phase-lock subsystems are described.

MITEQ, Hauppauge, NY (516) 439-9423.

Circle No. 207

■ QUARTZ FREQUENCY CONTROL PRODUCT CATALOG

This 32-page, full-color catalog contains information about the company's crystal units, monolithic crystal filters and crystal oscillators for computer, telecommunications, wireless data communications, CEM and other OEM markets. Specifications, definitions and application information are also included.

Tekmark Inc.,
Alpharetta, GA (770) 346-9102.

Circle No. 208

■ CAPABILITY BROCHURE

This four-page brochure describes the company's full capabilities for designing, developing and manufacturing custom RF and microwave filters for the 1 MHz to 40 GHz frequency range. The supply of dielectric material for filter production from nearby TRAK Communications companies is also described.

Advanced Filter Solutions,
Frederick, MD (301) 698-0114.

Circle No. 209

■ NEW COMPONENT CATALOG

This 150-page catalog features thousands of ICs, components, tools, test equipment and computer products for OEMs, engineers, educators and service/repair technicians. Product photographs and expanded descriptions are included. A user-friendly ordering process is also described.

Jameco Electronic Components,
Belmont, CA (800) 831-4242.

Circle No. 210

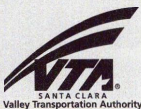
■ THERMOELECTRIC CONTROLLER BULLETIN

This one-page bulletin (No. 9905) introduces the model 5C7-350 temperature controller for use with thermoelectric modules. Key specifications and available options are described.

Oven Industries Inc.,
Mechanicsburg, PA (717) 766-0721.

Circle No. 211

CLASSIFIEDS



**COMMUNICATIONS
SYSTEMS MANAGER**
\$5520-\$6710 Monthly
Excellent Benefits, 7% PERS

Will be VTA's key technical leader on the design, implementation and ongoing operation and maintenance of the Advanced Communications System (new microwave system, bus and light rail communication center, and new vehicle equipment, including radios and automated vehicle locator systems). This Advanced Communications System will also include implementation of new Intelligent Transportation System applications such as automatic passenger counters, automated annunciators, traffic signal preemption, vehicle monitoring systems, and integrated fare collection technologies.

Requires BS in Engineering or related field and five years of professional experience in telecommunications systems, including supervisory experience.

For application and job bulletin contact:

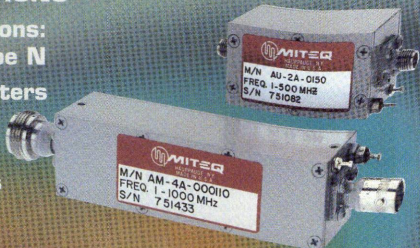
Santa Clara Valley
Transportation Authority (VTA)
Personnel Department
3331 North First Street, Bldg. B
San Jose, CA 95134-1906
or
Call: (408) 321-5575
e-mail: Personnel.vta.org

BIPOLAR

AMPLIFIERS

STANDARD OPTIONS

- Connector Options: SMA, BNC, Type N
- Integrated Limiters
- Input Bias Tee for Fiberoptic Photodetectors



FREQUENCY [MHz]	MODEL NUMBER	GAIN [dB, Min.]	GAIN FLATNESS [\pm dB, Max.]	VSWR IN/OUT	NOISE FIGURE			OUTPUT POWER [dBm, Min.]	DOMESTIC PRICE [1-8 PCS]
					F ₁	F ₂	F ₃		
0.01-200	AU-1442	35	0.5	2.0:1	1.2	1.2	1.2	5	\$300
0.01-200	AU-1447	56	0.5	2.0:1	1.2	1.2	1.2	12	\$325
0.01-500	AU-1310	30	0.5	2.0:1	1.3	1.4	1.5	8	\$300
0.01-500	AU-1332	45	0.5	2.0:1	1.3	1.4	1.5	10	\$325
0.01-1000	AM-1300	27	0.75	2.0:1	1.4	1.6	1.8	8	\$325
0.01-1000	AM-1431	35	0.75	2.0:1	1.4	1.6	1.8	10	\$350
0.02-1000	AM-1551	38	1.0	2.0:1	1.4	1.6	1.8	15	\$350
1-100	AU-3A-0110	55	0.5	2.0:1	1.2	1.2	1.2	12	\$300
1-200	AU-1464	35	0.5	2.0:1	1.2	1.2	1.2	6	\$275
1-200	AU-1494	56	0.5	2.0:1	1.2	1.2	1.2	11	\$300
1-500	AU-2A-0150	30	0.5	2.0:1	1.3	1.4	1.5	8	\$275
1-500	AU-3A-0150	45	0.5	2.0:1	1.3	1.4	1.5	10	\$300
1-500	AU-4A-0150	60	0.5	2.0:1	1.3	1.4	1.5	10	\$325
1-1000	AM-2A-000110	26	0.75	2.0:1	1.4	1.6	1.8	8	\$300
1-1000	AM-3A-000110	35	0.75	2.0:1	1.4	1.6	1.8	8	\$325
1-1000	AM-4A-000110	51	1.0	2.0:1	1.4	1.6	1.8	9	\$350
5-300	AU-1021	24	0.5	2.0:1	2.4	2.5	2.7	20	\$275
5-300	AU-1525	61	0.5	2.0:1	1.2	1.2	1.9	20	\$350
100-1000	AM-1412	35	0.75	2.0:1	1.4	1.6	1.8	15	\$350
100-2000	AM-1526	9	1.0	2.0:1	8	5.5	5.5	20	\$350
200-2000	AMMIC-1427	20	1.5	2.2:1	4.2	4.3	4.6	14	\$375
500-1000	AM-2A-0510	24	0.5	2.0:1	1.4	1.5	1.6	0	\$300
500-1000	AM-3A-0510	38	0.5	2.0:1	1.4	1.5	1.6	9	\$325
500-2000	AM-3A-0520	29	0.75	2.0:1	1.4	1.9	2.4	3	\$350
1000-2000	AM-3A-1020	29	0.5	2.0:1	1.8	2.1	2.4	10	\$325
1000-2000	AM-1477	39	1.0	2.0:1	1.8	2.1	2.4	15	\$350
1000-2000	AM-4A-1020	40	0.75	2.0:1	1.8	2.1	2.4	10	\$350

Maximum 2 week delivery for small quantities. For additional information, please contact Bill Pope at (516) 439-9115 or e-mail wpope@miteq.com



100 Davids Drive, Hauppauge, NY 11788
TEL: (516) 436-7400 • FAX: (516) 439-9333/436-7430

www.miteq.com

CIRCLE 130 ON READER SERVICE CARD



■ **Electrodynamics of Solids and Microwave Superconductivity**

Shu-Ang Zhou

John Wiley & Sons Inc.

626 pages; \$130

ISBN: 0-471-35440-6

Microwave superconductivity is of great interest now that practical applications are appearing in telecommunications and other areas. This book provides an introductory and comprehensive theoretical foundation for solid electrodynamics and microwave superconductivity to engineers and applied physicists.

"...an introductory and comprehensive theoretical foundation for solid electrodynamics and microwave superconductivity to engineers..."

Chapter 1 contains a review of classical electrodynamics, basic concepts and theoretical principles for the study of electromagnetic phenomena in a material media. Chapter 2 introduces continuum electromagnetic phenomena and its interaction with mechanical phenomena in material solids that may be deformed or in motion under electromagnetic and/or mechanical

loading. Particular emphasis is placed on electro-quasistatic and magneto-quasistatic problems.

Chapter 3 introduces the basic concepts of superconductivity and formulates macroscopic electrodynamic theories for superconductors in weak fields. Chapter 4 presents theoretical models for the study of electromagnetic properties and thermomagnetolectric effects in type II superconductors that maintain their state in very strong magnetic fields. Chapter 5 introduces the Josephson effect, the phenomenon of tunneling of electron pairs across a superconductor-insulator-superconductor junction. Applications of superconducting quantum interference devices are briefly discussed.

Chapter 6 introduces the theory of transmission lines based on a distributed model and Maxwell's equations. A full-wave analysis is performed to investigate properties of anisotropic superconducting transmission lines that may operate at extremely high frequencies. Chapter 7 is devoted to the introduction of theoretical models developed recently for the study of the interaction between electromagnetics and the mechanics of superconductors. This book is highly theoretical and not for the casual reader. However, it ties together both electromagnetic and mechanical phenomena in a way that is understandable.

To order this book, contact: John Wiley & Sons Inc., 605 Third Avenue, New York, NY 10158 (212) 850-6336 or (800) 225-5945.

■ **Feedforward Linear Power Amplifiers**

Nick Pothecary

Artech House Inc.

204 pages; \$75, £56

ISBN: 0-1-58053-022-2

The physical separation of communication channels has become a major problem within wireless transmission. Today's systems must use more complex modulation schemes to increase bandwidth efficiency, and these modulation techniques require highly linear amplifiers. This book describes the challenges and behavior of high power amplifiers linearized using the feedforward technique.

Chapter 1 begins with an overview of feedforward techniques and includes an introduction to a typical radio system for cellular, PCS or IMT2000/universal mobile telecommunications system applications. Specific concepts for RF operations are also discussed. Chapter 2 presents a mathematical-based approach to discussions of amplifier input and output characteristics, signal modulation formats, signal envelopes, peak-to-average ratios and statistical analysis. Power amplifiers and system design are discussed in Chapter 3, including transistors for RF power amplifiers, amplifier efficiency, operating classes, intermodulation performance and system design issues. The concept of a linear amplifier is introduced and practical examples are presented for different system configurations.

Chapter 4 reviews different linearization techniques, including feedback (RF feedback, envelope feedback, Cartesian loop and polar loop feedback), RF synthesis, envelope elimination and restoration, predistortion and feedforward systems. The principle of operation of feedforward linearization and dual-loop feedforward linearization is presented along with discussions on signal cancellation and loop control. Chapter 5 provides a detailed analysis of feedforward performance, covering such topics as gain, input/output match, noise figure, broadband signal cancellation, error amplifier performance and system efficiency. The book presents the subject in an extremely clear and easy-to-follow manner with an abundance of supporting block diagrams and graphics and a minimum of complex theory.

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) 171 973 8077.

"This book describes the challenges and behavior of high power amplifiers linearized using the feedforward technique."

Frank Bashore

Frank Bashore is a member of the Microwave Journal staff.

RFMD

Silicon innovationsSM

14

284

Si

28.086

Symbol

Atomic Number

Atomic Mass

Electrons in each shell

Some things just look better at a distance – grizzly bears, rattlesnakes and guard dogs come to mind – but choosing the right RFIC demands a closer look. At RFMD, we make silicon-based components for wireless applications ranging from remote meter reading using ISM-band transceivers to general-purpose amplifiers.

Using IBM Blue Logic™ process technology, we're creating a new silicon generation. Our commitment to innovative design, diversified technologies and accelerated product development keeps us at the forefront of the wireless industry.

Don't hang back – take a closer look at RFMD Si.

RF 
MICRO-DEVICES


7625 Thorndike Road • Greensboro, NC 27409-9421
 Phone 336.664.1233 • FAX 336.664.0454 • Online: <http://www.rfmd.com>

CIRCLE NO.	ADVERTISER	PAGE NO.	PHONE	FAX	WEB/E-MAIL ADDRESS
1	Advantest Corporation	135	+81-3-3342-7500		http://www. advantest.co.jp/index-e.html
2	Aerocomm Satellite Technology	212	+662-693-8300	+662-693-8304	http://www. aerocommthailand.com
3,4	Alpha Industries	80,184	508-894-1904	617-824-4579	http://www.alphaind.com
5,6	Amcom Communications Inc.	50	301-353-8400	301-353-8401	http://www.amcomusa.com
7	American Technical Ceramics	75	516-622-4700	516-622-4745	http://www.atceramics.com
8	Amplifier Research	117	215-723-8181	215-723-5688	http://www.ar-amps.com
9	Anaren Microwave	185	800-544-2414	315-432-9121	http://www.anaren.com
10,11	Anritsu Company	16,181	800-ANRITSU	972-644-3416	http://www.anritsu.com
12,13,14	Ansoft Corporation	89,91,93	412-261-3200	412-471-9427	http://www.ansoft.com
15	Antenna Research Associates	66	301-937-8888	301-937-2796	http://www.ara-inc.com
16	Apac	174			http://www.apac.com
17	Atlantic Microwave	120-1*	+44-1376-550220	+44-1376-552145	e-mail: sales@ atlanticmicrowave.co.uk
18	ATN Microwave Inc.	15	978-667-4200	978-667-8548	http://www.atnmicrowave.com
19	Berkeley Varianetics Systems	83	732-548-3737	732-548-3404	http://www.bvsystems.com
191,192	Cascade Microtech	COV 4	503-601-1000	503-601-1002	http://www. cascademicrotech.com
21	Communication Solutions Inc.	137	410-574-4557	410-574-4559	http://www.consol-inc.com
22	Communication Techniques	119	973-884-2580	973-887-6245	http://www.cti-inc.com
23,24,25,26	Comtech PST	153	516-777-8900	516-777-8877	http://www.comtechpst.com
28	Condor Systems Inc.	120	408-879-2236	408-377-6892	http://www.condorsys.com
29	CTT Inc.	69	408-988-8521	408-986-9097	http://www.cttinc.com
30	Daico Industries	COV 3	310-507-3242	310-507-5701	http://www.daico.com
31	Dielectric Laboratories	68	315-655-8710	315-655-8179	http://www.dilabs.com
32	Dow-Key Microwave Corp.	151	805-650-0280	805-650-1734	http://www.dowkey.com
33	Ducommun Technologies Inc.	209	310-513-7215	310-522-8994	http://www.ductech.com
34,35	Dynaware	77,207	978-469-0555	978-521-4589	http://www.dynaware.com
36	Eagleware Corporation	40-41	770-939-0156	770-939-0157	http://www.eagleware.com
37	EEV Inc.	140	914-592-6050	914-682-8922	http://www.eev.com
38,39,40	EMC Technology	139,141,143	609-429-7800	609-429-6814	http://www.emct.com
41	Emhiser Micro-Tech	28	408-446-3582	775-345-2484	http://www.emhiser.com/coo
42	Filfil Microwave	212	450-455-6082	450-424-5819	
43	Filtran Microcircuits	127	613-737-0706	613-737-0495	http://www.filtranmicro.com
44	Florida RF Labs	43	800-544-5594	888-544-5595	http://www.flrlabs.com
45	Focus Microwaves Inc.	195	514-335-6227	514-335-6287	http://www. focus-microwaves.com
46	Frequency Electronics	107	516-794-4500	516-794-4340	http://www.freqelec.com
47	Future Electronics	55	888-680-5892		http://www.future.ca/motorola/rf
48	General Microwave Corporation	48	516-226-8900	516-226-8966	http://www.gmwave.com
49	GGB Industries Inc.	3	941-643-4400	941-643-4403	http://www.picoprobe.com
50	H. Rollet & Co. Ltd.	76	+44-1992-509015	+44-1992-509005	http://www.hrollet.co.uk
51	HD USA	62	301-931-1048	301-931-1049	http://www.hdusa.net
52,53	Herley MDI	84,165	781-729-9450	781-729-9547	http://www.herleymd.com
54,55	Hewlett Packard	COV 2	800-452-4844	415-857-5518	http://www.hp.com
56,57		35			
58,59		67			
60,61		121			
62	Hittite Microwave	71	978-250-3343	978-250-3373	http://www.hittite.com
63	Huber + Suhner AG	42	+41-71-353-41-11	+41-71-353-44-44	http://www.hubersuhner.com
	Hyper	82-1*	+33-1-53-17-11-40	+33-1-53-17-11-45	http://www.hip.com/hyper
	IEEE MTT-S 2000	86			http://www.ims2000.org
64	IFR Americas	138	316-522-4981	316-329-5575	http://www.ifrinternational.com
65	IMI	62	978-373-9190	978-521-1846	http://www.imipcb.com
66	Infineon Technologies	86-1*			http://www. infineon.com/building-blocks
67	Insulated Wire Inc.	25	203-791-1999	203-748-5217	http://www.insulatedwire.com
	IWCE 2000/Interface Exhibitions	82	800-288-8606	720-489-3165	http://www.iwceconexpo.com
68	JCA Technology	27	805-445-9888	805-987-6990	http://www.jcatech.com
69,70	JFW Industries Inc.	8,54	317-887-1340	317-881-6790	http://www.jfwindustries.com
71	Johanson Manufacturing	103	973-334-2676	973-334-2954	http://www.johansonmfg.com
72	Johanson Technology	96	805-389-1166		http://www.johanson-caps.com
73	K&L Microwave Inc.	6	410-749-2424	410-749-5725	http://www.klmicrowave.com
74	Kaman Instrumentation	191	719-599-1821	719-599-1823	http://www. kamaninstrumentation.com
75,76,77	KMW	29,63,123	562-926-2033	562-926-6133	http://www.kmwinc.com
78	Lahtech Ltd.	212	+44-1544-260033	+44-1544-260310	http://www.labtechcircuits.com
79	Lark Engineering	176	949-240-1233	949-240-7910	http://www.larkengineering.com
80	Lorch Microwave	95	410-860-5100	410-860-1949	http://www.lorch.com
81	M-Tron Industries	76	800-762-8800	605-665-1709	http://www.mtron.com
82	Maury Microwave Corporation	9	909-987-4715	909-987-1112	http://www.maurymw.com

Catch the

SV MICROWAVE

**For the one source that satisfies
all your interconnect product needs!**

- 
- SMA Connectors (including hermetics)
 - Type N, TNC & BNC Connectors
 - Between & In-series Adapters
 - Blind Mate Connectors
 - K Connectors
 - Attenuators & Terminations (Call for our new catalog)

Also available, flexible and semi-rigid cable assemblies

Ready to supply off-the-shelf standards as well as custom and hard to find specials

SV MICROWAVE

3301 Electronics Way • West Palm Beach, Florida 33407

Tel: (561) 840-1800 • Fax: (561) 844-8551

CIRCLE NO.	ADVERTISER	PAGE NO.	PHONE	FAX	WEB/E-MAIL ADDRESS
83	MECA Electronics Inc.	189	973-625-0661	973-625-1258	http://www.mecaelectronics.com
84	Mica Microwave Corporation	88	408-363-9200	408-363-9220	http://www.mica-mw.com
	Micro Comm.	214	978-685-2272	978-794-5627	http://www.micsearch.com
85	Micro Lambda	201	510-770-9221	510-770-9213	http://www.micro-lambda.com
86,87	Micrometrics Inc.	85,87	603-641-3800	603-641-3500	http://www.micrometrics.com
88	Microwave & Video Systems Inc.	44-45	203-792-7474	203-792-7475	e-mail: mvsmicro@worldnet.att.net http://www.micvts.com
89	Microwave Circuits	212	202-829-3030	202-829-2639	http://www.micvts.com
90	Microwave Comm. Laboratories Inc. (MCL)	18	800-333-6254	727-381-6166	http://www.mcl.com
91	Microwave Communications & Components	114	82-2-3424-0800	82-2-3424-0808	http://www.mcc.com
92	Microwave dB	39	805-499-0410	805-498-0054	http://www.microwavedb.com
93	Microwave Development Company Inc.	17	603-870-6280	603-870-6210	http://www.mdc-inc.net
94	Microwave Development Labs	101	800-383-4189	781-453-8629	http://www.micro-dev.labs.com
95	Microwave Filter Company	204	800-448-1666	315-463-1467	http://www.microwavefilter.com
	Microwave Journal	156,192	800-225-9977	781-769-5037	http://www.mwjjournal.com
96	Microwave Power Devices	215	516-231-1400	516-231-8081	http://www.mpd.com
97	Microwave Specialty Corporation	144	760-744-1544	760-744-1565	http://www.microwavespecialty.com
98,99	Mini-Circuits	4-5	718-934-4500	718-332-4661	http://www.minicircuits.com
100,101	.....	7			
102,103	.....	11			
104,105	.....	47			
106,107	.....	52			
108,109	.....	56			
110,111	.....	81			
112,113	.....	131			
114,115	.....	157			
116,117	.....	161			
118,119	.....	183			
120,121	.....	187			
122,123	.....	193			
124,125	.....	211			
126,127,128	MITTEQ Inc.	49,105,125	516-436-7400	516-436-7430	http://www.miteq.com
129,130	.....	179,217			
131	Mitsubishi Electronics America Inc.	148-149	949-660-7080	949-975-1557	http://www.mitsubishichips.com
132	Modco	32	775-331-2442	775-331-6266	http://www.modcoinc.com
133	Modular Components National Inc.	60	410-879-6553	410-838-7629	http://www2.ari.net/modular
	Motorola Semiconductor Products Sector	133	800-441-2447	303-675-2150	e-mail: motorola.com/sp/s/rf http://www.murata.com
134	Murata Electronics	79	800-831-9172		
135,136,137	Narda Microwave-East, an L3 Communications Co.	109,129,213	516-231-1700	201-261-8339	http://www.nardamicrowave.com
138	Noisecon	19	201-261-8797	201-261-8339	http://www.noisecon.com
139	Phoenix Microwave Corp.	59	215-723-6011	215-723-6015	http://www.phoenixmw.com
140	Q-Tech Corporation	164	310-836-7900	310-836-2157	http://www.q-tech.com
141,142	QMI	13,203	978-988-9090	978-988-9393	http://www.qmiinc.com
143	Quasar Microwave Technology Ltd.	70	44-1626-834222	44-1626-832994	http://www.qmtl.com
144	Radio Research Instrument Co. Inc.	116	203-753-5840	203-754-2567	http://www.techexpo.com/www/radioresearch.com
145	Reactel	145	301-519-3660	301-519-2447	http://www.reactel.com
146	Remec Inc.	160	1-877-66-REMEC	408-432-1551	http://www.remec.com
	RF Globalnet	134			
147,148	RF Micro Devices	51,219	336-664-1233	336-664-0454	http://www.rfmd.com
149	Richardson Electronics	97	1-800-RFPOWER	630-208-2550	http://www.rfpower.net.com
150	RLC Electronics Inc.	23	914-241-1334	914-241-1753	http://www.rlelectronics.com
151	Rogers Corporation	20-21	480-961-1382	480-961-4533	http://www.rogers-corp.com/mwu
152	Rohde & Schwarz GmbH	115	49-89-41293115	49-89-41293115	http://www.fsp.nd.de
153	Sabritec	106	949-250-1244	949-250-1009	http://www.sabritec.com
154	Sage Laboratories	33	508-653-0844	508-653-5671	http://www.sagelabs.com
155	Salisbury Engineering Inc.	212	800-989-2141	302-846-3888	e-mail: sales@salisbury-engineering.com
156,157	Sarnoff Corporation	73,205	609-734-2507	609-734-2443	http://www.sarnoff.com/ad/wireless
	SCVTA	216	408-321-5575		e-mail: personnel.vta.org
158	Seavey Engineering Associates Inc.	124	781-829-4740	781-829-4590	http://www.seaveyantenna.com
159	Sector Microwave Industries Inc.	212	516-242-2300	516-242-8158	e-mail: sales@sectormicrowave.com
160	Special Hermetics Products Inc.	74	603-654-2002	603-654-2533	http://www.shp-seals.com
161	Spectrum	135-1*	49-89-354-8040	49-89-354-8040	e-mail: specclek@compuserve.com

ADVERTISING INDEX

Synergy offers a large off-the-shelf selection of 0°, (2-way to N-way), 90° and 180° splitters/combiners...with frequency ranges covering 10 KHz to 2.5 GHz. Available in 50 or 75 ohms, they come in a variety of non-hermetic and hermetic styles including surface mount.

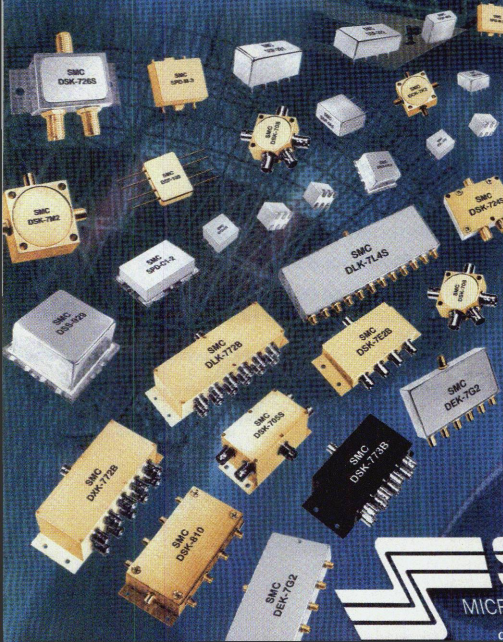
Most importantly, when you specify Synergy, you benefit from an uncompromising dedication to the best price/performance ratio possible, consistent high quality and fast deliveries.

Our engineering, sales, and applications team will answer technical questions and help with your custom designs.

For additional information, contact Synergy's Sales and Applications Team:

Synergy Microwave Corporation
201 McLean Boulevard, Paterson, NJ 07654
Phone: (973) 381-9800
Fax: (973) 381-9801
E-mail: sales@synergymw.com
World Wide Web: www.synergymw.com

SPLITTERS & COMBINERS



SYNERGY[®]
MICROWAVE CORPORATION

CIRCLE 170 ON READER SERVICE CARD

CIRCLE NO.	ADVERTISER	PAGE NO.	PHONE	FAX	WEB/E-MAIL ADDRESS
162	Stanford Microdevices	36-37	800-764-6642		http://www.stanfordmicro.com/sign
163,164	Stanford Telecom	116,152	978-441-0200	978-453-6299	http://www.stelmsd.com
165	State of the Art	106	800-458-3401	814-355-2714	http://www.resistor.com
166	Stellex Microwave Systems Inc.	147	800-321-5075	650-813-2525	http://www.stellexms.com
167	SV Microwave	221	561-840-1800	561-844-5551	e-mail: sales@svmicro.com
168,169,170	Synergy Microwave Corp.	65,111,223	973-881-8800	973-881-8361	http://www.synergymicrowave.com
171	T-Tech Inc.	70	770-455-0676	770-455-0970	http://www.t-tech.com
172	Technical Communities	14	650-853-5993		http://www.testmart.com
173	Teledyne Termax	58	+33-1-49-584900	+33-1-48-581046	http://www.teledyne-termax.com
174	Teledyne Electronic Technologies	169	650-962-6944	650-962-6845	http://www.teledynemicrowave.com
175	Tetra Electronic Industries	112	+972-3-5562775	+972-3-5561944	e-mail: gadil@tetra.co.il
176,177	Thomson Microsonics	175,177	+33-0492-9640-00	+33-0492-9630-25	http://www.microsonics.thomson-csf.com
178	Trans-Tech	163	301-695-9400	301-695-7065	http://www.trans-techinc.com
179	Tru-Connector	26	978-532-0775	978-531-6993	http://www.tru-con.com
180	Tusonix	158	520-744-0400	520-744-6155	http://www.tusonix.com
181	Vari-L	113	303-371-1560	303-371-0845	http://www.varil.com
182	Vectron International	171	1-88-VECTRON1	888-FAX-VECTRON	http://www.vectron.com
183	Vertical Net	167			http://www.industrydeals.com
184	Watkins Johnson Co.	31	800-851-4401	650-813-2447	http://www.wj.com
185	Wavesat	34	514-956-6300	514-956-8587	http://www.wavesat.com
186	Weinschel Corporation	150	301-846-9222	301-946-9116	http://www.weinschel.com
187	Werlatone	159	914-279-6187	914-279-7404	http://www.werlatone.com
188	Z-Communications	155	619-621-2700	619-621-2722	http://www.zcomm.com
189	Zeland Software	142	510-797-8109	510-797-8241	http://www.zeland.com
190	ZETA, a division of Sierra Networks Inc.	173	408-434-3600	408-433-0205	http://www.zeta-sni.com

*EURO-GLOBAL ONLY

Visit Microwave Journal on the Web at www.mwjjournal.com



microwave

JOURNAL

**NOVEMBER 1999
ISSUE**

- ▶ **DESIGN AND IMPLEMENTATION OF AN X-BAND DIELECTRIC RESONATOR FILTER**
- ▶ **A PRIMER ON BONDING WIRE PARAMETERS**
- ▶ **CIRCULAR-POLARIZED APERTURE-COUPLED PATCH ANTENNAS FOR AN RFID SYSTEM IN THE 2.4 GHZ ISM BAND**

▶ SALES REPRESENTATIVES

HARLAN HOWE, JR., PUBLISHER

Eastern and Central Time Zones

Carl Shaffers
National Sales Mgr.
685 Canton Street
Norwood, MA 02062
Tel: (781) 769-9790
FAX: (781) 769-5037
e-mail: cshaffers@mwjournal.com

Tim O'Callaghan
Eastern Reg. Sales Mgr.
685 Canton Street
Norwood, MA 02062
Tel: (781) 769-9790
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 23390
San Jose, CA 95133
Tel: (408) 224-9060
FAX: (408) 224-6106
e-mail: wynncook@ic.netcom.com

ED JOHNSON, ASSOCIATE PUBLISHER

International Sales

Sam Baird
Manager - Europe
Michel Zoghib
Garth Watson
46 Gillingham Street
London SW1V 1HH,
England
Tel: +44 20 7596 8740
FAX: +44 20 7596 8749

Australia

James Tonkin
Tinkin Media Pty. Ltd.
300 Seaside Highway
Terrigal NSW 2260, Australia
Tel: +61 43 85 1746
FAX: +61 43 85 2017

Germany, Austria, and Switzerland (German-speaking)

Juergen Wissing
Wissling Marketing Services
Riedstrasse 5
72813 St. Johann-
Waertingen
Germany
Tel: +49 7122 820310
FAX: +49 7122 820330

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-Ts Road
Taipei, Taiwan ROC
Tel: +886 2 396 5128
FAX: +886 2 396 4511

Israel

Oreet Ben Yaacov
Oreet International Media
15 Kinneret Street
51201 Bene-Berak, Israel
Tel: +972 3 570 6527
FAX: +972 3 570 6526



the microwave journal

Daico Offers Wireless Solutions With a Switch

Customized Performance Featuring

surface-mount control products with performance that exceeds MMIC technology, Daico offers customized solutions for your specific basestation designs. And with over 30 years of IF/RF and microwave experience, you can switch to Daico to do it right.

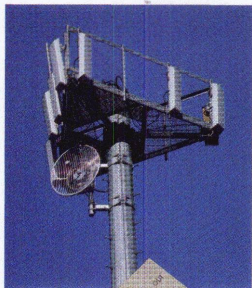
Affordable Prices Imagine getting

customized high-performance products that fit your budget. For your Wireless applications, our surface-mount High Dynamic Range Power/VSWR Detector provides 27dB dynamic range with temperature stability of ± 1 db over its full operating temperature and goes for under \$50 in 1K quantities. Best of all, you can get this kind of price and performance from Daico's full line of wireless components.

Production Quantities Daico now

delivers quality components in the quantities you need for all your basestation networks. From switches to detectors to subassemblies, we offer quantities of 1K, 10K, 50K or more. And with our fast development turnarounds, you can't lose.

Lower prices, higher volumes, customized performance. If the application is wireless, the solution is Daico.



DAICO Industries

We've Got Your Bases Covered™

1070 East 233rd Street Carson, CA 90745

Tel: 310-507-3242 Fax: 310-507-5701

Web: www.daico.com

CIRCLE 30 ON READER SERVICE CARD

Switches / Attenuators / Phase Shifters / MMICS / Detectors / Couplers / Modulators / Amplifiers / Subassemblies

CLEARLY THE BEST.

Ours you see it.

Theirs you don't.



Half
the Insertion
Loss

2x
Better
Crosstalk

Best
Tip
Visibility

Fully
Deembedded
Data

Introducing Cascade's New High Performance Characterization Probes

Take a good look at our HPC Probe.

Cascade Microtech's new High Performance Characterization probe is clearly ahead of the competition. The HPC40 has half the insertion loss, 2x better crosstalk, and the best tip visibility in the industry. That means you see better measurements. And that makes you look good.

Probe Tip, Know Thyself.

Unlike any other probe tip, each HPC Probe comes with its own individual set of fully deembedded data. Add our custom ISS and WinCal calibration software, and you can fine-tune your test environment and make high quality S-parameter measurements in record time.

Don't just believe your eyes, here's our introductory **FREE** probe offer.

For a limited time, when you buy a pair of HPC40 probes, you'll get your 3rd probe **FREE!** Visit the Cascade website for complete product specifications and offer details.

Cascade Microtech, Inc.
In the U.S. call us at 1-800-550-3279
Tel: (503) 601-1000 Fax: (503) 601-1002
E-mail: sales@cmicro.com
Japan: 03 5478-6100
Europe: +44 (0) 1295-812828
www.cascademicrotech.com



Partners with
Hewlett-Packard
in Innovative
Measurement Solutions