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AUGUST 1999
VOL. 42, NO. 8

CAD AND MEASUREMENT

MODELING OF METAL AND SUBSTRATE LOSSES

SIGNAL GENERATOR SPECTRAL PURITY CONSIDERATIONS

MTT-S SYMPOSIUM AND EXHIBITION WRAP-UP

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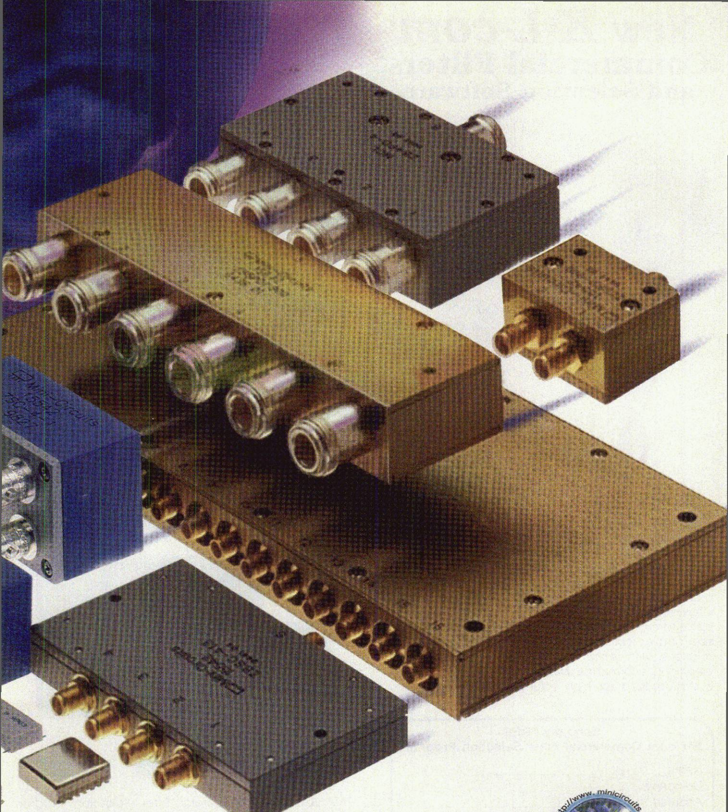
horizon house



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Center Frequency	• 10 to 3000MHz
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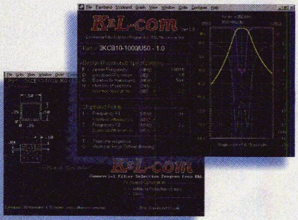

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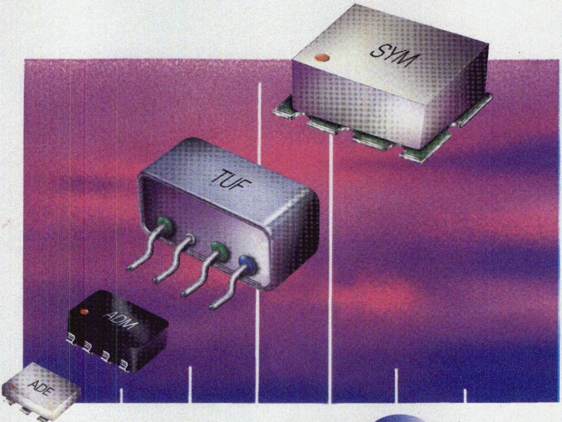
CIRCLE 50 ON READER SERVICE CARD

HIGH IP3 MIXERS

suppress noisy intermods



+30dBm IP3 5 to 2200MHz from $7.95 (10-49 qty.) WOW!

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TYPICAL SPECIFICATIONS (LO=+17dBm), Surface Mount

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*ADE-10H	400-1000	30	39	25	7.0	7.95**
*ADE-12H	500-1200	28	34	28	6.7	8.95**
SYM-18H	5-1800	30	45	40	5.75	17.95
SYM-10DH	800-1000	31	45	29	7.6	18.95
SYM-22H	1500-2200	30	33	38	5.6	19.95
•TUF-18DHSM	100-1800	27	41	33	7.3	21.95
*ADM-10DH	800-1000	30	35	37	6.0	15.95

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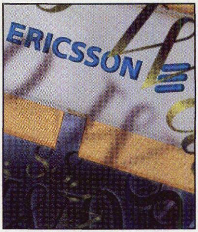
FEATURES

TUTORIAL

TECHNICAL FEATURES

[Continued on page 12]



ON THE COVER

165 W laterally diffused metal-oxide semiconductor (LDMOS) FETs for amplifier applications from 860 to 900 MHz are featured on this month's cover

Cover art courtesy of Ericsson RF Power Products

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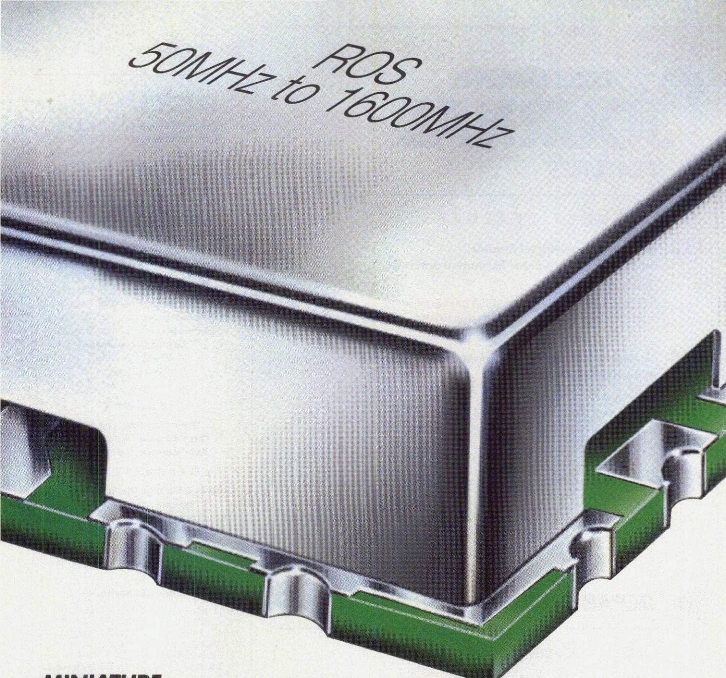

MINIATURE
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(qty. 5-49)

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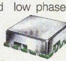

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Salt Lake City, Utah

ROS SPECIFICATIONS:

Model	Freq. Range (MHz)	V_{tune} (V) Max.	Phase Noise* Typ.	Harmonics** (dBc) Typ.	Voltage V	Current (mA) Max.	Price $ea. (5-49)
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.

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FEATURES

PRODUCT FEATURES

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CIRCLE 110 ON READER SERVICE CARD

COMING EVENTS

1999 IEEE GaAs IC Symposium
October 17–20, 1999
Monterey, CA

Sponsors: IEEE Electron Devices Society, Solid State Circuits Society and MTT-S. Topics: Developments in ICs using GaAs, InP and other compound semiconductor devices, including innovative RFIC device and circuit concepts, circuit design and fabrication; manufacturing technology and cost issues; CAD/CAM/CAT tools and techniques; IC testing and methodology; packaging technology; reliability; and advanced device, system (wireless, vehicular, medical and fiber system ICs) and optoelectronic applications. Contact: Jim Komiak, Sanders, a Lockheed Martin company (603) 885-6910, fax (603) 885-6881 or e-mail: james.j.komiak@lmco.com. Additional information is available at www.gaasic.com.

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. Additional information can be obtained from www.ee.virginia.edu/~isdrs/.

Seventh International Symposium on Recent Advances in Microwave Technology (ISRAMT '99)
December 13–17, 1999
Malaga, Spain

Sponsors: The University of Nevada, Reno and the University of Malaga, Spain. Topics: Microwave components and solid-state devices, antenna and radar technology, MICs/MMICs, remote sensing, biological effects and applications, communication systems, numerical methods and CAD, propagation/scattering and measurements, electro-optics, optical communications/networks and sensors, microwave superconductivity, industry/environmental effects, signal processing, microwave photonics and bandgap crystals/materials. Contact: Banmali Rawat, University of Nevada, Dept. of Electrical Engineering/MS 260, Reno, NV 89557-0153 (702) 784-6927 or e-mail: rawat@ee.unr.edu. Additional information is available at www.isramt99.ic.uma.es.

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 in thermal characterization of electronic components, subsystems and systems, including the generation and removal of heat from 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.

Topical Meeting on Silicon Monolithic ICs in RF Systems
April 26–28, 2000
Garmisch, Germany

Sponsors: IEEE MTT-S, DaimlerChrysler, NASA Lewis Research Center, Siemens and Technische Universität München. Topics: Analog and digital silicon monolithic ICs, planar circuit structures on Si and Si-based monolithic integrated microwave and millimeter-wave

devices, modeling of silicon monolithic ICs and field-oriented modeling of passive circuit structures, flip-chip technology, Si and SiGe bipolar devices, MOSFETs, MODFETs, advanced high speed device concepts making use of heterojunction and nanometer-band gap engineering, and the role of industry and university in long term research. Contact: Walter Fisch, Institute of High Frequency Engineering, Technische Universität München, Arcisstr. 21, D-80333, München, Germany +49 89 289 23367 or e-mail: siliconrf@hft.ei.tum.de.

Fifth International Workshop on Finite Elements for Microwave Engineering
June 8–9, 2000
Boston, MA

Sponsors: Worcester Polytechnic Institute, the University of Florence and Ansoft Co. Topics: Antenna applications 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 is available at www.ece.wpi.edu/~jinlee.

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

Call for papers. Sponsor: IEEE MTT-S. Topics: Advancement and application of RF and microwave theory and techniques, including analysis and design; components and assemblies; microwave technology (primarily passive); microwave technology (primarily active); 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 Dednah, Horizon House Publications, 685 Canton St., Norwood, MA 02062 (781) 769-7950, fax (781) 769-5037 or e-mail: kdednah@mwjournal.com.

2000 IEEE-APS Conference on Antennas and Propagation for Wireless Communications (APWC 2000)
November 6–8, 2000
Waltham, MA

Sponsors: IEEE Antenna and Propagation Society, and IEEE Boston Section. Topics: Military to commercial technology transition; architecture trends in future wireless systems; base station and satellite antenna developments; adaptive and active wireless communication arrays; novel antennas and passive array configurations; multiband operation and polarization characteristics; antennas for PCS, WLAN, WLL, RFID, etc.; mobile antennas and vehicle modeling; package integration and portable devices; microstrip antennas; antenna CAD; human interactions with antennas; MEMs; and indoor/outdoor propagation and channel models. Send to: Jennifer T. Bernhard, University of Illinois at Urbana-Champaign, Dept. of Electrical and Computer Engineering, 1406 W. Green St., Urbana, IL 61801 e-mail: jbernhar@uiuc.edu. Send: one original paper and three copies. **Deadline: April 7, 2000.** For additional information, call (781) 890-5290, fax (781) 890-5294, e-mail: bostonieee@aol.com. or go to www.eece.unm.edu/apw c2000/.

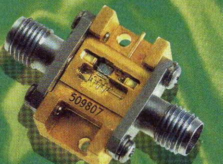
ULTRA-LOW NOISE
AMPLIFIERS
VHF TO V-BAND

MODEL NUMBER	FREQUENCY RANGE (GHz)	GAIN (dB, Min.)	GAIN VARIATION (±dB, Max.)	NOISE FIGURE (dB, Max.)	VSWR IN	VSWR OUT	POWER OUT @ 1 dB COMPR. (dBm, Min.)		DC POWER @ +15 V (mA, Nom.)
OCTAVE BAND AMPLIFIERS									
JS2-00500100-035-5A	0.5 – 1	35	1	0.45*	2:1	2:1	5		250
JS2-00500100-10-5A	0.5 – 1	35	1.2	1	2:1	2:1	5		250
JS2-01000200-035-5A	1 – 2	33	1	0.45*	2:1	2:1	5		250
JS2-01000200-10-5A	**1 – 2**	**33**	**1.2**	**1**	**2:1**	**2:1**	**5**	$395	**250**
JS2-02000400-035-5A	2 – 4	28	1	0.45*	2:1	2:1	5		175
JS2-02000400-10-5A	**2 – 4**	**28**	**1.2**	**1**	**2:1**	**2:1**	**5**	$450	**175**
JS2-04000800-070-0A	4 – 8	22	1	0.7	2:1	2:1	0		150
JS2-04000800-15-0A	**4 – 8**	**22**	**1.2**	**1.5**	**2:1**	**2:1**	**0**	$495	**150**
JS3-04000800-060-5A	4 – 8	30	1	0.6	2:1	2:1	5		175
JS3-04000800-15-5A	4 – 8	30	1	1.5	2:1	2:1	5		175
JS2-08001200-09-5A	8 – 12	15	1	0.9	2:1	2:1	5		150
JS2-08001200-15-5A	**8 – 12**	**15**	**1.2**	**1.5**	**2:1**	**2:1**	**5**	$495	**150**
JS3-08001200-080-5A	8 – 12	25	1	0.8	2:1	2:1	5		175
JS3-08001200-15-5A	8 – 12	25	1	1.5	2:1	2:1	5		175
JS2-12001800-16-5A	12 – 18	15	1	1.6	2:1	2:1	5		100
JS2-12001800-30-5A	**12 – 18**	**15**	**1.5**	**3**	**2:1**	**2:1**	**5**	$495	**100**
JS3-12001800-16-5A	12 – 18	23	1	1.6	2:1	2:1	5		175
JS3-12001800-30-5A	**12 – 18**	**23**	**1**	**3**	**2:1**	**2:1**	**5**	$495	**175**
JS4-12001800-12-5A	12 – 18	30	1	1.2	2:1	2:1	5		200
JS4-12001800-30-5A	12 – 18	30	1	3	2:1	2:1	5		200
JS2-18002600-20-5A	18 – 26	14	1	2	2:1	2:1	5		100
JS2-18002600-30-5A	18 – 26	14	1	3	2:1	2:1	5		100
JS3-18002600-20-5A	18 – 26	22	1	2	2:1	2:1	5		175
JS3-18002600-30-5A	18 – 26	22	1	3	2:1	2:1	5		175
JS4-18002600-16-5A	18 – 26	27	1	1.6	2:1	2:1	5		200
JS4-18002600-26-5A	18 – 26	27	1	2.6	2:1	2:1	5		200
JS2-26004000-35-5A	26 – 40	12	2	3.5	2:1	2:1	5		100
JS2-26004000-45-5A	26 – 40	12	2	4.5	2:1	2:1	5		100
JS3-26004000-35-5A	26 – 40	18	2	3.5	2.5:1	2.5:1	8		175
JS3-26004000-45-5A	26 – 40	18	2	4.5	2.5:1	2.5:1	8		175
JS4-26004000-40-5A	26 – 40	23	2.5	4	2:1	2:1	8		200
JS2-26004000-100-20A	26 – 40	17	1.25	10	2.3:1	2.3:1	20		**
JS4-40006000-65-0A	40 – 60	15	3	6.5	2.75:1	2.75:1	0		175
MULTIOCTAVE BAND AMPLIFIERS									
JS2-00500200-05-5A	0.5 – 2	32	1	0.5	2:1	2:1	5		250
JS2-00500200-20-5A	0.5 – 2	32	1	2	2:1	2:1	5		250
JS2-01000400-07-5A	1 – 4	27	1	0.7	2:1	2:1	5		200
JS2-01000400-20-5A	1 – 4	27	1	2	2:1	2:1	5		200
JS2-02000600-07-5A	2 – 6	24	1	0.7	2:1	2:1	5		125
JS2-02000600-20-5A	2 – 6	20	1	2	2:1	2:1	5		125
JS2-02000800-08-0A	2 – 8	22	1	0.8	2:1	2:1	0		125
JS2-02000800-20-0A	2 – 8	18	1	2	2:1	2:1	0		125
JS3-02001800-25-5A	2 – 18	21	2	2.5	2.5:1	2.5:1	5		150
JS3-02001800-50-5A	2 – 18	21	2	5	2.5:1	2.5:1	5		150
JS4-02001800-22-5A	2 – 18	30	2	2.2	2.5:1	2.5:1	5		200
JS4-02001800-50-5A	2 – 18	30	2	5	2.5:1	2.5:1	5		200
JS3-02002600-30-5A	2 – 26	21	2	3	2:1	2.1	5		150
JS3-02002600-40-5A	2 – 26	21	2	4	2:1	2:1	5		150
JS3-06001800-18-5A	6 – 18	23	1.3	1.8	2:1	2:1	5		125
JS3-06001800-30-5A	6 – 18	23	1.3	3	2:1	2:1	5		125
JS4-06001800-135-5A	6 – 18	31	1	1.35	2:1	2:1	5		200
JS4-06001800-30-5A	6 – 18	31	2	3	2:1	2:1	5		200

* Noise figures to 0.35 dB available on a limited basis.
** This unit requires +8V @ 500 mA and -8V @ 90 mA.

MITEQ's JS SERIES AMPLIFIERS

- **High Performance/Price Ratio**
- **Superior, Rugged Technology**
- **Low Phase Distortion Design**



Actual 18 to 40 GHz Design

MODEL NUMBER	FREQUENCY RANGE (GHz)	GAIN (dB, Min.)	GAIN VARIATION (±dB, Max.)	NOISE FIGURE (dB, Max.)	VSWR IN	VSWR OUT	POWER OUT @ 1 dB COMPR. (dBm, Min.)	DC POWER @ +15 V (mA, Nom.)
MULTIOCTAVE BAND AMPLIFIERS (Continued)								
JS3-08001800-17-5A	8 – 18	24	1.2	1.7	2:1	2:1	5	125
JS3-08001800-30-5A	8 – 18	24	1.2	3	2:1	2:1	5	125
JS4-08001800-13-5A	8 – 18	32	1.5	1.3	2:1	2:1	5	200
JS4-08001800-30-5A	8 – 18	32	1.5	3	2:1	2:1	5	200
JS3-08002600-30-5A	8 – 26	21	2	3	2:1	2:1	5	150
JS3-08002600-40-5A	8 – 26	21	2	4	2:1	2:1	5	150
JS3-12002600-25-5A	12 – 26	22	2	2.5	2:1	2:1	5	150
JS3-12002600-35-5A	12 – 26	22	2	3.5	2:1	2:1	5	150
JS4-12002600-22-5A	12 – 26	30	1.7	2.2	2:1	2:1	5	200
JS4-12002600-35-5A	12 – 26	30	1.7	3.5	2:1	2:1	5	200
JS3-18004000-38-5A	18 – 40	16	2.5	3.8	2.5:1	2.5:1	5	150
JS3-18004000-50-5A	18 – 40	16	2.5	5	2.5:1	2.5:1	5	150
JS4-18004000-30-5A	18 – 40	23	2.5	3	2.5:1	2.5:1	5	200
JS4-18004000-50-5A	18 – 40	23	2.5	5	2.5:1	2.5:1	5	200
ULTRAWIDE BAND AMPLIFIERS								
JS2-00100200-06-5A	0.1 – 2	32	1	0.6	2:1	2:1	5	250
JS2-00100200-15-5A	0.1 – 2	32	1	1.5	2:1	2:1	5	250
JS2-00100400-08-5A	0.1 – 4	27	1	0.8	2:1	2:1	5	200
JS2-00100400-12-5A	0.1 – 4	27	1	1.2	2:1	2:1	5	200
JS2-00100600-10-3A	0.1 – 6	23	1.5	1	2:1	2:1	3	175
JS2-00100600-20-3A	0.1 – 6	23	1.5	2	2:1	2:1	3	175
JS2-00100800-13-0A	0.1 – 8	20	1.5	1.3	2:1	2:1	0	175
JS2-00100800-25-0A	0.1 – 8	20	1.5	2.5	2:1	2:1	0	175
JS3-00101000-18-5A	0.1 – 10	26	1.5	1.8	2:1	2:1	5	150
JS3-00101000-35-5A	0.1 – 10	26	1.5	3.5	2:1	2:1	5	150
JS3-00101200-19-5A	0.1 – 12	25	1.5	1.9	2:1	2:1	5	150
JS3-00101200-35-5A	0.1 – 12	25	1.5	3.5	2:1	2:1	5	150
JS3-00101800-26-5A	0.1 – 18	23	1.5	2.6	2.5:1	2.2:1	5	150
JS3-00101800-40-5A	0.1 – 18	23	1.5	4	2.5:1	2.2:1	5	150
JS4-00101800-23-5A	0.1 – 18	29	1.8	2.3	2.5:1	2.2:1	5	200
JS4-00101800-40-5A	0.1 – 18	29	1.8	4	2.5:1	2.2:1	5	200
JS4-00102000-25-5A	0.1 – 20	28	1.8	2.5	2.5:1	2.5:1	5	200
JS4-00102000-35-5A	0.1 – 20	28	1.8	3.5	2.5:1	2.5:1	5	200
JS3-00102600-32-5A	0.1 – 26	20	1.8	3.2	2.5:1	2.5:1	5	150
JS3-00102600-42-5A	0.1 – 26	20	1.8	4.2	2.5:1	2.5:1	5	150
JS4-00102600-28-5A	0.1 – 26	27	2	2.8	2.5:1	2.5:1	5	200
JS4-00102600-50-5A	0.1 – 26	27	2	5	2.5:1	2.5:1	5	200
JS4-00103000-35-5A	0.1 – 30	20	2.5	3.5	2.5:1	2.5:1	5	200
JS4-00103000-45-5A	0.1 – 30	20	2.5	4.5	2.5:1	2.5:1	5	200
JS4-00104000-65-5A	0.1 – 40	14	3.5	6.5	2.75:1	2.75:1	5	200
JS4-00104000-85-5A	0.1 – 40	14	3.5	8.5	2.75:1	2.75:1	5	200

NOTE: Higher 1 dB compression levels are available on many designs.

For additional information or technical support, please contact either Rosalie DeSousa at (516) 439-9458, e-mail rdesousa@miteq.com or Rizwan Syed at (516) 439-9267, e-mail rsyed@miteq.com.

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Power Amplifiers for Wireless Communications

■ **Topics:** Devices for power amplifiers, MMIC technology, and linearization and measurement techniques.
■ **Site:** San Diego, CA
■ **Date:** September 13–14, 1999
■ **Contact:** Peter Asbeck (619) 543-6713 or e-mail: asbeck@ece.ucsd.edu. Additional information can be obtained at www.PAWorkshop.ucsd.edu.

Spread Spectrum Communications Systems: Commericial and Government Applications

■ **Topics:** Spread spectrum modulation techniques and applications for antijam communications, and ranging and synchronization for commercial, space and military electronics systems. Fee: $1445.
■ **Site:** Washington, DC
■ **Date:** September 13–17, 1999
■ **Contact:** P.J. Mondin, George Washington University Continuing Engineering Education Program, Washington, DC 20052 (800) 424-9773 or e-mail: PJ@ceep.gwu.edu.

Technical Management Program

■ **Topics:** Business trends and paradigms and methods to solve problems, plan strategies, motivate colleagues and balance the technical and managerial aspects of individual and organizational performance. Fee: $2295.
■ **Site:** Los Angeles, CA
■ **Date:** September 19–24, 1999
■ **Contact:** UCLA Extension, Dept. of Engineering, 10995 Le Conte Ave., Ste. 542, Los Angeles, CA 90024 (310) 825-3344 or e-mail: kkang@unex.ucla.edu.

Ansoft HFSS User Workshop

■ **Topics:** RF, microwave and wireless design solutions; interaction with the developers of Ansoft HFSS full-wave three-dimensional electromagnetic simulation software; and design of high frequency components, structures and antennas.
■ **Date:** September 23–24, 1999
■ **Site:** Baltimore, MD
■ **Contact:** David DiOrio, Ansoft Corp., Four Station Square, Ste. 200, Pittsburgh, PA 15219 (412) 261-3200 or e-mail: diorio@ansoft.com.

Imaging Radar Technology

■ **Topics:** Theory and practice of modern imaging radar technology, synthetic aperture radar/ISAR system design, processing and utilization. Fee: $1695.
■ **Site:** Washington, DC
■ **Date:** Sept. 29 - Oct. 1, 1999
■ **Contact:** University Consortium for Continuing Education, 16161 Ventura Blvd., M/S 752, Encino, CA 91436 (818) 995-6335 or e-mail: info@ucce.edu. Additional information can be obtained at www.ucce.edu.

EMC, Telecommunications and Product Safety Engineering Workshops

■ **Topics:** Designing to comply with North American telecommunications standards; product safety, including overvoltage categories, creepage and clearance, and pollution degrees; design for electromagnetic compatibility (EMC); and applied EMC for PC board designers.
■ **Site:** Nashua, NH
■ **Dates:** Various
■ **Contact:** Diane Querze, Silent Solutions, 20 Patch Road, Hollis, NH 03049 (603) 465-3920.

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.
■ **Date:** November 4–5, 1999
■ **Site:** Gaithersburg, MD
■ **Contact:** Steve Freiman or Carolyn Sladic, National Institute of Standards and Technology (301) 975-6119 or e-mail: stephen.freiman@nist.gov.

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■ **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.

Signal Generator Spectral Purity Considerations in RF Communications Testing

Today's wireless communications market, from cellular phones to wireless data, is expanding at an incredible rate. Along with this growth comes an increasing need for test equipment that verifies the performance of these devices and systems. Signal generators play a multifaceted role in the development of both receivers and transmitters. They are used for generating signals ranging from simple sinusoidal tones for LO substitution to fully modulated signals for receiver testing. This article focuses on the importance of using a signal generator with relatively high spectral purity for RF communications testing. The ideal signal generator would provide perfect sinusoids at carrier and sideband frequencies, but in reality all signals have imperfections. The foresight to take these flaws into account allows the engineer to select the appropriate signal generator and reduce development time.

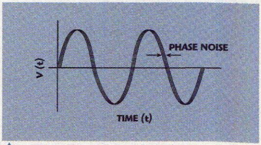
"...in reality all signals have imperfections. The foresight to take these flaws into account allows the engineer to select the appropriate signal generator and reduce development time."

WHAT IS SPECTRAL PURITY?

Spectral purity is the inherent frequency stability of a signal. Stability is defined over a period of time: short or long term. Long-term stability, or drift, is usually defined as frequency changes over a period of time greater than one second. Short-term stability is defined as frequency changes over less than one second. Current signal generator technology generally offers good long- and short-term stability. For wireless communications testing, short-term stability is of greater concern. This article discusses key spectral purity components and the importance of spectral purity in testing wireless communications equipment. Implications of spectral purity are briefly covered for LO substitution, phase noise measurements, receiver performance tests and radar applications.

Phase Noise

Perhaps the most common method for specifying the spectral purity of a signal generator is its phase noise. In the time domain, phase noise is exhibited as a jitter in the zero crossings of a sine wave, as shown in ***Figure 1***.



▲ *Fig. 1 Time domain phase noise jitter.*

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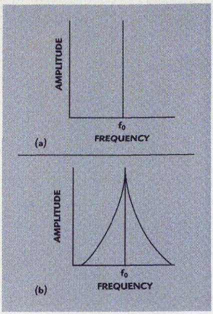


▲ *Fig. 2 A frequency carrier (a) without and (b) with phase noise sidebands.*

For a high performance signal generator, the phase noise is not usually discernible in the time domain. In the frequency domain, the phase noise appears as noise sidebands on the carrier, as shown in ***Figure 2***. The US National Bureau of Standards defines single-sideband (SSB) phase noise $\mathcal{L}(f)$ as the ratio of the noise power in a 1 Hz bandwidth at a frequency f away from the carrier to the signal power of the carrier:

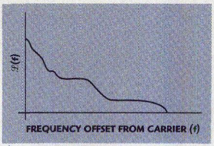
$$\mathcal{L}(f) = \frac{\begin{array}{c}\text{noise power in a 1 Hz}\\ \text{bandwidth at a frequency}\\ \text{f (Hz) away from the carrier}\end{array}}{\text{power level of the carrier}}$$

$\mathcal{L}(f)$ is expressed as decibels relative to the carrier per hertz (dBc/Hz). A 1 Hz bandwidth is used to allow the phase noise in other bandwidths to be easily calculated for comparison.

The SSB phase noise at a specified carrier frequency is often graphically represented on a log-log plot, as shown in ***Figure 3***. Phase noise can be conveniently displayed for a wide range of frequency offsets by using a log scale on the frequency axis.

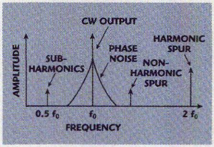
Spurious: Harmonics, Subharmonics and Nonharmonics

Spurious signals are frequency spikes that appear in the spectrum. These spectral components may be divided into three categories: harmonic, subharmonic and nonharmonic, as shown in ***Figure 4***.



▲ *Fig. 3 A typical phase noise plot.*

Fig. 4 Harmonic, subharmonic and nonharmonic signals. ▼



Harmonics are generated by device nonlinearities in the signal generator and are integer multiples of the carrier frequency. For example, a 100 MHz carrier frequency will have harmonics at 200 MHz, 300 MHz and so on. The amplitudes of the harmonics (relative to the amplitude of the carrier signal) are determined by the nonlinear characteristics of the components in the signal generator.

Subharmonics are generated when frequency multiplying to create the carrier frequency. The frequency being multiplied may leak through the signal path and appear at the output. For example, a 500 MHz signal multiplied by two to arrive at a 1 GHz carrier frequency might appear as a subharmonic.

Nonharmonics are frequency components that do not appear related to the carrier frequency. Although signal generator designers can determine the location of these spurious signals, they are unpredictable to the user. Today's signal generators are able to suppress harmonics, subharmonics and nonharmonics to a level acceptable for most applications.

Residual FM

Residual FM is another method commonly used to specify the frequency stability of signal generators. Residual FM includes the effects of both spurious signals and phase

[Continued on page 26]

noise. It is the integral of the SSB curve with limits set by the post-detection bandwidth. Common bandwidths are 300 Hz to 3 kHz and 20 Hz to 15 kHz.

SPECTRAL PURITY CONSIDERATIONS IN RF RECEIVER DESIGN

A spectrally pure signal generator provides high value to those designing and verifying analog and digital communications devices. As an example, a simple communications receiver, shown in ***Figure 5***, is used to illustrate the effects of phase noise and spurious signals on practical applications and measurements. Three major applications discussed here are LO substitution, phase noise measurements and receiver performance tests. All of these applications require the use of a signal generator with sufficient spectral purity.

LO Substitution

In receiver development, as well as transmitter development, a spectrally clean LO is required for upconversion and downconversion of signals. A signal generator is often used to substitute an onboard LO for testing and system troubleshooting. Looking at the downconversion in the receiver, the importance of spectral purity for LO substitution is readily apparent. Suppose that two signals are present at the input of the receiver, as shown in ***Figure 6***. These signals are mixed with an LO signal down to an intermediate frequency (IF) where highly selective IF filters separate one of the signals for ampli-

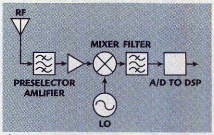
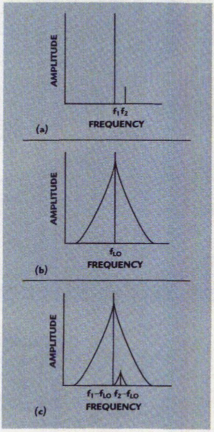


Fig. 5 A simple communications receiver.

Fig. 6 Phase noise effects at the mixer; the (a) RF input, (b) LO and (c) mixer output spectra.



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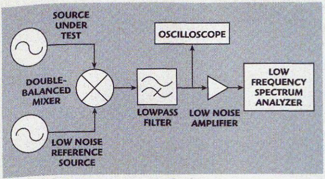


▲ *Fig. 7 Basic measurement setup for the two-source phase detector technique.*

fication, detection and baseband processing. If the desired signal is the larger signal, there is no difficulty in recovering it.

On the other hand, a problem might arise if the desired signal is the smaller of the two because any phase noise on the LO signal is translated directly to the mixer products. Notice that the translated noise in the mixer output completely masks the smaller signal. Even though the receiver's IF filtering might be sufficient to remove the larger signal's mixing product, the smaller signal's mixing product is no longer recoverable due to the translated LO noise.

Phase Noise Measurements

Eventually, the signal generator that is substituting as the LO must be replaced by the actual LO. The phase noise of this onboard oscillator must be measured to ensure a quality signal. In this case, a low phase noise signal generator can be used to make the measurement.

Many methods exist to measure phase noise. One of the most sensitive measurement techniques is the two-source phase detector technique. Here, the signal under test is downconverted to 0 Hz and examined on a low frequency spectrum analyzer. A low noise LO is required as the phase detector reference. The basic measurement setup for measuring phase noise using the two-source technique is shown in ***Figure 7***.

The noise measured by this two-source technique represents the combined noise of both the source under test and the reference source. This level is the upper limit for the phase noise of either device. Therefore, if the phase noise of the reference is better than the source under test, the phase noise of the source under test can be determined.

Receiver Performance Tests

After the design of the receiver is complete, various tests must be performed to confirm design parameters. The primary goal of most receiver tests is to measure the receiver's ability to maintain a certain sensitivity level in the presence of unwanted signals.

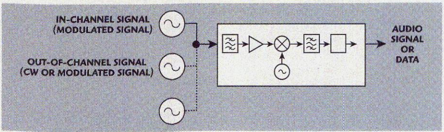
Receiver performance verification tests may be divided into in-channel and out-of-channel tests. Common in-channel tests include sensitivity and co-channel rejection. Common out-of-channel tests are spurious and intermodulation rejection, and adjacent-channel selectivity. All of these tests, except for sensitivity, require a modulated or unmodulated interfering signal with allowable uncertainties, phase noise and spurious content as defined in the communications standard. ***Figure 8*** shows the test setup for co-channel or out-of-channel rejection measurements.

For analog receivers, sensitivity is defined as the minimum power level at which the receiver can successfully detect and demodulate the incoming signal. For digital receivers, sensitivity is defined as the median level of the received signal that produces a specified bit error rate when the signal is modulated with a pseudorandom binary sequence of data. The important specification of the signal generator for sensitivity tests is power level accuracy (rather than spectral purity).

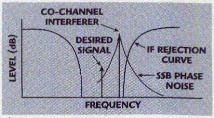
Co-channel rejection is the ability of the receiver to maintain sensitivity in the presence of an in-channel interfering signal. Frequently, this co-channel interfering signal will be a continuous-wave (CW) signal, as shown in ***Figure 9***. The specific communications standard defining this test will set phase noise and spurious signal requirements for the CW tone.

Spurious immunity is a measure of the ability of the receiver to receive a modulated input signal in the presence of unwanted input signals at frequencies other than those specified for adjacent- and alternate-channel tests. The specific communications standard defines the spurious signal frequency location and tolerable phase noise level.

Intermodulation rejection is a measure of the capability of the receiver to receive a wanted modulated signal without exceeding a given degradation due to the presence of two or more unwanted signals with a specific frequency relationship to the wanted signal frequency. Typically, two out-of-channel CW tones are placed so that their third-order intermodulation distortion product falls on top of the desired signal, as shown in ***Figure 10***. Intermodulation rejection measures how well the receiver rejects this unwanted distortion.

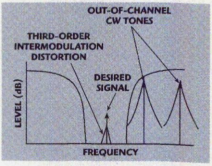


▲ *Fig. 8 The test setup for co-channel or out-of-channel rejection measurements.*



▲ *Fig. 9 Co-channel rejection.*

▼ *Fig. 10 Intermodulation rejection.*



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Adjacent-channel selectivity measures a communications receiver's ability to process a desired signal while rejecting a strong signal in an adjacent channel. Alternate-channel selectivity is a similar test where the interfering signal is spaced two RF channels away from the passband of the receiver. These tests are very important for both analog and digital units where channel spacings are narrow and many signals may be encountered in a small geographical area.

PHASE NOISE REQUIREMENTS FOR ADJACENT-CHANNEL SELECTIVITY

For many receivers, the SSB phase noise of the signal generator used to produce the interfering signal is a critical spectral characteristic. If the phase noise energy inside the passband of the IF filter is excessive, the receiver might appear to fail the test. This case is shown in ***Figure 11***.

The required signal generator SSB phase noise may be calculated using

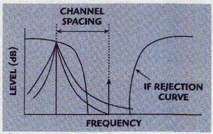
$$\Phi_n = 10\log\left(\frac{1}{B_e}\right) - P_{ac} - P_{mar}$$

where

- Φ_n = signal generator SSB phase noise (dBc/Hz) at the channel spacing offset
- B_e = receiver noise-equivalent bandwidth (Hz)
- P_{ac} = adjacent- or alternate-channel selectivity specification (dB)
- P_{mar} = test margin (dB)

Since B_e and P_{ac} are fixed by the specifications or design, the test margin determines the power that the signal generator phase noise is allowed to contribute to the IF passband of the receiver. A large test margin increases confidence that the receiver operates properly in the presence of signal-to-noise degradation due to fading in the channel or imperfections in receiver components. For a system using a new technology or new operating frequencies, a large test margin should be used to compensate for uncertainties.

For a receiver with a noise-equivalent bandwidth of 14 kHz, P_{ac} at the adjacent channel of 70 dB, margin of 10 dB and channel spacing of 25 kHz, the required SSB phase noise is –121 dBc/Hz at 25 kHz offset. This condition is typical for an analog FM receiver. Unlike the FM receiver in this example, most digital communications receivers have adjacent-channel selectivity values less than 15 dB. For a GSM receiver with a noise-equivalent bandwidth of 200 kHz, a P_{ac} at the adjacent channel of 9 dB, margin of 10 dB and channel spacing of 200 kHz, the required SSB phase noise is



▲ *Fig. 11 Phase noise in adjacent-channel selectivity.*

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TABLE I

MAXIMUM TOLERABLE SSB PHASE NOISE

	Analog FM	GSM	NADC	PDC
Channel spacing (kHz)	25	200	30	25
Approximate receiver noise bandwidth (kHz)	14	200	33	33
Adjacent-channel selectivity (dB)	70	9	13	1
Maximum SSB phase noise at offset (dBc/Hz)	–121 at 25 kHz	–72 at 200 kHz	–68 at 30 kHz	–56 at 25 kHz
Alternate-channel selectivity (dB)	–	41	42	42
Maximum SSB phase noise at offset (dBc/Hz)	–	–104 at 400 kHz	–97 at 60 kHz	–97 at 50 kHz

Fig. 12 A GSM adjacent- and alternate-channel selectivity spectrum.

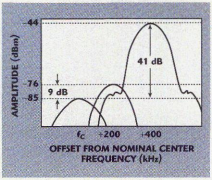
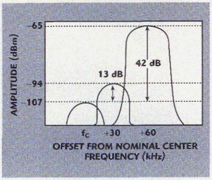


Fig. 13 An NADC adjacent- and alternate-channel selectivity spectrum.



–72 dBc/Hz at 200 kHz offset. The required SSB phase noise is driven primarily by P_{ac}.

Table 1 lists the values of adjacent- and alternate-channel selectivity for various communications systems as well as the required signal generator SSB phase noise. A 10 dB test margin was used. Clearly, for adjacent- and alternate-channel selectivity testing on many digital RF communications formats, the signal generator SSB phase noise is not as important as for analog FM systems.

For selectivity tests, the spectral shape of the signal is the characteristic of primary importance. The digital modulation formats used by GSM, CDMA, North American Digital Cellular (NADC) and personal digital cellular (PDC) characteristically leak a small amount of power into the adjacent channels. ***Figures 12***, ***13*** and ***14*** show amplitude vs. frequency for the selectivity values specified previously. The impact of the spectral shape on the adjacent and alternate channels of the receiver is evident. To properly test a digital radio receiver, the adjacent-channel power of a signal generator must be below the required system specification plus the desired test margin.

RADAR

Radar applications have traditionally required spectrally clean signal generators. Doppler radars determine the velocity of a target by measuring the small Doppler shifts in frequency undergone by the return echoes. Return echoes of targets approaching the radar are shifted higher in frequency than the transmitted carrier, while return echoes of targets moving away from the radar are shifted lower in frequency. Unfortunately, the return signal includes much more than just the target echo. In the case of airborne radar, the return echo also includes a large clutter signal that is basically unavoidable frequency-shifted echoes from the ground.

Figure 15 shows the typical return frequency spectrum of airborne pulsed-Doppler radar. In some situations, the ratio of main-beam clutter to target signal might be as high as 80 dB. This problem is aggravated when the received spectrum has frequency instabilities, specifically phase noise, caused by either the transmitter oscillator or the receiver LO. Such phase noise on the clutter signal can partially or totally mask the target signal, depending on the relative level of the target signal and its frequency separation from the clutter signal.

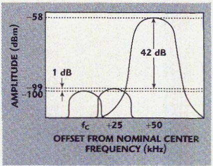
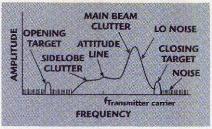


Fig. 14 A PDC adjacent- and alternate-channel selectivity spectrum.

Fig. 15 An airborne pulsed-Doppler radar's typical return frequency spectrum.



CONCLUSION

As the wireless communications revolution moves forward and the frequency spectrum becomes increasingly crowded, the bandwidth requirements for signals become tighter and tighter. Systems must be designed such that only the desired signal is detected in the presence of adjacent-channel signals and other channel interference. More stringent tests on communications devices must be passed. At the same time, test equipment must also meet these strict requirements. A spectrally pure signal generator complements the other test equipment on a development engineer's bench and is highly valued for applications such as LO substitution and receiver testing. ■

Reference

1. "Testing and Troubleshooting Digital RF Communications Receiver Designs," Hewlett-Packard Application Note 1314 (Literature # 5968-3579E).

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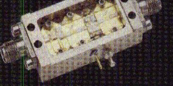
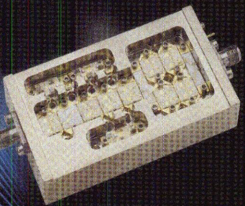
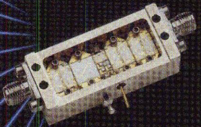
AMPLIFIERS

for every application







ULTRA BROAD BAND

Model	Freq. Range GHz	Gain dB min	N/F dB max	Gain Flat +/-dB	1 dB Comp. pt. dBm min	3rd Order ICP typ	VSWR In/Out max	DC Current mA
JCA018-203	0.5-18.0	20	5.0	2.5	7	17	2.0:1	250
JCA018-204	0.5-18.0	25	4.0	2.5	10	20	2.0:1	300
JCA218-506	2.0-18.0	35	5.0	2.5	15	25	2.0:1	400
JCA218-507	2.0-18.0	35	5.0	2.5	18	28	2.0:1	450
JCA218-407	2.0-18.0	30	5.0	2.5	21	31	2.0:1	500

MULTI OCTAVE AMPLIFIERS

Model	Freq. Range GHz	Gain dB min	N/F dB max	Gain Flat +/-dB	1 dB Comp. pt. dBm min	3rd Order ICP typ	VSWR In/Out max	DC Current mA
JCA04-403	0.5-4.0	27	5.0	1.5	17	27	2.0:1	550
JCA08-417	0.5-8.0	32	4.5	1.5	17	27	2.0:1	550
JCA28-305	2.0-8.0	22	5.0	1.0	20	30	2.0:1	550
JCA212-603	2.0-12.0	32	5.0	3.0	14	24	2.0:1	550
JCA618-406	6.0-18.0	20	6.0	2.0	25	35	2.0:1	600
JCA618-507	6.0-18.0	25	6.0	2.0	27	37	2.0:1	800

MEDIUM POWER AMPLIFIERS

Model	Freq. Range GHz	Gain dB min	N/F dB max	Gain Flat +/-dB	1 dB Comp. pt. dBm min	3rd Order ICP typ	VSWR In/Out max	DC Current mA
JCA12-P01	1.35-1.85	35	4.0	1.0	33	41	2.0:1	1000
JCA34-P02	3.1-3.5	40	4.5	1.0	37	45	2.0:1	2200
JCA56-P01	5.9-6.4	30	5.0	1.0	34	42	2.0:1	1200
JCA812-P03	8.0-12.0	40	5.0	1.5	33	40	2.0:1	1700
JCA1218-P02	12.0-18.0	22	4.0	2.0	25	35	2.0:1	700

LOW NOISE OCTAVE BAND LNA'S

Model	Freq. Range GHz	Gain dB min	N/F dB max	Gain Flat +/-dB	1 dB Comp. pt. dBm min	3rd Order ICP typ	VSWR In/Out max	DC Current mA
JCA12-3001	1.0-2.0	40	0.8	1.0	10	20	2.0:1	200
JCA24-3001	2.0-4.0	32	1.2	1.0	10	20	2.0:1	200
JCA48-3001	4.0-8.0	40	1.3	1.0	10	20	2.0:1	200
JCA812-3001	8.0-12.0	32	1.8	1.0	10	20	2.0:1	200
JCA1218-800	12.0-18.0	45	2.0	1.0	10	20	2.0:1	250

NARROW BAND LNA'S

Model	Freq. Range GHz	Gain dB min	N/F dB max	Gain Flat +/-dB	1 dB Comp. pt. dBm min	3rd Order ICP typ	VSWR In/Out max	DC Current mA
JCA12-1000	1.2-1.6	25	0.75	0.5	10	20	2.0:1	80
JCA23-302	2.2-2.3	30	0.8	0.5	10	20	2.0:1	80
JCA34-301	3.7-4.2	30	1.0	0.5	10	20	2.0:1	90
JCA56-401	5.4-5.9	40	1.0	0.5	10	20	2.0:1	120
JCA78-300	7.25-7.75	27	1.2	0.5	13	23	2.0:1	120
JCA910-3000	9.0-9.5	25	1.2	0.5	13	23	1.5:1	150
JCA910-3001	9.5-10.0	25	1.2	0.5	13	23	1.5:1	150
JCA1112-3000	11.7-12.2	27	1.1	0.5	13	23	1.5:1	150
JCA1213-3001	12.2-12.7	25	1.1	0.5	10	20	2.0:1	200
JCA1415-3001	14.4-15.4	35	1.4	1.0	14	24	2.0:1	200
JCA1819-3001	18.1-18.6	25	1.8	0.5	10	20	2.0:1	200
JCA2021-3001	20.2-21.2	25	2.0	0.5	10	20	2.0:1	200

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Pac-3 Test Packs a Bonus

A recent test of the new and improved Pac-3 PATRIOT interceptor missile at the White Sands Missile Range proved to be more impressive than planned. The $12 M test was designed to gather data and check the missile's ability to detect, track and engage a target. However, the Pac-3 also intercepted and hit the target — a Hera test missile that had been fired six minutes earlier from approximately 175 miles away. The test flight was the first for the onboard radar seeker, which locates the target and feeds information to an onboard processor that determines homing commands. Unlike the original PATRIOT missile, which was used during the Persian Gulf War in 1991 and employed a proximity warhead to destroy its targets, the Pac-3 is a hit-to-kill weapon. The updated version is designed to protect troops by actually hitting enemy ballistic missiles, cruise missiles and aircraft.

Tactical Command and Control System Operational in Middle East

Air Force units in Kuwait now have a more capable command and control system that is able to provide total air defense coverage during a conflict, including the planning and execution of theater air operations. Developed by Electronic Systems Center at Hanscom Air Force Base in Massachusetts, the improved Operations Module has been successfully fielded and fully deployed in the Middle Eastern nation ahead of schedule. The fielding of additional Operations Modules is on schedule for delivery to air control squadrons in Europe and the Republic of Korea. Full deployment is expected to be completed by the fall.

The primary functions of the Operations Module are aircraft control and warning, close air support coordination and control, airspace management, airborne airstrike coordination and control, ground target sensor surveillance and tactical airlift support. When linked to their AN/TPS-75 radars, these deployable command and control centers are capable of forming expeditionary air control squadrons that provide complete flexibility to joint force commanders.

Upgrades to the Modules include the addition of secure voice equipment, improved access to global communications, the capability to electronically receive an air tasking order and the capability to process and exchange data over a Joint Tactical Information Distribution System (JTIDS) network. JTIDS, a jam-resistant, spread spectrum, UHF frequency-hopping system that delivers high capacity, secure data and voice transmission capability, has become the US Defense Department's primary tactical data link. The integration of JTIDS into the Operations Module enhances the system's interoperability and makes it the only system in the Air Force currently able to forward JTIDS data to other tactical data links while providing support to theater operations and delivering sustained, 24-hour airspace surveillance, battle management, and command and control.

Greece to Purchase 50 Additional Lockheed Martin F-16s

Following a long and intense evaluation that included consideration of the Boeing F-15 and several other fighters on the world market, the government of Greece has announced plans to purchase at least 50 more Lockheed Martin F-16 aircraft. Greece has already taken delivery of 80 F-16s purchased under previous orders, and will be acquiring an advanced version of the F-16 designated the F-16 Block 50+. (The advanced version includes the latest core avionics and color displays, conformal tanks for extended range and other advanced capabilities.)

The total program, including the aircraft, mission equipment and a support package, is worth approximately $2 B to various suppliers; the value to Lockheed Martin is approximately $1.4 B. Delivery of the new aircraft will begin approximately 24 months after contract signature, which is anticipated to occur later this year following Congressional approval.

More than 3900 F-16 aircraft have been delivered to the air forces of 19 countries. Lockheed Martin has a firm backlog for 130 additional aircraft not including the new sale to Greece and other pending orders. The US Air Force intends to purchase at least 30 additional F-16s over the next several years.

Lockheed Martin Wins $135 M E-2C Radar Contract

Defense Daily reports that Lockheed Martin has been awarded a $135 M contract to supply 22 APS-145 airborne surveillance radars for the US Navy's Northrop Grumman E-2C carrier-based airborne early warning and control aircraft. The contract is the largest order to date for the APS-145 radar and includes options for eight more radar sets and kits for foreign sales that could bring its total value to more than $200 M.

The US Navy, Japan, Taiwan, Singapore, Israel and France operate the E-2C for airborne surveillance and border patrol. The APS-145 also has been modified for use on the US Customs Service P-3C patrol aircraft and the EC-130J early warning and control aircraft, both also by Lockheed Martin.

Raytheon to Develop JPALS

Raytheon Company has been awarded a $5.8 M Air Force contract to develop the Joint Precision Approach and Landing System (JPALS), a future multiservice, low visibility landing system that replaces aging systems with a single technology for all services and missions. JPALS is a military variant of the local area augmentation system (LAAS) civil landing system technology that will provide improved low visibility operations in benign and hostile environments and military/civil interoperability. Both the military and civil versions of this technology augment the basic GPS signal, providing precise and reliable landing guidance in a format already familiar to pilots.

During the initial 32-month JPALS program contract phase, Raytheon will develop the system's architecture, validate standards, and build and test prototype ground and avionics systems. Raytheon Systems Company's Integrated Systems Division ATC group in Salt Lake City, UT is leading this project as well as a Federal Aviation Administration/industry partnership program to develop the civil LAAS.

US State Department to Control Satellite Component Sales

Communications Daily reports that the US State Department is moving to control all overseas commercial satellite exports. The US Commerce Department is concerned that a transfer of satellite-related items formerly on the Commerce Control List to the State Department's Munitions Control List could hamper US aerospace companies unnecessarily and overstep the intentions of Congress. The State Department claims that the National Defense Act of 1999 transfers to it the export authority for "all satellite components, accessories, attachments and related technical assistance, including, without exception, all launch support activities." Concerns by some in the satellite industry that the State Department would fail to distinguish between friendly nations and those that could pose a security risk when dealing with satellite exports might be alleviated by its International Traffic in Arms Regulations. The primary beneficiary of the turf war between the Commerce and State Departments will be France, the second largest supplier of satellite components. ■

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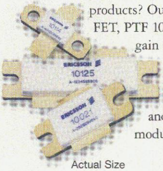

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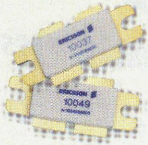

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Raytheon Named Preferred Bidder for ASTOR Programme

The UK's Ministry of Defence used the Paris Air Show (held 12–20 June) to announce that an industrial consortium led by Raytheon UK subsidiary Raytheon Systems Ltd. had been selected as the preferred bidder for the country's £800 M, multiservice Airborne Stand-off Radar (ASTOR) programme. Designed to provide an airborne battlefield surveillance capability based on the use of a synthetic aperture/moving target indicator (SAR/MTI) radar, the ASTOR specification includes requirements for interleaved (but not concurrent) SAR and MTI functions, a maximum surveillance range of between 250 and 300 km, swath and spotlight SAR modes (with a spotlight resolution of approximately 0.5 m), the ability to track moving ground targets at speeds down to less than 10 kmph, the ability to detect and track helicopters in flight and the ability to operate off tether. The radar makes use of Doppler processing while its MTI facility features automatic target tracking and sector scan.

The Raytheon solution is built around a Bombardier Global Express long-range business jet that has been modified to incorporate a sensor based on the Raytheon Advanced SAR System (ASARS)-2: radar, workstations for an onboard mission crew of three, a communications suite (including a Link 16/Joint Tactical Information Distribution System (JTIDS) terminal and X- (8 to 12 GHz) and Ku- (12 to 18 GHz) band data links) and a defensive aids suite. The all-important radar sensor makes use of the latest standard hardware used in the US Air Force's ASARS-2 sets together with a new, 4.6-m-long, electronically steered antenna that is being developed by UK contractor Marconi Electronic Systems. SAR processing for the system is understood to be supported by the UK's Defence Evaluation and Research Agency.

The system will comprise a training package, a mission support subsystem, six mobile Tactical Ground Stations (TGS), two deployment Operational-level Ground Stations (OLGS), and five air vehicles and onboard mission systems. The training package will comprise a flight simulator; flight-, rear- and ground station crew trainers (all served by associated instructor workstations); and three classroom facilities. The mission support subsystem will include a mission support reference sample facility, a portable mission planning system, a data replay facility and a software support facility. The six TGS units will be mounted on Pinzgauer rough terrain vehicles and make use of communications modules, eight workshop modules, 14 trailer-mounted generator modules, six support modules, six antenna trailers, six data link modules and six remote terminals. The two OLGS facilities will comprise two sets of communications modules, five sets of workshop modules, two sets of communications/data link modules, seven generator modules and four remote terminals. The ASTOR air vehicles will be capable of operating at altitudes in excess of 14,326 m, have provision for in-flight refuelling, be capable of flying 13-hour missions and have a ferry range of approximately 11,112 km.

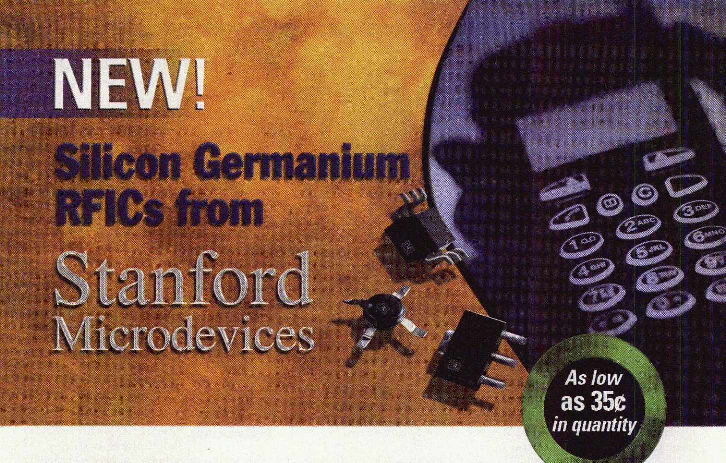
Of the £800 M programme cost, approximately £600 M are devoted to the front end of the system with the remaining £200 M going to through-life support. As currently envisaged, a formal ASTOR contract will be signed before the end of the year and the capability is scheduled to enter service during 2005. The ASTOR system will be based at RAF Waddington in the UK where it will create 300 service and 50 civilian posts supported by a force of approximately 40 contractor personnel.

Philips Targets Dual-band Digital Cellular Market with New Front-end Receiver IC

Netherlands contractor Philips Semiconductors is targeting the dual-band, digital cellular telephone market with the new model SA3600 low power, front-end receiver IC. The device integrates 800 and 1900 MHz band low noise amplifiers and downconverters and features an on-chip LO frequency doubler, input/output buffer amplifiers, matching circuitry and control-mode logic to reduce external glue components. The 800 MHz band amplifier/mixer package consumes 10 mA (2.7 V supply) while the 1900 MHz band architecture's consumption value is 14 mA at the same supply level. According to a company spokesman, such values represent a 35 percent power savings on current best-in-class GaAs RF front-end ICs. At 881 MHz (with an external, interstage, surface acoustic wave filter attached), the device has a gain of 24 dB, noise figure of 2.6 dB and input IP3 of –10.5 dBm. The equivalent values at 1960 MHz are 22 dB, 3.1 dB and –10.4 dBm, respectively. The SA3600 device is currently available and is presented in a 24-pin, plastic thin shrink, small outline package.

Thomson Retained to Supply NH90 IFF Interrogator

French contractor Thomson-CSF Communications has been retained by Italian helicopter manufacturer Agusta to supply identification friend-or-foe (IFF) interrogators for use aboard the naval variant of the four-nation (France, Germany, Italy and the Netherlands) NH90 military helicopter. The equipment selected is derived from the TSX 2500 family of modular systems, which includes the TSB 2500 interrogator-transponder that is installed aboard Sweden's Saab S 100B Argus airborne early-warning and control aircraft. Here, the device comprises a combined Mk XII interrogator/Mk XII Mode S transponder unit and antenna control or adapter unit. As an interrogator, the unit operates at a frequency of 1030 (±0.2) MHz in Mode 1, 2, 3/A, C and 4; as a transponder, the



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 GHz	Gain@ 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

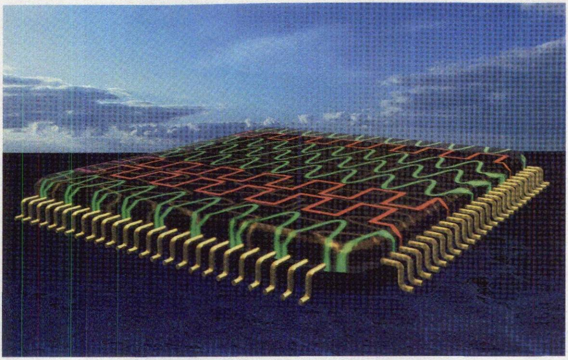
unit uses a frequency of 1090 (±0.5) MHz to provide Mode 1, 2, 3/A, 4 and S coverage. As applied to the NH90, the TSX 2500 interrogator will operate with the helicopter's European Navy Radar, which is being developed by a consortium of Thomson-CSF, Germany's DaimlerChrysler Aerospace and Italy's FIAR. This latest retainer follows a contract Thomson was awarded by Eurocopter Deutschland for the supply of TSC 2000 Mode S IFF transponders for use aboard both the naval and battlefield transport variants of the NH90.

UK Sentries to Get ACE Capability

Three of the UK's seven E-3D Sentry Airborne Warning and Control System aircraft are to be equipped with an Airborne Mission Support System (AMSS) that will provide them with an Airborne Command Element (ACE) facility. Developed against the Royal Air Force's Urgent Operational Requirement (UOR) 42/99, the Racal Defence Electronics AMSS equipment is located at station 18 in the aircraft and will allow an onboard commander (two-star rank) to receive and display tactical information in near real time. Data types available through the system include air-tasking orders, combat search and rescue plans, area weather reports and intelligence updates.

The equipment proposed is based on Racal's existing Lightweight Mission Support System (LMSS), which comprises a carry-on display/processor/disc drive/communications interface unit and a keyboard. LMSS incorporates a 500 MHz DEC Alpha processor (with 256 MB of RAM); a 36 cm, 1024 × 768 pixel high resolution liquid crystal display; and a twin 3.5-inch, 4.3 GB, removable hard disc drive. As applied to the E-3D, AMSS will be linked to the outside world via a high frequency radio, a format that eventually will be replaced by a satellite communications subsystem. The ACE capability will be further enhanced by the availability of a JTIDS situational awareness facility that will provide the commander with a PC-based data link monitoring and recording capability that passively monitors JTIDS/Link 16 networks. UOR 42/99 is a result of the UK's experience during Operation Allied Force and, as of press time, AMSS is scheduled to begin air trials in October or November. AMSS is one of a number of E-3D upgrades currently being pursued that will see the platforms being fitted with the Radar System Improvement Programme package for its AN/APY-2 surveillance radar, a new high frequency communications radio and an enhanced electronic support measures system alongside the ACE capability. ■

MIXED SIGNALS



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Recreational GPS Report Released

Frost & Sullivan has released an update to report 5332-22, "North American Global Positioning Systems Applications Markets." This stand-alone segment analysis addresses the recreational portion of the market, including marine, land and private aviation. In general, the discussion is limited to units costing less than $1000 (although aviation units may exceed this price). The update includes projected sales of specific companies in the market and focuses on specific market trends, including price (which in many cases has dropped below $200 per hand-held unit and may drop below $150 in the next few years); cross-segment marketing, including the transfer of products between applications; usability affected by the combination of hardware and software as well as ergonomic functionality; reliability; status marketing as affected by price, value and status premium; and bundling, including the trend to build the products into the platform to be used. Technological trends discussed include antenna design, signal reception, maps, display technologies, wide area augmentation systems (WAAS), and GPS and wireless communications links.

The recreational GPS market participants mentioned in the study include Magellan Systems Corp., Garmin International, Lowrance/Eagle Electronics, Apelco/-Raytheon Marine Co., Trimble Navigation, Micrologic, Si-Tex Marine Electronics, II Morrow, Bendix-King, Northstar Technologies, Narco Avionics and Terra. The strategic analysis and forecasts address market overviews and definitions, revenue forecasts, competitive analysis and market share, product analysis, market trends and liability for the marine, land and aviation recreational areas. For additional information, contact Frost & Sullivan at (650) 961-9000.

China Unicom to Invest $843 M for CDMA Network

China Daily's Business Weekly reports that China Unicom, a small rival to the state-owned giant China Telecom, will select several foreign systems suppliers to provide equipment for its planned CDMA technology mobile telephony network. The company plans to invest $843 M to establish a nationwide CDMA network with an initial capacity of two million lines this year. The capacity is expected to expand to 10 million lines in 2000. Motorola and Lucent Technologies along with Samsung and Nortel currently have contracts for a small-scale trial providing limited CDMA services in several Chinese cites. China's Ministry of Information has authorized Unicom to acquire these trial systems.

To date, the European-based GSM system has cornered China's digital mobile market, which reportedly adds one million subscribers each month. However, CDMA approval is expected to create a huge new market for manufacturers in the US where CDMA technology dominates cellular telephone use. According to China's World Trade Organization (WTO) entry commitments, Beijing has promised to phase out all geographic restrictions for mobile/cellular services within five years of WTO accession. China, which currently prohibits foreign investment in telecommunications services, will allow 49 percent foreign investment in all services and 51 percent foreign ownership for value-added and paging services within four years. However, faltering US-China relations following the NATO bombing of the Chinese embassy in Belgrade earlier this year could delay or suspend all of these activities.

Projects Worth $80 B Planned/Proposed for ATM

Allied Business Intelligence has released a new report, "Air Traffic Management Systems: Changes and Opportunities in Global ATC Equipment Markets," which evaluates the size of the air traffic control (ATC) equipment market over the next decade and identifies more than $80 B in planned and proposed projects. The need to transition air traffic management (ATM) to a new level of performance is driven by increasing air traffic that is straining capacities and safety envelopes in the airspaces of the most developed regions of the world. In developing regions, particularly China, economic growth is causing rapid installation of ATM infrastructures. The global market for radar systems is expected to expand from $2 B to $4 B per year in less than 10 years.

A more quickly growing market is ATM software, which is expected to reach $2 B in five years. This market is driven by flexibly programmed commercial computer systems and the flow of data streams from a variety of sensor systems. Early successes with GPS signals for navigation have made GPS the cornerstone of new ATM management architectures. Likewise, early Federal Aviation Administration results with differential GPS trials have led to the deployment of a WAAS that was expected to be operational in North America in 1998. Near-term developments will take the system to Category I precision. The report discusses why and where the system will be deployed.

An enhancement to aircraft Mode S avionics turns them into GPS squitters, the backbone system for automatic dependence surveillance-broadcast (ADS-B). This process, coupled with voice and data switches, puts communication-navigation surveillance (CNS/ATM) at the threshold of realization. The reasons for delays in ADS-B implementation are examined and the size of the market for CNS/ATM-enabling technologies is quantified. (These delays also impact the rate of conversion from airport surveillance radar to secondary surveillance radar scans.) The report also discusses the conversion from instrument landing systems to the less expensive local area augmentation system (LAAS). Precision runway monitors (PRM) furnish safe, simultaneous parallel runway use. Until LAAS is available, PRMs will experience relatively strong market growth. For additional information, contact Tim Archdeacon, Allied Business Intelligence (516) 624-3113 or e-mail: info@alliedworld.com.

Next-century Satellite Communications Study Released

A new report, "Satellite Communications for the Next Century: Global Markets for GMPCS, LEOs, MEOs and GEOs 1999–2004," has been released by The Insight Research Corp. The report is motivated by the fact that 50 percent of the world's population does not have access to a telephone. By 2000, more than 60 percent of the world's population still will not have access to terrestrial wireless service let alone broadband data communications service. Global Mobile Personal Communications via Satellite (GMPCS) offers a unique technical solution to the limitations of existing terrestrial and celestial networks and provides messaging, voice and data communications directly to the end user. The system, operating from a constellation of satellites, is able to reach anyone, anywhere, anytime. GMPCS networks will provide basic and enhanced services to all regions of the world, thus offering the potential for true universal service.

The hard reality is considered that telecommunications services today consist of islands of sophisticated terrestrial telecommunications infrastructure located primarily in North America, western Europe and the Pacific Rim, which serve less than 40 percent of the world's population. If an individual does not live in the right part of the world or travels outside of the developed countries, he or she is essentially a nonparticipant in the information age. Intense, unmet demand exists on the part of these prospective users for messaging, narrowband and wideband telecommunications services. The study takes a short- and long-term view of existing and planned GMPCS networks, cost and revenue projections as well as economic, technical and regulatory issues, which will help or hinder the future of satellite systems. For additional information, contact The Insight Research Corp. (973) 605-1400 or fax (973) 605-1440. ■

AROUND THE CIRCUIT

INDUSTRY NEWS

■ Defense contractor **General Dynamics Corp.**, Falls Church, VA, has signed an agreement valued at $1.05 B to acquire three defense electronics units of **GTE Corp.**'s government systems organization. The operations are considered prime assets in the defense markets as the industry continues its consolidation of second-tier suppliers.

■ **Narda Microwave-East**, a division of **L-3 Communications**, has acquired **DBS Microwave**, El Dorado Hills, CA, a designer and manufacturer of amplifier and amplifier-based products in the microwave and millimeter-wave frequencies.

■ **SUSS MicroTec AG**, the holding company of **Karl Suss**, has purchased key assets of **Fairchild Technology's Semiconductor Equipment Group (SEG)**. With the purchase of the Falcon and series 2000/6000 coating systems, SUSS has won new strategic areas of the microelectronics market and will integrate SEG systems into its existing product line starting in 2000. In related news, **Samsung Electro Mechanics Co. Ltd.** has placed orders with Karl Suss for a complete SABER line system. The production-oriented tool set comprises a SUSS MA/BA6-BSA mask aligner as well as a bond aligner and will be installed by Samsung at its operations in Suwon, Korea for use in producing advanced microelectrical-mechanical system devices for the automotive and consumer markets.

■ Defense electronics firm **Condor Systems Inc.**, San Jose, CA, has purchased **The Boeing Company**'s ARGOSystems electronic warfare product line. The aquisition, completed on June 23, included the sale of the trade name ARGOSystems. Financial terms of the transaction were not disclosed.

■ **Texas Instruments Inc.** has entered into an agreement to purchase **ATL Research A/S**, a Denmark-based independent research and development company specializing in RF engineering for cellular communications, to enhance the company's expertise in next-generation wireless communications applications. The transaction was expected to close by the end June; financial terms were not disclosed.

■ **TriQuint Semiconductor Inc.**, Hillsboro, OR, and **RF Solutions LLC**, Atlanta, GA, have jointly agreed to utilize RF Solutions' third-party RFIC design services in conjunction with TriQuint's GaAs IC foundry services. The agreement is intended to provide customers with turnkey GaAs RFIC services and an RF design presence in the southeastern US.

■ **Yokohama Denshi Seiko Co. Ltd. (YDS)** of Japan has entered into an agreement with precision chip device manufacturer **Barry Industries Inc.**, Attleboro, MA, to serve as its original equipment manufacturer (OEM) for thin-film products. The alliance is intended to allow Barry Industries to expand its thick-film product capabilities into the thin-film arena and, in turn, enable YDS to expand its product line into the thick-film market in Japan.

■ Singapore-based **Achieva Components Pte. Ltd.** has entered into an agreement with microprocessor crystal and clock oscillator supplier **Ecliptek Corp.**, Costa Mesa, CA, to be the first distributor of the company's quartz frequency control devices in Asia, including Indonesia, Malaysia, Singapore, Thailand and the Philippines.

■ Technology and engineering solution provider **Radian International**, a **Dames & Moore Group** company, has entered into a cooperative research and development agreement (CRADA) with the US Federal Aviation Administration's (FAA) Office of Air Traffic Systems Development located at New Jersey's Atlantic City International Airport to develop a team that will exchange information, research and user feedback among the FAA and commercial sectors in regard to meterological measurement and sensing equipment and, ultimately, develop aviation weather products to enhance air safety and efficiency. The CRADA is expected to be active for at least three years, but may be extended as projects develop and the two parties agree on further research applications.

■ **California Micro Devices (CAMD)** and **Flip Chip Technologies (FCT) LLC** have entered into a nonexclusive license agreement that provides CAMD with access to FCT's Ultra CSP™ manufacturing technology. The agreement is intended to enhance CAMD's line of integrated passive devices in chip scale packages and strengthen FCT's leadership position in the growing wafer-level packaging industry.

■ Lumped and distributed filter technology manufacturer **Bree Engineering** has opened a new 3000-square-foot facility located at 1269 Linda Vista, San Marcos, CA 92069 (760) 510-4950, fax (760) 510-4959.

■ **ATN Microwave Inc.** has moved to a custom-built 23,000-square-foot facility located at 101 Billerica Ave., Bldg. 4, North Billerica, MA 01862 (877) 286-8665, (978) 667-4200, fax (978) 667-8548.

■ In response to a growing demand by European customers for easier access to engineering support in the development of new space programs, **Honeywell Space Systems** will open an office in conjunction with its **Space & Aviation Control Support Center** at 1 Rue Marcel Doret BP 14, 31701 Blagnac, France, a suburb of Toulouse. This location will be the fourth for the company, which manufactures control products and systems for satellites and launch vehicles in the commercial, military and human space markets.

■ **Advanced Semiconductor Inc. (ASI)**, North Hollywood, CA, will immediately begin supplying microwave and RF semiconductors, which have been discontinued by **Motorola**. ASI will ship the parts from inventory or manufacture replacements to order to continue the supply for critical applications.

[Continued on page 52]

■ **National Technical Systems (NTS)**, Fullerton, CA, has established the only full-service compliance testing capability for NEBS/GR telecommunications standards in the western US. The complete test package, which covers Bellcore GR-63, -1089 and -487 standards and all other collateral testing required by the rapidly growing West Coast telecommunications industry, is expected to reduce the customer's engineering liaison time and expense, allow for team monitoring of test programs and eliminate shipping charges and other costs associated with having equipment tested in eastern US laboratories.

■ Calibration laboratory **Liberty Labs Inc.**, Kimballton, IA, has constructed what is believed to be the world's largest ground test plane for conducting antenna calibrations. The antenna bed cost $500 K and measures 50 × 80 meters. The new ground test plane, along with tightened test procedures and better instrumentation, has allowed the company to improve measurement uncertainty related to the ground plane to values of 0.2 dB or less over the frequency range of 30 to 100 MHz.

■ **Western Technologies Inc.**, Beaverton, OR, and **Clare Micronix Integrated Systems Inc.**, Aliso Viejo, CA, have signed an agreement to develop a proprietary ASIC that is installed into, and becomes part of, the miniature electronics Ear/Micro Phone,™ a new technology that will eliminate the telephone's mouthpiece. The Ear/Micro Phone is designed to be used inside the ear and operates as an earphone and microphone. It functions as a transducer whereby a small air column of sound (the user's voice) is induced upon the transducer, producing electric signals that are directed to a propriety ASIC and ultimately connected to a cellular or cordless telephone.

■ **SaRonix**, Menlo Park, CA, has entered into an agreement with merchant market distributor **Sterling Electronics**, El Monte, CA, to offer its full line of frequency control products, deliverable in five days, to a broad spectrum of customers in the telecommunications, wireless process control automation, computer peripheral, and medical and industrial markets.

■ **Powell Electronics Inc.**, Philadelphia, PA, has entered into an agreement with **RF Industries Ltd.'s Connectors Division**, San Diego, CA, to distribute its full line of coaxial and cable products.

■ **Pacific Wireless Manufacturing Inc.**, Aptos, CA, has named **Richardson Electronics Ltd.** an authorized distributor of the company's C230X series 2.4 GHz GaAs MMIC and PMANT series 2.4 GHz parabolic grid antenna products.

■ **Hittite Microwave Corp. (HMC)**, Woburn, MA, and **United Monolithic Semiconductor (UMS)**, Orsay, France, have signed an agreement where HMC will utilize UMS MMIC die for its surface-mount ball-grid array pack-

[Continued on page 54]

THE HARDEST PART ABOUT INCORPORATING OUR LATEST VARACTOR DIODES INTO YOUR DESIGNS IS DECIDING WHAT TO DO WITH ALL THAT EXTRA SPACE.

SCD80 -vs- SOD323 side-by-side comparison

		
Packages	**SCD80**	**SOD323**
Size in mm (l x h x w)	1.3 x 0.7 x 0.8	1.7 x 0.9 x 1.25
Lead Inductance	0.6nH	2.0nH

Varactor Diodes in SCD80 package

Appl.	part #	C1V [pF]	C3V [pF]	C28V [pF]	rs [Ω]
VCO	BBY51-02W	5.3	3.5	-	0.37
	BBY52-02W	1.9	1.3	-	0.90
	BBY53-02W	5.3	2.4	-	0.37
	BBY55-02W	19.0	12.5	-	0.20
	BBY56-02W	40.6	13.7	-	0.25
	BBY57-02W	18.3	6.5	-	0.34
	BBY58-02W	18.3	8.5	-	0.25
VHF tuning	BB659	38.3	-	2.60	0.65
	BB659C	39.0	-	2.60	0.60
	BB644	41.8	-	2.60	0.60
	BB689	56.5	-	2.70	0.85
UHF tuning	BB555	18.7	-	2.10	0.58
	BB565	20.0	-	2.00	0.60
SAT tuning	BB857	6.6	-	0.50	1.50

The new Infineon SCD80 package is the smallest available, and rounds out our comprehensive line of VARACTOR, PIN and Schottky diodes. It not only saves space, but its low parasitics result in the best performance available at high frequencies. As the leader in wireless components, we've learned the secrets to success: Think small.

To learn more, visit our website to download data sheets and application notes, SPICE and S-parameters.

www.infineon.com/varactor

Infineon technologies

Siemens Microelectronics is now Infineon Technologies.

CIRCLE 42 ON READER SERVICE CARD

aged millimeter-wave MMIC product line. The new products will address point-to-point/multipoint, local multipoint distribution system (LMDS), very small aperture terminal/USAT and low earth orbit/medium earth orbit satellite telecommunications applications and complement both companies' current MMIC standard product offerings.

■ Test and measurement equipment provider **Hewlett-Packard Co. (HP)**, Palo Alto, CA, and asymmetric digital subscriber line (ADSL) manufacturer **Alcatel** have announced the joint development of a fast, efficient, high volume and cost-effective manufacturing test solution for Alcatel's ADSL 1000 modem product line based on the HP 79000 functional test platform. The system offers a complete functional and parametric test solution available to all ADSL modem manufacturers and is suited for ADSL-DMT and ADSL G.lite products. It provides a 400 Hz measurement resolution over a 2 MHz span, which results in full-power spectral density measurements in less than three seconds. In related news, HP's recently launched outreach program for potential Y2K-related failures has reportedly caught on with customers. Several companies have already heeded the company's offer to help develop Y2K preparedness and contingency plans. Test customers are encouraged to contact HP directly or visit its Web site at www.hp.com/go/tm-year2000 to determine the Y2K status of their HP products.

■ **Micro Substrates Corp.**, Tempe, AZ, has licensed microelectronic device manufacturer **HEI Inc.**, Victoria, MN, to manufacture its VIA/BGA™ mm-wave ball-grid array packages used for local multipoint distribution system (LMDS), point-to-point radio, SATCOM and high speed telecommunications applications.

■ **Circuit Assembly Corp.**, Irvine, CA, has been issued a patent for its technology used in mass-terminating ribbon cable to a connector. The technology provides a method of assembly that compensates for tolerance mismatch between the connector housing, contacts and cable by forcing the cable conductors to accurately align with the interdigital transducer (IDT) slot of the contacts, lowering attrition rates during the IDT process.

■ **Magellan Corp.**, a satellite navigation and communications subsidiary of **Orbital Sciences Corp.** located in Santa Clara, CA, and integrated system supplier **Magna International Inc.** have announced the formation of **Magna Works**, a joint venture that will provide advanced vehicle navigation systems to the automotive industry. The new company, to be headquartered in the Detroit, MI area, will design and integrate custom, state-of-the-art vehicle navigation and information systems for OEMs of passenger and commercial vehicles in North America and Europe. In related news, Magellan and Australian automotive audio entertainment system supplier **Eurovox Pty. Ltd.** have jointly agreed to design, develop and manufacture advanced, satellite-aided, in-vehicle navigation systems for markets in Australia and New Zealand. Magellan will license its vehicle navigation technology to Eurovox. Under the terms of a separate technical support and services agreement, Eurovox will develop navigation equipment for OEMs and original equipment importers as well as consumer and commercial applications. Further details of the agreement were not released.

■ **Cable Television Laboratories Inc. (CableLabs®)** has named five cable modem suppliers whose products have been certified for retail sale, including **Askey Computer Corp.**, **Cisco Systems**, **Philips Electronics**, **Samsung Information Systems of America** and **Sony Corp**. The certification informs consumers that the modem complies with CableLabs' cable modem specification. Five companies already have been recognized by CableLabs certification, including **Toshiba**, **Thomson Consumer Electronics**, **3Com**, **General Instrument** and **Arris Interactive**.

■ Smart antenna system provider **Metawave® Communications Corp.** has opened offices in Taipei, Taiwan and Shanghai, China to support sales, service and manufacturing operation for its Spotlight® smart antenna systems. The announcement follows a technical cooperation agreement with the Shanghai Post & Telecommunications Administration and **Shanghai New Globe Co.** providing for the development of a smart antenna for GSM networks, the predominant technology in Asia.

■ The Automatic RF Techniques Group (ARFTG) will offer a new Microwave Measurement Student Fellowship to recognize and provide financial assistance to graduate students who wish to pursue research related to improvement of RF and microwave measurement techniques. One or more $7500 award may be granted each year based on available funding and the number of qualified applicants. The next deadline is October 1. For more information visit ARFTG's Web site at www.arftg.org/fellow.html or contact Jeffrey Jargon, NIST, 325 Broadway, M/S 813.01, Boulder, CO 80303 (303) 497-3596, fax (303) 497-3970 or e-mail: jargon@boulder.nist.gov.

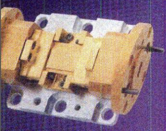
■ **Space Electronics Inc.**, San Diego, CA, has announced the formation of a partnership with the Directorate of Testing and Technology, Radiation Tolerance Assured (RTA) and Support Center, White Sands, NM. The partnership is intended to form a bond between government and industry that addresses diminishing manufacturing sources and material shortages (DMSMS) microelectronics problems by providing several services, including design, assembly, RTA certification, screening qualification, procurements and logistic support, and fenced storage of microelectronics for all military programs. Initial solutions for DMSMS microelectronics devices are currently in production at Space Electronics for the B-2 program and Abrams M1A2 SEP program.

■ **Stanford Telecommunications Inc.**'s wholly owned subsidiary, **Stanford Wireless Broadband Inc.**, has concluded the installation of the first full-featured wireless broadband access system in Madrid, Spain. Stanford's equipment has been successfully integrated into a state-of-the-art, high power broadband multicarrier LMDS system designed and integrated by **TTT SL** of Spain.

[Continued on page 56]

MILLIMETER WAVE COMPONENTS

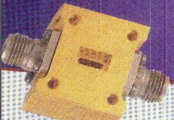
AMPLIFIERS • MIXERS • MULTIPLIERS



AMPLIFIERS

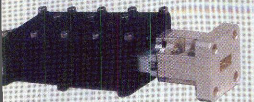
Model Number	Frequency (GHz)	Gain (dB, Min.)	Gain Flatness (±dB, Max.)	Noise Figure (dB, Max.)	I/O VSWR (Max.)	Output Power at 1dB Comp.* (dBm, Typ.)
JSW4-18002600-18-5A	18-26	28	1.0	1.8	2.0:1/2.0:1	5
JSW4-26004000-25-5A	26-40	25	2.5	2.5	2.0:1/2.0:1	5
JSW4-18004000-32-8A	18-40	21	2.0	3.2	2.0:1/2.5:1	8
JSW4-30005000-45-5A	30-50	21	2.5	4.5	2.5:1/2.5:1	5
JSW4-40006000-65-0A	40-60	16	2.5	6.5	2.5:1/2.5:1	0

* Higher output power options available



MIXER/CONVERTER PRODUCTS

Model Number	Frequency (GHz)			Conversion Gain/Loss (dB, Typ.)	Noise Figure (dB, Typ.)	Image Rejection (dB, Typ.)	LO-RF Isolation (dB, Typ.)
	RF	LO	IF				
LNB-1826-30	18-26	Internal	2-10	42	2.5	20	45
LNB-2640-40	26-40	Internal	2-16	42	3.5	20	45
ARE3436LC1	34-36	15.5-16.5	2.7-3.3	25	4	20	60
SBW3337LG2	33-37	33-37	DC-4	-7.5	8	N/A	25
TB0440LW1	4-40	4-42	.5-20	-10	10.5	N/A	20
DB0440LW1	4-40	4-40	DC-2	-9	9.5	N/A	25
SBE0440LW1	4-40	2-20	DC-1.5	-10	10.5	N/A	20



MULTIPLIERS

Model Number	Frequency (GHz)		Input Level (dBm, min.)	Output Power* (dBm, min.)	Fundamental Feed Through Level (dBc, min.)	DC current @+15VDC (mA, nom.)
	Input	Output				
MAX2M260400	13-20	26-40	10	12	18	160
MAX2M200380	10-19	20-38	6	14	18	200
MAX2M300500	15-25	30-50	10	8	18	160
MAX4M400480	10-12	40-48	10	8	18	250
MAX3M300300	10	30	10	10	60	160
MAX2M360500	18-25	36-50	10	8	18	160
MAX2M200400	10-20	20-40	10	10	18	160
TD0040LA2	2-20	4-40	10	-3	30	N/A

* Higher output power options available

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AROUND THE CIRCUIT

■ **Semiconductor Packaging Materials Co.**, a division of **SEMX Corp.** located in Armonk, NY, has achieved QS9000 certification for meeting the basic requirements of the ISO 9000 standard and satisfying the more rigorous specifications of the automotive industry.

■ **Decibel Products**, an **Allen Telecom Inc**. company, has been certified by Brazil's FINAME. The certification will permit Brazilian-based communications companies to use special government-subsidized financing and funding programs to purchase Decibel's line of wireless communications equipment. FINAME is the Brazilian Development Bank agency responsible for promoting the expansion, retrofitting and revamping of Brazilian plant facilities by providing long-term loans for the sale of domestic-made machinery and equipment.

■ **Garwood Laboratories Inc.** is celebrating its 45th year as a testing services provider. Established in 1954 to service the aerospace industry, the company has expanded into all industries offering climatics, dynamics, space simulation, EMC, hydraulics and pneumatics, product safety, and automotive and packaging testing.

■ **California Eastern Laboratories (CEL)** is celebrating its 40th anniversity. Founded in 1959, the company today represents **NEC**'s RF, wireless and optoelectronic semiconductor products exclusively. In related news, CEL and **ATN Microwave**, North Billerica, MA, have announced the installation of a noise parameter test system at the CEL headquarters in Santa Clara, CA. The system promises significant improvements in measurement speed and user interface and features two Wavevue™ software modules, which will form the basis for ATN's new NP5C noise parameter system.

■ Precision crystal, oscillator and filter producer **International Crystal Manufacturing Co. Inc.**, Oklahoma City, OK, reports that 95 percent of its manufactured products are deliverable on time or ahead of schedule due to enhanced computerized tracking and scheduling software.

FINANCIAL NEWS

■ **Comtech Telecommunications Corp.** reports sales of $10.5 M for the third quarter, ended April 30, compared to $8.7 M for the third quarter in 1998. Net income was $498 K (18¢/share), compared to $388 K (15¢/share) for the same period in 1998.

■ **REMEC Inc.** reports sales of $43.2 M for the first quarter, ended April 30, compared to $50.6 M for the first quarter in 1998. Net loss was $3.4 M (14¢/diluted share), compared to a net income of $2.3 M (9¢/diluted share) for the same period in 1998.

■ **CoWare™ Inc.**, a provider of system-level design tools for complex system-on-a-chip development, has raised $8 M during its second round of venture funding, which began in October 1996. The new financing, added to its first round completed in April 1997, brings the company's

[Continued on page 58]

total funding to approximately $14 M. CoWare will use the new funding to continue expanding its operations domestically and globally, particularly in sales, marketing and product development.

■ Wireless communications filter product developer **Superconductor Technologies Inc.**, Santa Barbara, CA, has signed a working capital credit agreement with Venture Bank @ PNC, a division of PNC Bank, for a maximum of $2.5 M, which has replaced its previous credit line of $1.5 M.

CONTRACTS

■ **Sprint PCS** has signed a three-year contract with **Nortel Networks** for cdmaOne™ equipment and services for Phase III of Sprint PCS' nationwide wireless network development and expansion. Under the terms of the $520 M contract, Nortel will provide equipment and services that will enable Sprint PCS to expand coverage and increase network capacity to meet rapidly growing customer demand. The new contract represents the continuation of a successful relationship between the two companies in which Nortel has provided solutions for all three phases of Sprint's wireless network deployment.

■ **Stanford Telecommunications Inc.**, Sunnyvale, CA, has been awarded a five-year contract with a potential value of $100 M to provide critical services to facilitate meeting short- and long-term telecommunication requirements within the FAA. **Stanford Telecom's Communication Systems Integration Group** will provide engineering support to the FAA's operation of existing networks as well as aid in planning and supporting the implementation of network modernization to allow the FAA to meet the challenges of the 21st century.

■ In a move that will speed the maturity and commercial availability of its indium phosphide (InP) IC technology, **TRW Inc.**, Redondo Beach, CA, has entered into a 24-month contract valued at $600 K with the Australian government-owned Commonwealth Scientific and Industrial Research Organization (CSIRO) to produce a set of InP chips designed by CSIRO. The circuits, which include low noise amplifier, mixer and high speed digital receiver chips, will be integrated into a variety of CSIRO radio astronomy and telecommunication demonstration systems.

■ **Berkeley Varitronics Systems Inc.**, Metuchen, NJ, has been awarded a contract by Procelbras of Brazil to provide CDMA test transmitters and Rhino rubidium frequency sources to help with rapid build-out in Brazil's underground rail system. Financial terms of the contract were not disclosed.

PERSONNEL

■ The Cellular Telecommunications Industry Association (CTIA) board of directors has elected **Richard P. Ekstrand**, president and CEO of Rural Cellular Corp. (RCC), to serve as secretary. Ekstrand has been with RCC since its inception in 1990.

▲ Richard R. Rogers

■ **Richard R. Rogers** has been promoted to VP of Amplifier Research's (AR) AMREP division. Rogers has been with AR since 1993 and will continue to play an active role in the company's marketing communications program as marketing manager.

■ **Peter Spaulding** has been appointed VP and general manager at Boldt Metronics International's business unit. Spaulding brings to the company more than 30 years of experience in multinational, multiplant manufacturing environments at such companies as General Electric, TRW Globe Motors and, most recently, Wilton Tool Group. He is also the founder of HEI Inc.

▲ Michael J. Sanator

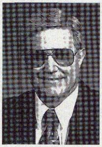
▲ Robert A. Koezler

■ Narda Microwave-East has promoted **Michael J. Sanator** to VP, operations and **Robert A. Koelzer** to VP, engineering. Sanator has been with the company since 1997 as director of operations; Koelzer joined the company in 1985 as product line manager for passive products.

■ CTS Corp. has named **Douglas Rasmussen** VP and general manager of its frequency products operations. Rasmussen has extensive electronic components industry experience and, most recently, served as VP and general manager at Honeywell Optoelectronics.

■ Integrated RF power product manufacturer Xemod Inc., Sunnyvale, CA, has appointed **Michael Foster** VP, sales and **James Harter** VP, operations. Foster brings to the company more than 20 years of technology sales experience and, most recently, served as VP, sales and marketing at P-Com Inc.; Harter has more than 25 years of experience in leading manufacturing and operations efforts in several industries and, most recently, served as VP, operations for terrestrial satellite equipment manufacturer EFData Corp.

■ RIFOCS Corp. has promoted **Richard Buerli**, formerly director of engineering, to VP, engineering.



▲ Lew Backer

■ **Lew Backer** has joined Storm Products' Advanced Technology Group as western regional sales manager for the Microwave Business Unit. Backer has more than 15 years of cable, connector and microwave cable assembly experience and, most recently, was director of marketing and sales for AMP's Precision Cable Division. In addition, **Colin Scrimgeour** has joined the company as quality assurance manager. Most recently, Scrimgeour was quality manager for Telecommunication Devices.

[Continued on page 60]

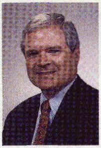
▲ Michael W. Murphy

■ **Michael W. Murphy** has been appointed director, customer support for Microwave Instrumentation Technologies LLC. Murphy joins the company after 22 years of service with Rockwell International Corp. and The Boeing Company.

▲ Lyn Bresnen

■ Trompeter Electronics Inc. has named **Lyn Bresnen** new business development manager. Bresnen brings to the company 20 years of experience in technical sales and marketing and has held positions at Johnson Components and Amphenol Corp. In addition, **Gayland Fisher** has joined the company as regional sales manager. Fisher has 25 years of experience in sales, marketing and engineering and, most recently, served as national distributor manager at Power-One.

■ Texas A&M University engineering professors **Kyle T. Alfriend** and **B. Don Russell** have been named to the National Academy of Engineering. Alfriend heads the aerospace engineering department and Russell is associate vice chancellor for engineering. Academy election is among the highest professional honor for engineers.



▲ David A. Wilson

■ Uniphase Corp. has appointed **David A. Wilson** director of administration for its Broadband Products division. Previously, Wilson was director of finance and accounting for Harris Corp.'s Electronic Systems Sector.

■ SaRonix has named **Jacques Dorian** northeast regional sales manager. Before joining the company, Dorian owned a manufacturing representative firm and sold crystals and oscillators.

NEW MARKET ENTRY

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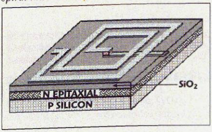
MODELING OF METAL AND SUBSTRATE LOSSES IN CMOS AND BICMOS INDUCTORS FOR RFICS

This article presents an improved lumped-element equivalent circuit of silicon integrated inductors that accurately characterizes the effects on the quality factor (Q) of the electromagnetic coupling between the metal strips and substrate. In the proposed model, a magnetic coupling describes the interaction between the substrate and the metal spirals. The equivalent circuit is extracted using a characterization procedure that, from two-port wideband measurement of the S parameters, automatically yields the value of the lumped element via the method of least square minima.

The continuous evolution of silicon technology is introducing some innovations in the RF design of transceivers for wireless communications, in particular on-chip spiral inductors. Currently, technology scaling allows CMOS and BiCMOS processes to operate at RF and a great effort is underway to obtain a monolithic solution that meets mobile telecommunication standard specifications. The goal of a CMOS or BiCMOS single chip with low power consumption and reduced fabrication cost can be met only if these technologies succeed in replacing bipolar and GaAs in the RF analog part. Therefore, inductors need to be realized on a silicon substrate along with all of the other devices in a single chip. In fact, the need for high Q integrated inductors in RFICs is increasing. These devices are typically used in low voltage/low power designs to realize narrowband impedance matching, tuned loads (resonant tanks), low noise degeneration and feedback, and linear filters with high dynamic range.

Integrated inductors on GaAs have been successfully realized with Q values on the order of tens. The lower substrate resistivity of silicon, especially for CMOS processes, reduces the Q values due to the increased substrate losses. For these reasons it is important, in CAD applications, to model these effects using an accurate lumped-element circuit deduced from experimental or numerical characterization. This article discusses this topic and proposes an improved lumped-element equivalent circuit for silicon integrated inductors. Experimental data are also presented.

Fig. 1 An integrated spiral inductor.



INTEGRATED INDUCTORS

The layout of a simple integrated inductor is shown in ***Figure 1***. The top level of metal

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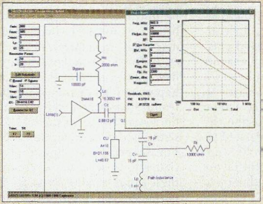

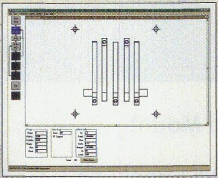

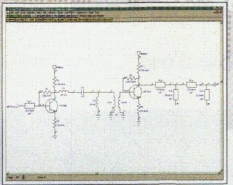

(the less resistive) is used to realize the spiral, and a second metal level is used to provide access to the second port of the device. The substrate is silicon with a thin epitaxial layer.

As these devices are designed for low cost consumer applications, the technology used should be completely standard. Therefore, a distinction must be made between design and process parameters. Design parameters (area, shape, metal strip width, distance between metals and number of turns) can be manipulated by the designer to optimize the inductor's features; process parameters (substrate resistivity and metal line conductivity) are set by the technology. This constraint is critical because a silicon substrate is intrinsically characterized by high losses; a CMOS substrate is characterized by a very low resistivity if compared with bipolar and BiCMOS substrates. Moreover, metal resistivity contributes to a further degradation of the Q of these devices.

Simple spiral inductors realized in standard technology are characterized by a Q defined as[1]

$$Q \equiv 2\pi \frac{\text{energy stored}}{\begin{array}{c}\text{energy loss}\\ \text{in one}\\ \text{oscillation cycle}\end{array}} \qquad (1)$$

Q values between 5 and 8 were reported previously,[1–3] with inductors realized in a CMOS standard process. These values are too low to allow these devices to be used in commercial applications and an effort is needed to increase the Q.

Recently, the interest in the realization of RF transceivers for consumer electronics has motivated a major research effort to realize inductors on silicon. The activity has been focused on innovative structures to achieve Qs as high as possible and on equivalent circuits to describe the physical behavior of the integrated inductors.[4,5] Interesting results were obtained using many metal layers (connected in series[6] or in shunt[7]) to create a three-dimensional (3-D) multilayer geometry. Moreover, the most recent technological processes provide thicker (2 to 3 µm) and more conductive metal layers (10 mΩ/sq), allowing a reduction of the ohmic losses. Another innovative solution has been proposed[8] with the introduction of a polysilicon shield below the spiral that limits the coupling between the spiral and the substrate.

However, to improve the Q of the integrated inductors, it is important to study their physical behavior. This effort permits understanding of the effects that limit their performance and, consequently, their design can be optimized. Actually, it has not been demonstrated whether Q is limited mainly by substrate or metal losses. In fact, some authors[9] believe that metal series resistance causes a very important limitation in the inductor's features while others[10,11] affirm that the low resistivity of the CMOS substrate is the most serious problem. For this reason, an equivalent circuit that allows separate evaluation of these two dissipative terms is very important in the optimization of these integrated devices.

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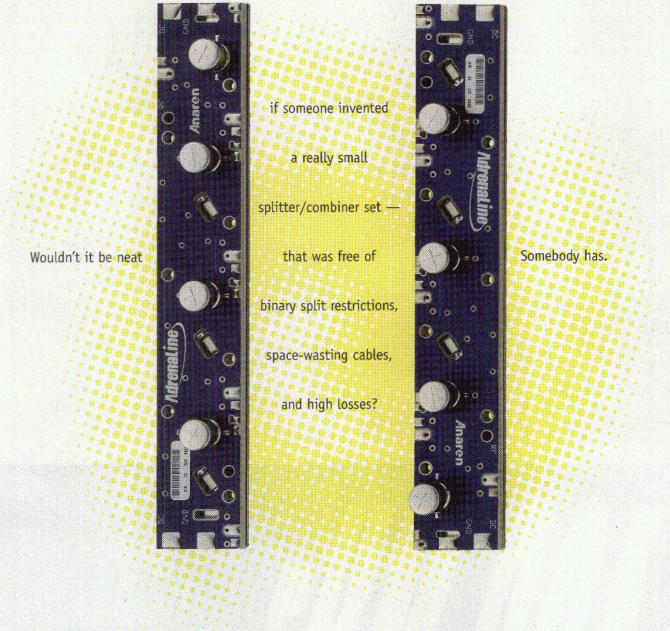

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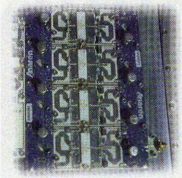

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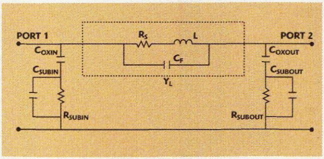
THE IMPROVED EQUIVALENT CIRCUIT

Since the geometrical dimensions of these devices are small compared to the wavelength, it is possible to model them using a lumped-element circuit. The equivalent circuit usually found in the literature is shown in ***Figure 2***. Several lumped elements constitute this circuit: R_S = series resistance caused by the finite conductivity of the metals, C_F = fringing field capacitance between each side of the spiral, C_{OXin} and C_{OXout} = capacitive effect of the oxide



▲ *Fig. 2 The classical equivalent circuit.*

▼ *Fig. 3 The improved equivalent circuit.*

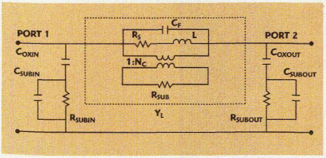
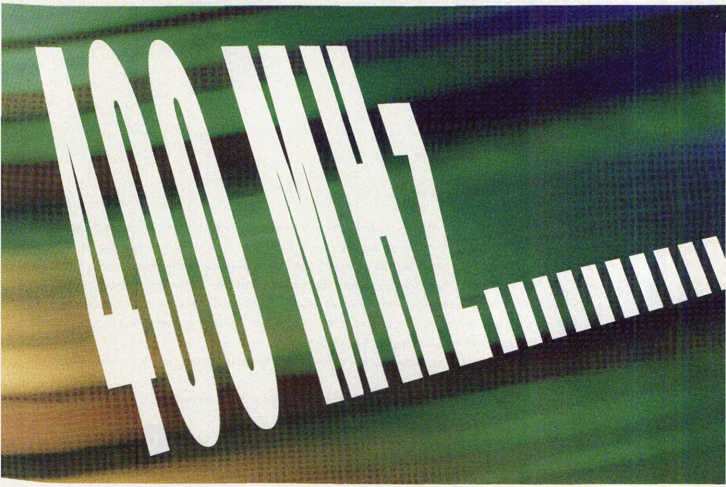


TABLE I

GEOMETRICAL CHARACTERISTICS OF THE DESIGNED INDUCTORS

Name	Lx (μm)	Th (μm)	W (μm)	S (μm)	N	L (nH)
Ind1c	300	1	9	4	2	2.99
Ind2c	300	1	9	4	4	7.83
Ind3c	300	1	9	4	6	12.30
Ind1b	300	1	24	4	2	1.83
Ind2b	300	1	14	4	2	2.51
Ind3b	300	1	14	4	4	5.96
Ind4b	300	1	9	4	6	12.30

Lx = length of the most external side of the spiral
Th = metal thickness
W = width of the metal strips
S = space between each side of the spiral
N = number of turns
L = estimated inductance value



layer, C_{SUBin} and C_{SUBout} = capacitive coupling with the substrate, and R_{SUBin} and R_{SUBout} = losses associated with the electrical coupling with the substrate.

This model appears to be inadequate for the accurate description of the coupling with the substrate because it neglects completely the magnetic coupling between the spiral and substrate. In fact, the electromagnetic field induced by the current on the spiral induces opposite currents in the low resistive CMOS substrate. Thus, to better describe this coupling, a substrate resistance (R_{SUB}) coupled through a transformer to the inductor was inserted in the equivalent circuit, as shown in ***Figure 3***. It is important to note that though apparently two new lumped parameters (N_C and R_{SUB}) were introduced, the elements are equivalent to a shunt resistance equal to $(N_C)^2 R_{SUB}$ and the transformer is introduced only to better describe the physical phenomenon.

This effect, which probably could be neglected in the GaAs or bipolar inductors, is very important in CMOS technology. In fact, the CMOS substrate is characterized by a doping concentration so high that in most modern technologies the equivalent resistivity of the substrate is close to 0.01 Ω-cm. This resistivity causes a loss angle close to 1 rad in the frequency range of interest.

VALIDATION OF THE EQUIVALENT CIRCUIT AND EXPERIMENTAL RESULTS

Seven integrated inductors were designed: four using BiCMOS technology and three using CMOS technology. The geometrical characteristics of the inductors are listed in ***Table 1*** together with the nominal inductance values calculated using the Grover method.[12] All of the devices have been realized using a relatively thin metal (1 μm). ***Figure 4*** shows a photograph of the die, which highlights the layout of the spiral inductor and the reference ground structure.

The S-parameter measurements were performed using an on-wafer microwave measurement station connected to an automatic network analyzer. The two ports have been designed to match Cascade RF coplanar probes used for on-chip measurement. S-parameter measurements were performed at 101 frequency points in the 100 MHz to 13 GHz frequency band.

A detailed description of the characterization and the de-embedding procedure has been published previously.[13] The measured S parameters of the device under test and the reference ground appear as input. The value of all

Fig. 4 Top view of an integrated inductor and test pattern.

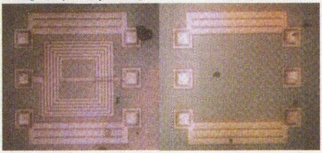
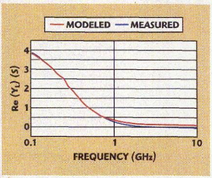


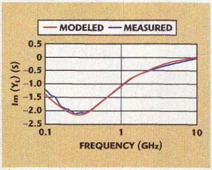
TABLE II

EXTRACTED LUMPED-ELEMENT FOR THE INTEGRATED INDUCTORS

	L (nH)	R_S (Ω)	C_S (fF)	R_{SUB} (Ω)	C_{OXin} (fF)	C_{SUBin} (fF)	R_{SUBin} (Ω)	C_{OXout} (fF)	C_{SUBout} (fF)	R_{SUBout} (Ω)
CMOS										
Ind1c	3.7	10	18	800	70	150	100	140	200	100
Ind2c	7.3	15.5	22	720	120	200	100	170	200	120
Ind3c	11.4	21	42	640	150	260	100	220	250	150
BiCMOS										
Ind1b	2.0	4.5	36	1250	200	180	250	300	280	200
Ind2b	2.4	6.9	39	1125	200	280	280	350	160	200
Ind3b	6.8	10.5	43	800	300	290	290	400	180	210
Ind4b	13.0	20.5	58	1058	370	280	280	420	100	150

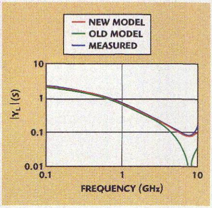


▲ *Fig. 5 The real part of Y_L for the BiCMOS inductor.*



▲ *Fig. 6 The imaginary part of Y_L for the BiCMOS inductor.*

▼ *Fig. 7 $|Y_L|$ vs. frequency.*



the lumped elements, which constitute the equivalent circuit, constitute the output. The complete results are listed in ***Table 2***.

The frequency behavior of Y'_L, Y'_{SUBin} and Y'_{SUBout} (relative to the extracted model) was compared with that of Y_L, Y_{SUBin} and Y_{SUBout} (directly deduced from S-parameter measurements) to validate the characterization procedure based on the least square minima method. In all cases, good agreement was found across the entire measurement frequency range. As an example, ***Figures 5*** and ***6*** show the comparison of the admittance Y_L and Y'_L for the BiCMOS inductor Ind3b. In the proposed model, R_S is assumed to be independent of frequency. In fact, the metal used is thin if compared to the skin depth, and a constant distribution of the current in its section in the frequency range of interest is assumed. This assumption is confirmed by the fact that also including a frequency-dependent resistance R_S did not obtain a better fitting than the one proposed.[14]

Comparing these results with the ones obtained by the same fitting procedure applied to the classical equivalent circuit, it is possible to appreciate the better fitting achieved with the improved equivalent network. An illustration of this fact is shown in ***Figure 7***, which compares the frequency behavior of $|Y'_L|$ of Ind3B obtained from the two equivalent networks and the measured data. The improvement is particularly evident when the amplitude is small, that is, near the inductor self-resonance frequency.

To further validate the method, some of the extracted parameters have been compared to the expected parameters estimated from geometrical and technological data. ***Table 3*** lists the results relative to the value of L (estimated using the Grover method), R_S (estimated from the resistance per square of the metal), and C_{OXin} and C_{OXout} (estimated from the area and fringing-field oxide capacitance as described in the process design rules). The agreement is good, the errors be-

TABLE III

A COMPARISON BETWEEN INDUCTORS EXTRACTED PARAMETERS AND THE EXPECTED ONES

	Estimated				Extracted			
	L (nH)	R_S (Ω)	C_{OXin} (fF)	C_{OXout} (fF)	L (nH)	R_S (Ω)	C_{OXin} (fF)	C_{OXout} (fF)
CMOS								
Ind1c	2.99	11.0	66	96.7	3.7	10.0	70	140
Ind2c	7.83	18.0	108	138.0	7.3	15.5	120	170
Ind3c	12.30	22.6	127	157.0	11.4	21.0	150	220
BiCMOS								
Ind1b	1.83	4.1	271	333	2.0	4.5	200	300
Ind2b	2.51	6.3	186	252	2.4	6.9	200	350
Ind3b	5.71	10.5	301	338	6.8	10.5	300	400
Ind4b	12.30	22.0	290	314	13.0	20.5	370	420

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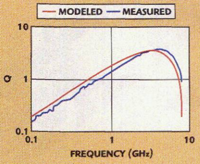
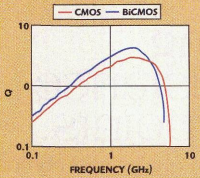


▲ *Fig. 8 Q vs. frequency for BiCMOS inductor ind2b.*



▲ *Fig. 9 Q vs. frequency deduced from measurements of the integrated inductors.*

TABLE IV

Q_{MET} AND Q_{SUB} FOR A BiCMOS AND CMOS INDUCTOR

	f = 0.9 GHz		f = 1.8 GHz		f = 3.5 GHz	
	Q_{MET}	Q_{SUB}	Q_{MET}	Q_{SUB}	Q_{MET}	Q_{SUB}
Ind4b	3.14	14.0	5.57	4.80	4.5	0.98
Ind3c	3.27	7.5	5.10	2.15	3.1	0.35

ing on the order of 30 percent for the capacitance values and even lower for the inductance and resistance values (15 and eight percent, respectively). Note that these figures refer to the nominal values of the process parameters and do not include their spread.

QUALITY FACTOR

The Q of integrated inductors can be evaluated directly as a function of frequency using the two-port characterization of the improved structure, valid up to the self-resonant frequency of the inductor,[10] using

$$Q(\omega_i) = \frac{\mathrm{Im}\left(\dfrac{1}{Y_{\pi 11}(\omega_i)}\right)}{\mathrm{Re}\left(\dfrac{1}{Y_{\pi 11}(\omega_i)}\right)} \tag{2}$$

where $Y_{\pi 11}$ is deduced from the de-embedded measured data.[13] Once the improved equivalent circuit has been characterized by the fitting procedure described previously, the Q can also be deduced from the equivalent network of the intrinsic inductor. Thus,

$$Q'(\omega_i) = \frac{\mathrm{Im}\left(\dfrac{1}{Y'_{\pi 11}(\omega_i)}\right)}{\mathrm{Re}\left(\dfrac{1}{Y'_{\pi 11}(\omega_i)}\right)} \tag{3}$$

where $Y'_{\pi 11}$ is calculated from the values of the elements of the equivalent network. Of course, the two Qs are practically coincident if the equivalent circuit is accurate. It is evident, as shown in ***Figure 8***, which refers to inductor ind2B, that Q and Q' compare quite well at every frequency at which measurements were performed.

The measured Q values obtained for the inductors are rather low. In fact, as reported previously, the observed maximum Q deduced from measurements is close to 4 for BiCMOS inductors and close to 3 for the CMOS inductors, as shown in ***Figure 9***. Nevertheless, from the model it is possible to deduce some interesting considerations about the reduction of the Q caused by metal and substrate losses.

In the improved equivalent circuit, the substrate losses are modeled by the resistors R_{SUB}, R_{SUBin} and R_{SUBout}, whereas losses due to the finite conductivity of the metal strips are modeled by the resistor R_S. Therefore, it is possible to define two other Qs (Q_{MET} and Q_{SUB}), which take into account metal and substrate losses separately. Q_{MET} and Q_{SUB} are readily deduced from the equivalent network. In particular, Q_{MET} is calculated by Soyer et al.[9] in the limiting case of $R_{SUB} \to \infty$, $R_{SUBin} \to \infty$ and $R_{SUBout} \to \infty$, whereas Q_{SUB} is calculated by the same expression but in the limiting case of $R_S \to 0$. A comparison of the values of Q_{MET} and Q_{SUB} provides insight into the influence of the two loss mechanisms at different frequencies. The same results show that Q', Q_{MET} and Q_{SUB} are related, at least approximately, by the usual Q composition rule

$$\frac{1}{Q'} = \frac{1}{Q'_{MET}} + \frac{1}{Q'_{SUB}} \tag{4}$$

The good agreement between the extracted and estimated values of R_S validates the hypothesis on which the definitions of Q_{MET} and Q_{SUB} were based. Q_{MET} and Q_{SUB} were extracted for all of the inductors designed and measured, and metal losses were determined to dominate at low frequency while the substrate losses limit the achievable Q at high frequency. ***Table 4*** lists the values of Q_{MET} and Q_{SUB} for a CMOS and BiCMOS inductor. The comparison between the behavior of Q_{MET} and Q_{SUB} highlights that metal losses are dominant at low frequencies, while substrate losses are more important at high frequencies. Moreover, Q_{MET} is an increasing function of frequency (in the frequency range of interest) while Q_{SUB} is a decreasing function. It is possible to define a crossover frequency of the inductor, that is, the frequency

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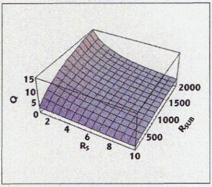
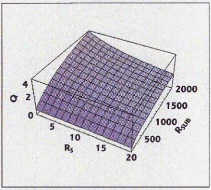


Fig. 10 BiCMOS Q vs. R_S and R_{SUB} at 900 MHz.

Fig. 11 BiCMOS Q vs. R_S and R_{SUB} at 2.4 GHz.



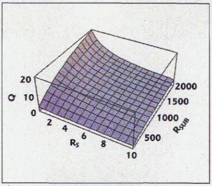
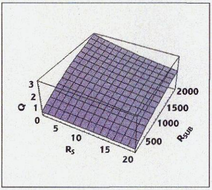


Fig. 12 CMOS Q vs. R_S and R_{SUB} at 900 MHz.

Fig. 13 CMOS Q vs. R_S and R_{SUB} at 2.4 GHz.



at which Q_{MET} and Q_{SUB} are the same. In general, it was determined that CMOS inductors are characterized by lower Qs and lower crossover frequencies f_C (1.2 vs. 1.8 GHz). This result is probably due to the larger resistivity of the BiCMOS substrate, which reduces its contribution to the total loss.

In addition, similar conclusions can be derived by analyzing the plots shown in ***Figures 10***, ***11***, ***12*** and ***13***. These data are derived from the extracted model. It is evident that Q is more dominated by ohmic losses in the low spectrum of RF wireless communications. At frequencies higher than f_C, the slope of the curve shows that Q is more sensitive to R_{SUB}. An accurate comparison of the 2.4 GHz data highlights how this phenomenon is more evident in CMOS inductors.

To confirm these results, the characterization of a number of additional inductors (different from the previous examples) whose measurements

[Continued on page 74]

were provided by STMicroelectronics were performed. These results, not fully reported for brevity, show the same degree of approximation as those discussed previously.

CONCLUSION

An improved equivalent circuit for silicon integrated inductors has been presented. This model, characterized by the introduction of a substrate resistance magnetically coupled with the inductor, accurately describes the loss mechanism in both the metal and the low resistivity substrate. The model permits evaluation of two Qs separately, depending on the two loss mechanisms, thus enabling the designer to understand which are the most convenient ways to improve the Q value. In fact, if at the frequency of interest Q_{MET} is lower than Q_{SUB}, the better solution to increase the Q is to reduce the metal series resistance by increasing the metal thickness.[7] In contrast, if Q_{SUB} is lower than Q_{MET}, a good solution is to limit the magnetic coupling between the spiral and substrate, for example, by introducing a pattern shield.[8]

ACKNOWLEDGMENT

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CIRCLE 137

LOW COST BRIEFCASE SATPHONE TERMINAL ANTENNAS

Two low cost L-band briefcase satphone terminal antennas, a two-element linear array of probe-fed metallic discs and a 2 × 2-element sequential feed planar array of aperture-coupled microstrip patches are investigated. The two antennas were tested indoors in an anechoic chamber and outdoors while connected to an NEC S1 transceiving terminal. A comparative study shows that the 2 × 2-element array is a superior choice having 14 dBi gain, less than 1.6 dB axial ratio over the global mobile satellite communications frequency band of 1.525 to 1.661 GHz and high quality voice communications via Optus B series satellites.

Mobile satellite communications is an emerging technology that shapes the planet like a global village. In contrast to cellular-based mobile communications, which due to economical reasons is restricted mostly to densely populated areas, land mobile satellite communications represents an ideal way of putting people in remote places in touch with the rest of the world. This communications capability is irrespective of geographic features such as mountains, lakes, rivers and oceans. With the recent introduction of new domestic mobile satellite communications services using geostationary satellites[1] in countries such as Australia (Mobilesat™), Japan (N-star) and the US (AMSC), there has been a demand for antenna systems that would allow these voice, data and facsimile services to be accessed. Generally, two types of antenna systems can be used to access mobile satellite services: stationary portable systems, usually of briefcase type, and fully mobile systems such as those installed on a land vehicle.

Portable/briefcase terminals are very popular for international businessmen, construction workers, miners, emergency crews, relief workers and journalists.[2] Some advantages of the portable system over its vehicle-mounted counterpart include its lighter weight, thus it can be carried as an attaché and used on a fixed platform; its ability to be used in locations where vehicle access is denied, such as in a hotel room, dense forests, relief areas and emergency situations; and its lower cost and higher reliability as it does not require satellite tracking electronics. Factors that require improvement over existing systems include size, weight and cost without sacrificing performance. Though briefcase antennas are plentiful in the market,[3] their cost is a prohibitive factor for ordinary users. For example, a typical flat antenna for these applications costs more than US$1500.

The main goal of this article is to investigate two low cost, low profile antennas developed for briefcase satphone terminal use. To fulfill this goal, the antennas are designed and developed with very low cost materials and tested both indoors and outdoors. The developed antennas are a two-element linear array of cavity-backed metallic disc antennas and a thin-film, 2 × 2-element sequentially fed aperture-coupled patch antenna array. The configuration and specifications of briefcase terminal anten-

[Continued on page 80]

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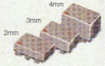

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ADE-1	4	0.5-500	+7	5.0	55**	15	1.99
ADE-1ASK	3	2-600	+7	5.3	50**	16	3.95
ADE-2ASK	3	1-1000	+7	5.4	45**	12	4.25
ADE-12	2	50-1000	+7	7.0	35	17	2.95
ADE-4	3	200-1000	+7	6.8	53**	15	4.25
ADE-14	2	800-1000	+7	7.4	32	17	3.25
ADE-901	3	800-1000	+7	5.9	32	13	2.95
ADE-5	3	5-1500	+7	6.6	40**	15	3.45
ADE-13	2	50-1600	+7	8.1	40**	11	3.10
ADE-20	3	1500-2000	+7	5.4	31	14	4.95
ADE-18	3	1700-2500	+7	4.9	27	10	3.45
ADE-3GL	2	2100-2600	+7	6.0	34	17	4.95
ADE-3G	3	2300-2700	+7	5.6	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-35	3	1600-3500	+7	6.3	25	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-1MH	3	2-500	+13	5.2	50**	17	5.95
ADE-12MH	3	10-1200	+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-42MH	3	5-4200	+13	7.5	29**	17	14.95
ADE-10H	3	400-1000	+17	7.0	39	30	7.95
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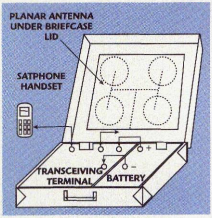
nas are described and practical designs of both antennas are presented. Indoor testing results including radiation patterns, gain and axial ratio in an anechoic chamber, and outdoor field trials with an NEC S1 transceiving terminal are presented. Finally, a comparative study is performed based on the resulting performance, ease of manufacture and cost.



▲ *Fig. 1 A typical portable/briefcase satphone terminal.*

THE BRIEFCASE SATPHONE TERMINAL

System Composition

A briefcase satphone terminal should include several components: a medium to high gain (on the order of 10 dBi) antenna; a transceiving terminal (also called a baseband processor) for modulation and demodulation of transmitted and received signals, respectively; a lightweight 12 V rechargeable battery as a power source; interface cables and sockets; auxiliary components such as a compass and map to aid in aligning the antenna with the satellite; and a casing preferably made from a lightweight microwave transparent material. ***Figure 1*** shows a typical briefcase mobile satphone terminal. The briefcase houses a satphone handset, transceiving terminal and battery. A 2 × 2-element planar antenna is fitted under the lid of the briefcase. (The arrows show the signal flow directions.) The input of the antenna is connected to the terminal; a satphone handset is also connected to the terminal for voice communications. The battery energizes the system. The antenna is manually adjusted to lock to the satellite by changing the lid angle while the antenna is attached to the briefcase. Alternatively, the antenna can be taken out and placed in an elevated position to clear obstacles. The alignment process requires a few seconds and is aided with a compass and map.

TABLE I

BRIEFCASE SATPHONE TERMINAL ANTENNA SPECIFICATIONS

Electrical	
Receive frequency (MHz)	1525 to 1559 (for Inmarsat, AMSC and Mobilesat™)
Transmit frequency (MHz)	1626.5 to 1660.5 (for Inmarsat, AMSC and Mobilesat™)
Polarisation	RHCP
Beam	fixed beam with minimum 30° 3 dB beamwidth
Axial ratio (dB)	6 maximum within the coverage region
Gain (dBi)	10 or more
Return loss (dB)	10
Power handling (W)	> 3
Mechanical	
Connector	SMA/N/TNC
Alignment	manual to any angle
Size/shape	minimum low profile with reasonable aerodynamics profile
Operation	portable and separable for electronics
Weight (kg)	< 1.0 preferred
Environmental	waterproof, shock absorbent and exposure to direct sunlight
Operating temperature (°C)	–20 to 50
Commercial	
Cost	< $200 (a guide only)

Briefcase Satphone Terminal Operation

In the initial stage of operation, the correct look angle of the antenna is determined using the map and compass supplied with the system. The system is turned on and the received power levels are observed on the handset display. The antenna is then adjusted to acquire the maximum received power level. (This maneuver should take a few seconds.) Once the antenna is locked to the satellite with the strongest signal, voice communications can commence. The terminal also can be connected to a computer or fax machine for data and fax communications, respectively.

Satphone Antenna Specifications

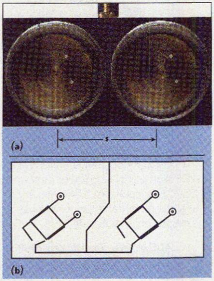
Complete specifications[4] for the briefcase satphone antenna, listed in ***Table 1***, depict electrical design parameters and the mode of operation. These specifications are valid for Inmarsat Mini-M, American AMSC and Australian Mobilesat and show that the antenna requires a bandwidth of nine percent (at the center frequency of 1.6 GHz) to cover both transmit and receive bands.

SATPHONE TERMINAL ANTENNA DESIGN

Two low cost antenna systems have been designed. To keep the manufacturing cost as low as possible, the antennas are manufactured using low cost materials such as aluminum, thin laminates and plastic foams. The use of standard substrates, which are usually very expensive, is minimized. The detailed designs of the antennas are presented in the following sections.

The Two-element Linear Array

Figure 2 shows the two-element linear array with two cavity-backed



▲ *Fig. 2 The two-element linear array antenna's (a) disc elements on top and (b) feed network on the bottom.*

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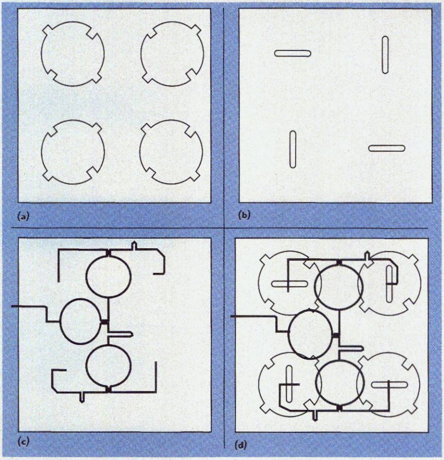
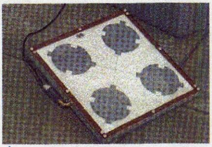
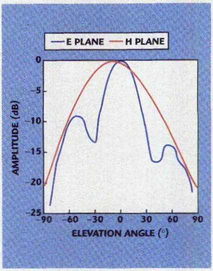


▲ *Fig. 3 The 2 × 2-element sequentially fed patch antenna's design layouts; the sequentially rotated (a) patch antennas and (b) slots on the ground plane, (c) feed network and (d) plan view.*



▲ *Fig. 4 The manufactured 2 × 2-element sequentially fed planar briefcase antenna.*

Fig. 5 The two-element cavity enclosed circular disc antenna's E- and H-plane radiation patterns. ▼



electromagnetically coupled circular metallic disc elements.[5] The circular antenna element, cavity and supporting rectangular plate are made of aluminum. The feed network is etched on RO3003, a high frequency substrate material. The inter-element distance between the two elements is s. The coupling between antenna elements and the feed network is via coaxial probes, which in turn are electromagnetically coupled to the metallic disc via coaxial capacitors. This method enhances the bandwidth of the antenna elements to nine percent at 1.6 GHz.[5] The right-hand circular polarization is achieved with orthogonal feed probes and two 3 dB hybrid couplers. The input power is divided equally between the antenna elements using a two-way T-junction power divider. The overall dimensions of the antenna are 26 × 13 × 1.4 cm and the weight is 2.5 kg.

The 2 × 2-element Sequentially Fed Array

Figure 3 shows the practical design layouts of the second design, a multilayer 2 × 2-element sequentially fed array,[6] as generated by HP EEsof Academy Layout.™ The four views show perturbation segmented patches rotated with a sequence of 90° clockwise, four apertures on the ground plane rotated using the same sequence, the corporate feed network layout of three Wilkinson power dividers and the plan view of the multilayer antenna composed of the three previously described layouts, respectively. As can be seen in the feed network layout, the outputs of the power divider are adjusted with delay lines providing the required 0°, 90°, 180° and 270° transmission phases of sequentially fed antenna elements.

The patches are etched on a thin-film laminate (0.76 mm thick) while the slots and feed network are etched on the top and bottom sides of RO3003 material, respectively. The PCBs are placed on a PVC baseplate and secured as tiered layers with spacers, foams and screws. The manufactured antenna connected to a cable assembly and ready for testing is shown in ***Figure 4***. The overall dimension of the antenna is 26 × 26 × 1.4 cm and the weight is < 0.8 kg.

INDOOR TESTING RESULTS

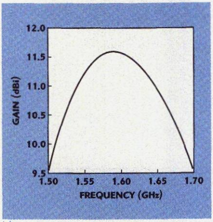
All of the testing was performed at the University of Queensland's anechoic chamber, which is equipped with an HP8030A microwave receiver. Note that the radiation patterns are shown only at 1.6 GHz as similar patterns are observed at the other frequencies within the Mobilesat frequency bands.

The Two-element Linear Array

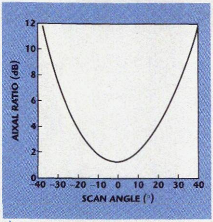
Figure 5 shows the plots of the two-element linear antenna array's measured radiation patterns in both E-plane ($\phi = 0°$) and H-plane ($\phi = 90°$) at 1.6 GHz. The antenna elements are placed at an inter-element distance $s = 0.75\ \lambda$. The measured 3 dB beamwidth in the E- and H-planes is 32° and 74°, respectively.

Two side lobes in the E-plane radiation pattern plot are clearly observed. In contrast, the H-plane radiation pattern has no side lobe. The left side

[Continued on page 84]



▲ *Fig. 6 The two-element linear array's measured gain vs. frequency.*



▲ *Fig. 7 The two-element linear array's axial ratio vs. scan angle.*

TABLE II

MEASURED RESULTS OF THE TWO-ELEMENT LINEAR ARRAY ANTENNA

Frequency (MHz)	1525	1661
3 dB E-plane beamwidth (°)	32	32
3 dB H-plane beamwidth (°)	74	74
Gain (dB)	10.6	10.9
Axial ratio (dB)	0.8	1.2

lobe is approximately 10 dB down from the main lobe and the right side lobe is approximately 15 dB down from the main beam. The position of both side lobes is at 60° from the peak of the main lobe at 0°. The asymmetric behavior of the side lobes can be attributed to the mutual coupling between the feed probes.[7] If required, this condition can be eliminated using a four-feed-probe arrangement of the patch antenna feed system.

The gain is measured in the sweep frequency range of 1500 to 1700 MHz so that the antenna performance is checked for a wider bandwidth than the specified frequency band. ***Figure 6*** shows the measured gain vs. frequency plot at boresight direction (θ = 0°). The measured antenna gain is 10.6 dBi at 1.525 GHz and 10.9 dBi at 1.661 GHz. These results indicate that the antenna meets the gain specification.

Figure 7 shows the plot of the measured axial ratio vs. scan angle at 1.6 GHz. The plot shows that the axial ratio at boresight direction is 0.8 dB and less than 3 dB within ±20° off the boresight direction. The axial ratio at other frequencies is also measured. The axial ratio is only 0.8 dB at 1.525 GHz and 1.2 dB at 1.661 GHz. A summary of the measured results of the two-element linear array is listed in ***Table 2***.

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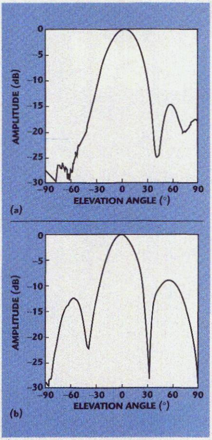
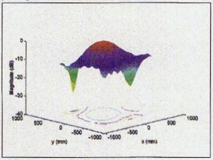


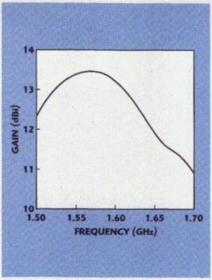
▲ *Fig. 8 The far-field radiation patterns for the 2 × 2-element sequentially fed antenna array at 1.6 GHz; (a) E-plane and (b) H-plane.*

Fig. 9 A three-dimensional radiation pattern plot of the 2 × 2-element antenna. ▼



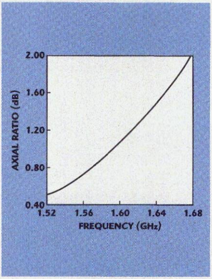
The 2 × 2-element Sequentially Fed Array

The E- and H-plane radiation patterns of the 2 × 2-element sequentially fed antenna array were measured in the anechoic chamber at 1.6 GHz, as shown in ***Figure 8***. The radiation pattern plots show that the 3 dB beamwidth is 34° for the E-plane pattern and 30° for the H-plane pattern. The side lobes show asymmetry both in the E- and H-planes; they are 10 and 13 dB down off the main beam for the H-plane, and 15 and 26 dB for the E-plane. A three-dimensional plot of the antenna's near-field radiation pattern is shown in ***Figure 9***, displayed in the holographic zone using an xy-scan at a distance of 1 m at 1.6 GHz.



▲ *Fig. 10 The 2 × 2-element sequentially fed array's gain vs. frequency at boresight.*

Fig. 11 The 2 × 2-element array's axial ratio vs. frequency. ▼



Having achieved satisfactory radiation patterns, the antenna gain was measured and the results are shown in ***Figure 10***. Gain is 13.1 dBi at 1.525 GHz and 11.8 dB at 1.661 GHz. This measured performance confirms that the antenna meets the required specification.

In the next step, the on-axis axial ratio vs. frequency of the 2 × 2-element sequentially fed planar antenna was measured and is shown in ***Figure 11***. The plot shows that the axial ratio is less that 0.45 dB at 1.525 GHz and 1.7 dB at 1.661 GHz. These are very satisfactory results compared to the required specification of 6 dB. The measured results of the 2 × 2-element sequentially fed array antenna are listed in ***Table 3***.

TABLE III

MEASURED RESULTS OF THE 2 × 2-ELEMENT SEQUENTIALLY FED ARRAY ANTENNA

Frequency (GHz)	1.525	1.661
3 dB E-plane beamwidth (°)	34	34
3 dB H-plane beamwidth (°)	30	30
Gain (dB)	13.1	11.8
Axial ratio (dB)	0.45	1.7

OUTDOOR FIELD TRIALS

Finally, the antennas were tested outdoors while connected to an NEC S1 transceiving terminal[8] in the South-East Queensland region of Australia. In all of the investigated cases, the antennas were separated from the briefcase terminal and placed on the case to examine the flexibility of operation. The antenna was pointed toward the satellite with the aid of the map and compass installed in the terminal. The tests were performed under different climatic conditions such as clear sky, cloudy sky and rain.

The received power in all climatic conditions did not vary substantially. The received power levels, as indicated by the phone handset, were in the range of 10 to 11 for the two-element linear array and 12 to 13 for the 2 × 2-element sequentially fed planar array antenna. These instrument readings represent very good signal strength according to the user's manual of the Mobilesat transceiving terminal.[8] Note that according to the manual a reading of 04 represents the threshold and a reading of 20 corresponds to overload. Using the experimental setup, a call from the satphone to a PSTN user via Optus B series satellites was also attempted. No matter which of the two antennas was used, a high quality voice link was established.

[Continued on page 88]

TABLE IV

A COMPARISON OF THE TWO BRIEFCASE TERMINAL ANTENNA SYSTEMS

	Two-element Metallic Disc Linear Array	2 × 2-element Sequentially Fed Aperture-coupled Patch Array
Total components	45	33
Input connector	SMA	SMA
Total cost (A$)	170	140
Net weight (kg)	2.5	0.8
Dimensions (cm)	26 × 13 × 1.4	26 × 26 × 1.4
Assembly time (hrs)	3 min	< 1
Gain (dBi) (min)	10.6	11.8
Beamwidth (°)		
E-plane	32	34
H-plane	72	30
Signal strength (on the Satphone handset monitor) (min)	10	13
Voice quality	very good	very good/excellent

ANTENNA COMPARISON

A summary of the two developed antenna systems is listed in ***Table 4***. Comparison of the two antennas clearly depicts the superiority of the 2 × 2-element sequentially fed array antenna over the two-element array. The main advantages of the 2 × 2-element antenna are its lower manufacturing cost (A$140), lower weight and superior performance, though the two-element array system has wider beamwidth in the H-plane and, hence, is easier to align with the satellite.

CONCLUSION

Two low cost antenna arrays, a two-element metallic disc linear array antenna and a 2 × 2-element sequentially fed aperture-coupled planar array antenna, have been investigated. The two-element antenna array has demonstrated satisfactory performance in terms of antenna beamwidth, gain and axial ratio. The disadvantages of this antenna include an intensive assembly process due to the large number of components, probe soldering and a relatively large structure (weighing more than 2.5 kg). In contrast, the 2 × 2-element sequentially fed aperture-coupled antenna array appears to be advantageous in terms of its fully planar design, assembly using tiered layers without probe soldering, lower cost due to the use of inexpensive materials and readily available components, and suitability for the portable briefcase terminal since it weighs less than 1 kg. Satphone manufacturers and vendors should develop considerable interest in the antenna system due to these advantageous features.

ACKNOWLEDGMENT

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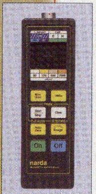

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TECHNICAL FEATURE

Compact Internal Multiband Microstrip Antennas for Portable GPS, PCS, Cellular and Satellite Phones

Compact multiband internal integrated microstrip antennas have been developed for different combinations of hand-held portable global positioning systems (GPS), PCS, cellular satellite phones, Personal Computer Memory Card International Associate (PCMCIA) communication cards and wireless modems. Multiband internal microstrip antennas may be integrated in the printed circuit board or plastic case of the communication equipment and, in this form, are not easy to break. The devices are mechanically rigid and reduce the overall size of the portable communication equipment. Internal integrated microstrip antennas are easily shielded to reduce their interaction with the human body. Hence, they provide good performance beside the human body as well as in free space. Multiband internal integrated microstrip antennas may be designed with only one feed point to be used with a single multiband duplexer, or they may have multiple feed points to be used with multiple single-band duplexers.

Conventional GPS and satellite receivers are usually fixed and used only in free space. Therefore, their antennas are required to be right-hand circularly polarized with hemispherical coverage. Combining GPS and satellite phones with hand-held portable PCS and cellular phones has introduced new, more challenging antenna requirements. Antennas for different combinations of portable GPS, PCS, satellite and cellular phones are required to operate over multifrequency bands while remaining small in size and light in weight. Furthermore, portable GPS, PCS, satellite and cellular phones are usually used in urban areas, often inside buildings or vehicles. Thus, they suffer from multipath reflections, which produce fading and/or polarization rotation. Their antennas must be sensitive to two perpendicularly polarized waves rather than vertically or right-hand circularly polarized and one of the antenna diversity techniques must be used. Moreover, portable GPS, PCS, satellite and cellular phones are randomly oriented by their operators and, therefore, their radiation patterns must be quasi-isotropic rather than having hemispherical coverage or any type of directivity.

PCS, satellite and cellular phones always operate while next to the human head. Thus, their antennas are required to fulfill these requirements beside the human body as well as in free space. The effect of the human body on the antenna and also the effect of the antenna on the human body should be as small as possible. Unfortunately, none of the existing portable GPS, PCS, satellite or cellular phone external antennas, such as helical, quadrifilar-helical or monopole antennas, exhibits good performance beside the human body. Since they are external, these antennas get too close to the human head while the phone is in operation and are not easy to shield. It has been determined that some of these antennas lose more than 80 percent of their efficiency beside the human body.[1] Furthermore, they are all sensitive to only one polarization. External antennas, especially helical antennas, are diffi-

[Continued on page 92]

MOHAMED SANAD AND NOHA HASSAN
AMANT
Reno, Nevada

cult to manufacture in an accurate, repeatable way and cannot provide a 50 Ω input impedance without using a separate matching circuit, which increases cost and losses. Such external wire antennas cannot be integrated in the PCB or plastic case; they increase the total size of the phone, especially if they are retractable, and are easy to break or bend. Moreover, external antennas require an internal diversity antenna to solve fading problems. It is also difficult to design an efficient multiband external antenna for different combinations of GPS, PCS, satellite and cellular phones.

INTERNAL INTEGRATED MULTIBAND MICROSTRIP ANTENNAS

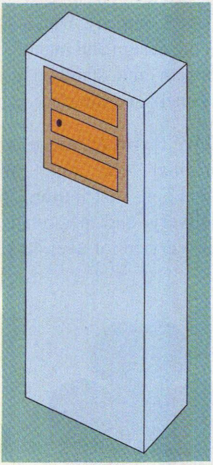
Probably the most promising technique to significantly reduce the interaction between the hand-held portable GPS, PCS, satellite and cellular phone antennas and the human body is to use multiband internal integrated antennas such as microstrip antennas,[2] as shown in ***Figure 1***. Some special configurations of microstrip antennas feature a very small size and good performance beside the human body.[3] They are sensitive to both vertically and horizontally polarized waves and their radiation patterns have good isotropic characteristics.[4] Internal antennas may be integrated with the PCB or plastic case and are easily shielded. Furthermore, microstrip antennas can be designed to provide multifrequency bands for different combinations of GPS, PCS, satellite and cellular phones. Multiband internal integrated antennas are very rigid and reduce the overall size of the phone. In addition, they can use an E- and H-field components diversity technique, which is the only technique that does not require a separate diversity antenna.[5] Conventional microstrip antennas do not meet any of these requirements.

In this research, new compact multiband internal integrated microstrip antenna configurations having one feed point have been developed to meet such requirements. This compact multiband internal integrated microstrip antenna concept was applied to different combinations of GPS, PCS, satellite and cellular phones, PCMCIA communication cards and wireless modems. It should be noted that designing multiband internal microstrip antennas having multiple feed points is much easier than designing multiband antennas having a single feed point and, hence, the multiple-feed case is not presented here.

DUAL-BAND INTERNAL INTEGRATED MICROSTRIP ANTENNAS FOR PORTABLE GPS/CELLULAR PHONES

A new internal integrated dual-band microstrip antenna design having one feed point has been developed for portable GPS/cellular phones. It consists of three stacked layers. The total size of the antenna is 53 × 30 × 3.25 mm. Each of the layers has only one common ground plane, which is the ground plane of the lower layer. The layers also have one feed probe connected to the central element of the middle layer. The

Fig. 1 An internal multiband microstrip antenna integrated with a hand-held GPS receiver or satellite phone combined with PCS or cellular capability.



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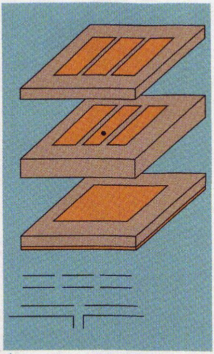
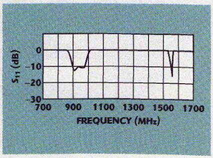
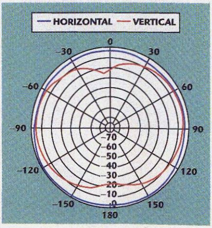


▲ *Fig. 2 A dual-band internal microstrip antenna for GPS/cellular handset applications.*

Fig. 3 The GPS/cellular dual-band antenna's return loss. ▼



thickness of the lower layer is 1 mm while the thickness of the middle and upper layers is 1.5 and 0.75 mm, respectively. ***Figure 2*** shows the antenna configuration and details of each layer. The dielectric constant of the lower layer is 2.94 (Duroid 6002); the dielectric constant of the middle and upper layers is 10.2 (Duroid 6010). The lower layer contains only one wide patch while each of the middle and upper layers consists of three narrow elements separated by very narrow gaps. All elements of the antenna have the same 51 mm length. The width of the lower wide element is 30 mm. The middle and upper layers have similar geometries. The widths of their narrow elements are 10, 9 and 8 mm, respectively, and the width of the gap between adjacent elements is 1.5 mm. Only the central element of the middle layer is directly fed by a coaxial cable and connector, while all the other elements are indirectly fed by coupling as parasitic elements. The lower element generates the GPS frequency band, which is less than one percent at 1.575 GHz. Both the middle and upper layers cover the required band of cellular phones, which is 70 MHz, centered at 925 MHz (890 to 960 MHz for GSM).



▲ *Fig. 4 Horizontally and vertically polarized patterns in the horizontal plane of the GPS/cellular antenna at 1575 MHz.*

The measured return loss of the antenna is shown in ***Figure 3***. The antenna provides a bandwidth of 70 MHz at the cellular frequency band with a return loss of –10 dB or less. The radiation patterns of the antenna were measured in the principal planes at several frequencies in the cellular and GPS bands. The bandwidths of the radiation patterns were even wider than the bandwidths of the input impedance. For example, the vertically and horizontally polarized radiation patterns in the horizontal plane at 1575 (GPS band) and 900 MHz (cellular band) are shown in ***Figures 4*** and ***5***, respectively, while the antenna was mounted on the phone and both the antenna and phone were vertically oriented. As can be seen, the antenna is sensitive to both vertically and horizontally polarized waves and has quasi-isotropic radiation patterns. Similar results were obtained in the other principal planes and at all the frequencies in the cellular and GPS bands.

On the other hand, the effect of the antenna on the human body (as well as the effect of the human body on the antenna) has been studied and determined to be small. The antenna demonstrates good performance in free space as well as beside the human body while held next to the head. The detailed results of the interaction between the antenna and the human body very closely matched results published previously.[5]

DUAL-BAND MICROSTRIP ANTENNAS FOR PORTABLE GPS/PCS PHONES

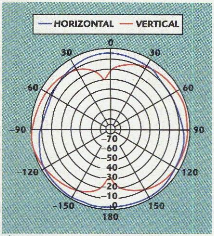
Another dual-band internal microstrip antenna design has been developed for portable GPS/PCS phones. The geometry of the antenna is similar to the geometry of the GPS/cellular phone antenna shown previously. The two antenna designs are different only in dimensions and substrate material. The total size of the GPS/PCS antenna is 27 × 20 × 2.5 mm. The thickness of each of the lower and middle layers is 1 mm while the thickness of the upper layer is 0.5 mm. The same substrate material has been used in all three layers (Duroid 6010 with a dielectric constant of 10.2). The lower element covers the GPS frequency band, which is less than one percent at 1.575 GHz. Both the middle and upper layers provide the required PCS band, which is 140 MHz, centered at 920 MHz (1850 to 1990 MHz).

The measured return loss of the antenna is shown in ***Figure 6***. The antenna provides a bandwidth of 140 MHz at the PCS frequency with a return loss of –10 dB or less. The radiation patterns of the antenna were measured at several frequencies in the PCS and GPS bands, in free space and beside the human body. The radiation patterns were very close to those of the GPS/cellular antenna and, therefore, are not presented here. The antenna demonstrates good performance in free space as well as when held next to the human head.

MULTIBAND ANTENNAS FOR PORTABLE SATELLITE/CELLULAR PHONES

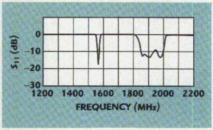
Satellite phones require two narrow frequency bands (1610 to 1626.5 MHz and 2483.5 to 2500 MHz for downlink and uplink low earth orbit (LEO) communication, respectively), while cellular phones require one wide frequency band (890 to 960 MHz for GSM). Therefore, each application requires two substrate layers to cover these frequency bands. The microstrip antenna for portable satellite/cellular phones consists of four stacked substrate layers.

The total size of the antenna is 53 × 30 × 3.5 mm. As with the previous design, all layers have only one common ground plane, which is the ground plane of the first (lower) layer. The antenna also has one feed probe connected to the central element of the third layer. The thickness of the first layer is 0.5 mm, the thickness of the second and fourth (upper) layers is 0.75 mm and the thickness of the third layer is 1.5 mm. The dielectric constant of the first and second layers is 2.2 (Duroid 5880) and 2.95 (Duroid 6002), respectively, and the dielectric constant of the third and fourth layers is 10.2 (Duroid 6010). The first and



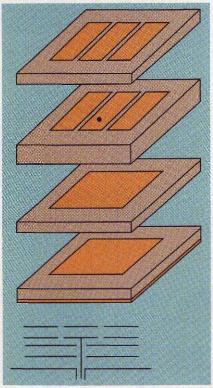
▲ *Fig. 5 The GPS/cellular antenna's patterns in the horizontal plane at 900 MHz.*

Fig. 6 The GPS/PCS antenna's return loss. ▼



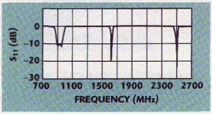
second layers consist of only one element each. The third and fourth (upper) layers consist of three narrow elements each, separated by very narrow gaps. Only the central element of the third layer is directly fed by a coaxial cable and connector; all other elements are indirectly fed by coupling as parasitic elements. ***Figure 7*** shows the antenna configuration and details of each layer. The first layer covers the lower frequency band of the satellite phone (1610 to 1626.5 MHz for the LEO uplink), while the second layer covers the upper frequency band of the satellite phone (2483.5 to 2500 MHz for the LEO downlink). Both the third and fourth layers cover the required cellular phone band (890 to 960 MHz for GSM).

The measured return loss of the antenna is shown in ***Figure 8***. The antenna provides the required frequency bands with a return loss of –10 dB or less. The radiation patterns of the antenna were measured at several frequencies in the satellite and cellular bands, in free space and beside the human body. Again, the antenna demonstrated good performance in free space as well as next to the human head.



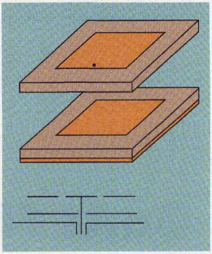
▲ *Fig. 7 A multiband internal microstrip antenna having one feed point for portable satellite/cellular phone applications.*

Fig. 8 The satellite/cellular antenna's return loss. ▼



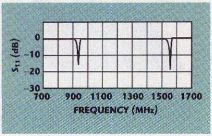
ANTENNAS FOR PORTABLE GPS/PCMCIA PAGERS AND WIRELESS MODEMS

PCMCIA cards are small form factor adapters for personal computers, personal communications or other electronic devices.[5] They are approximately the size and shape of a credit card and can be used with any personal portable computer system equipped with a PCMCIA slot. These PCMCIA cards are used for input/output features such as wireless modems and pagers, and are designed to provide messaging capability to laptops, notebooks, palmtops and other portable computer systems. These cards may also work as standalone pagers when they are not connected to a computer. Since these pagers may also be held or stored in an operator's pocket, their antennas must have a negligible human body effect. Furthermore, these antennas must have almost the same resonant frequency, input impedance and radiation patterns in free space and inside the PCMCIA type II slot in any portable computer. Some of these PCMCIA communication cards require a wide bandwidth while others require a very narrow bandwidth, and GPS may be combined with either case.



▲ *Fig. 9 A dual-band internal microstrip antenna having one feed point for portable GPS/PCMCIA communication card and wireless modem applications.*

Fig. 10 The GPS/PCMCIA antenna's return loss while the card is inside the PCMCIA slot of a hand-held palmtop computer. ▼



The dual-band GPS/cellular internal integrated antenna could be used with the wideband PCMCIA communication cards combined with GPS. For the case of the narrowband PCMCIA communication cards combined with GPS, the dual-band microstrip antenna is much simpler. It consists of only two layers, as shown in ***Figure 9***. The total size of the antenna is 53 × 30 × 2 mm, and the thickness of each layer is 1 mm. The dielectric constant of the lower and upper layers is 2.2 (Duroid 5880) and 10.2 (Duroid 6010), respectively. Each layer contains only one wide patch. The lower layer covers the GPS frequency band, while the upper layer covers the required band of the PCMCIA communication card.

Figure 10 shows the return loss of the dual narrowband microstrip antenna contained in a PCMCIA pager card while the pager card was inside the PCMCIA slot of a palmtop computer. It was determined that inserting the antenna into the PCMCIA slot has a negligible effect on the antenna's resonant frequency and return loss. The radiation patterns of the GPS/PCMCIA pager card internal integrated dual-band microstrip antenna were measured in different situations and at different frequencies in both the GPS and PCMCIA communication card bands. The radiation patterns were quasi-isometric and sensitive to both vertically and horizontally polarized waves. Furthermore, the performance of the antenna inside the PCMCIA slot beside the human body was still good.

CONCLUSION

Compact multiband internal integrated microstrip antennas have been

[Continued on page 98]

developed for different combinations of portable hand-held GPS, satellite, PCS and cellular phones, PCMCIA communication cards and wireless modems. These multiband antennas are designed with only one feed point in order to be used with one multiband duplexer. They also may have multifeed points in order to be used with different single-band duplexers. When multifeed points are used, the different layers of the antenna may be stacked together or separated and located away from each other to increase the isolation between the different frequency bands. However, designing stacked multiband microstrip antennas having one feed point is much more complicated than designing separate microstrip antennas having multiple feed points.

Single-feed multiband stacked antennas consist of several layers of substrate material having different dielectric constants. With different combinations of substrate material having dielectric constants ranging from 2.2 to 10.2, the overall size of the dual-band GPS/cellular phone antenna is 53 × 30 × 2.25 mm. The size of the GPS/PCS dual-band antenna is 27 × 20 × 2.5 mm and the size of the satellite/cellular multiband antenna is 53 × 30 × 3.5 mm. The overall size of the GPS/PCMCIA communication cards and wireless modem dual-band internal microstrip antenna is 53 × 30 × 2 mm. Of course, all of these dimensions may be further reduced by using substrate materials having higher dielectric constants.

Multiband internal integrated microstrip antennas are sensitive to both vertically and horizontally polarized waves with good radiation pattern characteristics in free space as well as next to the human body. Internal integrated microstrip antennas are relatively easy to shield. The interaction between the shielded antennas and the human body was determined to be less than the interaction between the human body and any external wire antenna, such as monopole, helical and quadrifilar-helical antennas.

ACKNOWLEDGMENT

The Duroid 5880, 6002 and 6010 materials are products of Rogers Corp., Chandler, AZ. ■

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The 1999 MTT-S IMS: The String of Broken Records Continues

As Wall Street and the economy continue to reach new heights, so too does the MTT-S International Microwave Symposium (IMS) and Exhibition. This year from June 13 to 18, Anaheim, CA hosted the biggest and most attended IMS ever — a feat that has been often repeated since the wireless revolution took the microwave industry hostage.

The symposium started a day earlier to help handle the increased number of technical presentations and workshops. Right from the start it was clear this convention would be a blockbuster. Attendance at the weekend workshops was at record levels, as was advanced registration. Within the first few hours of the industry exhibition's opening on Tuesday it was apparent that the exhibitors were destined to have an enormously productive show as well. Of course, the pleasant Southern California weather and the proximity of so many of our industry's businesses helped to make the venue one of the best yet. Throughout the week, smiles were on everyone's faces.

The local committee, headed by Robert Eisenhart, chose the theme "The Magic Touch of Microwaves" as an appropriate expression of how today's RF and microwave technology is magically transforming our lives throughout the world. Never has there been a more ambitious utilization of our craft than in the current worldwide telecommunications revolution, and the evidence was clearly on display in the technical presentations and throughout the exhibition. The committee members are to be commended for their hard work in making IMS a huge success.

Social Events

A hockey arena at first seemed like a strange place for Monday night's *Microwave Journal*/MTT-S reception. However, few facilities in the area could have contained the large crowd of eager engineers looking to catch up with their colleagues and sample the drinks and hors d'oeuvres. A hockey rink it was, a party floor it became (and a good one at that). The five-piece jazz band was hard pressed to compete with the chatter of old friends and new acquaintances. (A montage of the evening as well as scenes from the industry exhibition appears on pages 102 and 103.)

The Industry-hosted Cocktail Reception was held Wednesday evening before the IEEE MTT-S Awards Banquet. Following a sumptuous dinner, a number of distinguished MTT-S members were recognized for their exemplary service and technical achievements. "Marilyn Monroe" and "Frank Sinatra" supplied the night's entertainment.

The Technical Program

A record number of technical papers were selected this year for presentation. The technical program committee voted to expand the symposium by an extra day to allow adequate time for each paper's full presentation. Four hundred and sixty technical papers were presented during 65 podium presentation sessions and three interactive forum

[Montage on pages 102 and 103]
[Text continued on page 104]

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SKY-60	2500-6000	+7	6.2	28	14.95
SKY-60LH	2500-6000	+10	6.2	28	16.95
SKY-60MH	2500-6000	+13	6.2	28	17.95
SKY-60H	2500-6000	+17	6.2	28	18.95
SKY-53R	2800-5300	+7	5.7	28	14.95
SKY-53LHR	2800-5300	+10	5.7	28	16.95
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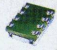
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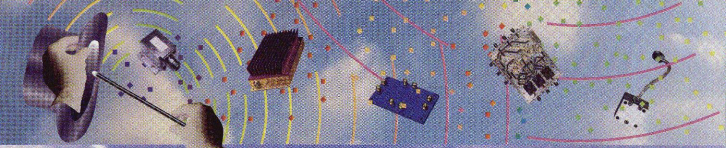

Highlights of the *MWJ*/MTT-S Reception & Exhibition

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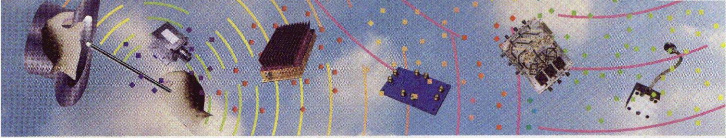


sessions. In addition, there were 21 workshops and a number of noontime panel sessions. The program also included the student paper contest, student awards, and an RF and microwave education forum. In all, the symposium, along with its traditional companions — the 1999 IEEE Radio Frequency Integrated Circuits (RFIC) Symposium and the 53rd Conference of the Automatic Radio Frequency Techniques Group (ARFTG) — provided a superb forum for coverage of today's developing RF and microwave technologies.

The RFIC symposium consisted of two workshops, an open session, five presentation sessions containing more than 50 presentations and a panel session. The one-day ARFTG conference included technical presentations, an exhibition and a tutorial workshop entitled "Measurements for Wireless Front-end Technologies." The majority of the conference's technical presentations supported its "Nonlinearity Characterization" theme.

The Industry Exhibition

Records were also set at this year's industry exhibition. Four hundred and fifty-three companies exhibited their products and technologies in 675 exhibition booths that filled two large convention halls. Floor traffic was strong all three days of the exhibition and sales leads were abundant. The popular Microwave Application & Product Seminars (µAPS) were also well attended with 38 presentations held during five sessions over three days. Few, if any, complaints were voiced at the exhibitors' breakfast on the show's last day. Many of the participants were heard commenting that this exhibition was the best they had ever attended, a satisfying tribute to the hard work of everyone involved in the show and another indicator of the vitality of our industry.

Among the new products and technologies on display at the industry exhibition were ANADIGICS' new line of low cost GaAs MMIC SPDT reflective switches designed to support wireless high and low power applications from DC to 3 GHz. Anaren Microwave displayed its new Adrenaline® four-way high power splitter/combiner designed for modular amplifier use. The low loss stripline networks cover the 1.8 to 2.2 GHz bands for DCS, PCS and W-CDMA high power amplifier applications.

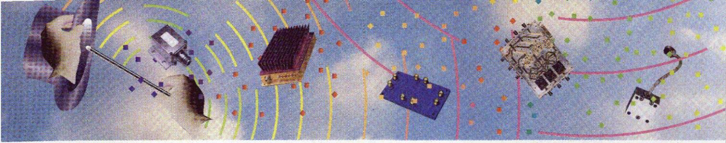
Anritsu introduced the industry's first single-unit, self-contained 65 GHz vector network analyzer. The instrument features excellent dynamic range without compromising on output power, and is designed to meet the testing needs of higher frequency systems, such as wireless networking, low earth orbit satellite communications systems and intelligent transportation systems. A microwave source, test set and analyzer are incorporated in one bench-top instrument.

Ansoft demonstrated Serenade version 8.0, its premier PC-based high frequency design suite. The software update includes new capabilities that speed the design of cellular phones, pagers, wireless local area networks, satellite communications and telecommunications systems. The Symphony™ system simulator, a new high frequency system analysis tool that provides powerful RF and digital signal processing capabilities, is an added feature. Serenade version 8.0 is a component of the Serenade Design Environment, a single software suite that provides high frequency system and circuit electromagnetic simulation, synthesis and design capabilities.

Applied Wave Research demonstrated the latest upgrade to its Microwave Office™ version 3.0, which includes Apollo, an advanced integrated layout editor. This new function expands the depth of the circuit simulation and electromagnetic analysis software suite's functionality into the physical layout of MMIC, RFIC and RF PCBs, and is built upon a single object-oriented database.

Dow-Key Microwave highlighted its low cost, long-life magnetic switches that are capable of up to five million opera-

[Continued on page 106]



tions while handling 100 W of CW power. The line includes a SPDT fail-safe switch, DPDT transfer switch and SP6T multiposition switch specifically targeted toward test equipment applications.

Ericsson announced a two-stage version of its popular High Impedance Technology (HIT™) power hybrid line. These new hybrids provide power amplification for applications traditionally covered by power transistors. The HIT design incorporates impedance matching, bias circuitry and temperature compensation inside the device package. The first units are intended for PCS applications in the 1.9 to 2 GHz frequency range.

Focus Microwave featured a live demonstration of fast load pull and intermodulation measurements using an Anritsu three-port Scorpio network analyzer, and displayed 7/16 and 2.4 mm connector TRL calkits, on-wafer and probe mounting hardware for CCMT and harmonic tuners, and 3 to 40 GHz manual tuners. In addition, high SWR PMT prematching tuners and a virtually lossless MLTF test fixture were displayed.

As always, Hewlett-Packard displayed several new products, including a 50 GHz four-port coaxial transfer switch featuring excellent repeatability, long life and more versatility for signal routing applications; a new HP ESG-D series of RF digital signal generators that speed development of third-generation wireless communications components and receivers; and major enhancements to the HP 8753 and HP 8720 network analyzer families. HP EEsof introduced the HP RF Compiler, a circuit synthesis software tool that offers the ability to automatically generate circuit schematics from behavioral specifications. Design engineers may now enter circuit specifications and a list of allowable components into a wizard that returns both the circuit topology and component values, thus generating the design for a working circuit directly from a specification.

ITS Electronics showed its INTERWAVE 99 family of wireless communications products that include a dual-input base station receiver, base station transmitter and Internet subscriber units. The design architecture is implemented to minimize spectral regrowth, adjacent-channel power and error vector magnitude critical to today's advanced modulation schemes used with CDMA and other wireless network architectures.

Merrimac Industries displayed its Mini-mix™ mini-quad, mini-coupler and mini-filter products. The company's Multi-Mix process features fusion bonding of multilayer structures that provides

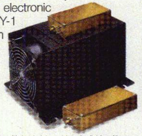
[Continued on page 108]

ULTRA-LINEAR AMPLIFIERS

UP TO 50W OUTPUT

20 to 1000MHz *from only* $1995 (1-9)

Worry free operation and a mountain of exceptional features make Mini-Circuits high power LZY amplifiers incredibly easy to use! Unconditionally stable, these amplifiers have their own heat sink and fan for cool operation while automatic electronic cutoff protects against overload and burnout. At 20W output, LZY-1 and -2 non-linearity is typically 0.3dB and 0.5dB respectively with low harmonic distortion. And these ultra-linear amplifiers are very versatile too. Applications include land mobile, FM broadcast, amateur and military radio, paging, lab use, and high power testing of components. Compare these amplifiers to units costing much more. You'll see why Mini-Circuits LZY amplifiers are the powerful choice!



Comes with heat sink and fan. Available without heat sink and fan for custom applications.

LZY SPECIFICATIONS:

	LZY-1	LZY-2
Frequency (MHz)	20-512	500-1000
Gain (dB)		
Minimum	39	40
Flatness Max	±1.5	±1.5
HARMONIC DISTORTION		
(Typ.,dBc @ 20W)	-32	-45
Power (dBm)		
Min. Output (1dB Comp)	+44	+43
Max. Input (no damage)	+10	+10
Dynamic Range (Typ)		
NF (dB)	8.6*	8.0
IP3 (dBm)	54	54
VSWR Input (Max.)	2.0:1	2.0:1
DC Power**		
Volt V	+26	+28
Max. Current (A)	7.3	8.0
Price ($ea. qty. 1-9)	1995	2195

*80-512MHz, 11.6dB typ. at 20MHz

**LZY-1 at 25W output, LZY-2 at 20W output. Includes fan.

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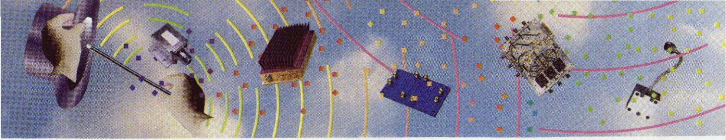


a homogeneous dielectric medium for superior performance at microwave frequencies. The components are extremely small, lightweight and rugged and can be qualified for space applications.

Motorola presented a new RF LDMOS family of devices optimized for third-generation wireless applications. The devices are fully characterized, individually tuned to operate at frequencies from 2 to 2.4 GHz and suitable for linear transmitter applications. Also on display was a dual-band/dual-mode GaAs integrated power amplifier that incorporates two pseudomorphic high electron mobility (pHEMT) GaAs amplifier chains in one package for TDMA/AMPS (824 to 849 MHz) and PCS TDMA (1850 to 1910 MHz) cellular telephone applications.

The newly named Raytheon RF Components unit (formerly Raytheon Microelectronics) displayed many of its 3 and 3.5 V GaAs heterojunction bipolar transistor (HBT) and pHEMT MMIC products for cellular and PCS use as well as a series of higher power pHEMT amplifier MMICs for cellular/GSM and PCS/DCS1800 base station use. Along with the new name comes a renewed effort by the business unit to streamline its operation to become more responsive to customer needs.

RF Micro Devices introduced a high power, high efficiency linear amplifier module ideally suited to 3 V digital cellular systems. The device uses advanced GaAs HBT technology and is designed for use as the final RF amplifier in 3 V PCS CDMA and TDMA hand-held digital cellular equipment, spread spectrum systems and other applications in the 1850 to 1910 MHz frequency band.

Rogers introduced ULTRALAM® 1000 series woven-glass reinforced polytetrafluoroethylene (PTFE) laminates. This material matches the dielectric constant and loss tangent characteristics of other woven-glass PTFE laminates, thus permitting users to secure an additional material source for their ongoing programs without the need to revise their circuit designs.

Sonnet Software gave away CD ROMs containing Sonnet Lite, a free three-dimensional (3-D) planar electromagnetic (EM) solver for two-layer metal circuits in an effort to familiarize as many students and engineers as possible with the use of this type of design tool. The software is a somewhat simplified version of Sonnet em,® the company's comprehensive 3-D EM simulator software.

Toshiba America Electronic Components featured several new products including 60 W C-band GaAs FETs for power amplifier applications for satellite communications (SATCOM) transmitter and very small aperture terminal (VSAT) use, and its expanded MMIC line with the addition of eight new wideband modules in the L-, C-, X- and Ku-bands for PCS, digital point-to-point radio, VSAT, SATCOM and radar applications. Also on display was a new 1 V RF transistor family in the 50 MHz to 1.9 GHz frequency range.

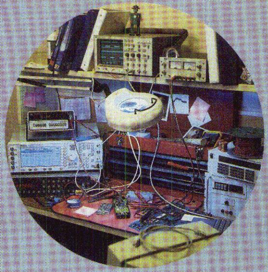
Xemod, a manufacturer of integrated RF power amplifier products for wireless networks, announced the addition of a new set of 30 W power modules to its QuikPAC™ power amplifier module line. In addition, the company introduced a new internally biased line of amplifier modules that offers a preset operating point on each of its 30, 60 and 120 W amplifier modules.

A number of companies distributed electronic versions of their product catalogs, such as GaAsTEK's CD ROM containing a complete listing of its RF-to-millimeter-wave products and services, and Hittite's CD ROM containing its complete RF and microwave integrated circuit line. In addition, K&L Microwave distributed its KEL-com™ commercial filters and selection software that allows the user to specify standard filters and submit quote requests directly to the factory via the company's Web site.

Unfortunately, space limitations permit only a sample of the many new products and technologies on display in the exhibition to be highlighted. Many equally interesting items were also exhibited.

Looking Ahead to Boston

The first MTT-S IMS of the new millennium will be held at the Hynes Convention Center in downtown Boston June 11 to 16, 2000. Boston has always been an exciting location for this event with so much of our industry residing in the northeast and the charm of one of the country's most interesting cities. Already many of this year's participants have enthusiastically agreed to attend, providing the potential for an even larger Microwave Week than before. We hope you too will plan to attend and continue this record-breaking trend. See you in 2000! ❍



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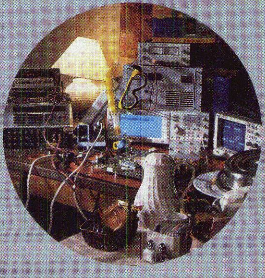
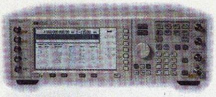
[SPARE BEDROOM]



[HOTEL ROOM ON FAMILY VACATION]



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Being an engineer is an occupation that's pretty tough to leave at the office. So the last thing you need is test equipment that won't do what you need it to.

WE'RE AS DEDICATED TO GIVING YOU A FLEXIBLE DIGITAL SIGNAL GENERATOR AS YOU ARE TO CREATING THE PERFECT DESIGN.

Yet when we talked with R&D engineers, they told us traditional signal generators lack flexibility.

We responded by enhancing our digital ESG-series signal generators. Now you can create custom formats by choosing from over 15 modulation types, a variety of filters, and data rates from 50 Hz to 12.5 MHz. And of course, you can also generate existing as well as developing formats like CDMA, GSM, NADC, PDC, DECT, PHS, TETRA and W-CDMA.

The result? You spend less time dealing with inadequate test equipment and more time finding the perfect design. And hopefully free up some of that cherished vacation time to spend with the kids in the wading pool.

Introducing high spectral purity models

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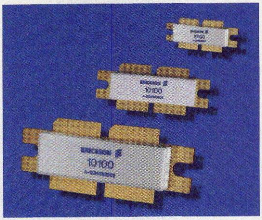


A 165 W LDMOS FET FOR 900 MHz OPERATION

An internally matched, common source, N-channel, enhancement-mode laterally diffused metal-oxide semiconductor (LDMOS) FET intended for large-signal amplifier applications in the 860 to 900 MHz frequency range has been developed. The model PTF 10100 LDMOS FET is rated at 165 W minimum power output and is optimized for amplification of cellular base station signals.

Fig. 1 Typical output power and efficiency vs. input power.

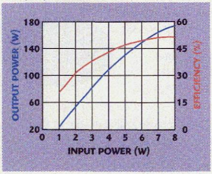
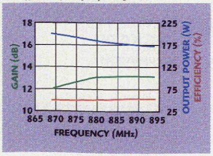


Fig. 2 Typical gain, output power and efficiency vs. frequency.



The new device is designed in a push-pull configuration and features a typical drain efficiency of 50 percent, resulting in lower power consumption. It supports the new digital modulations as well as traditional analog applications. The PTF 10100 FET operates from a standard 28 V DC supply with a power gain of 13 dB (typ), and its rugged design permits operation into a 10:1 output load mismatch without device degradation. In addition, the new device has a drain-source breakdown voltage of 65 V (min) and external circuitry is minimized due to its internally matched feature, increasing reliability and improving manufacturability for high volume production. ***Figure 1*** shows the PTF 10100 FET's typical output power and efficiency vs. input power at 880 MHz with V_{DD} = 28 V and I_{DQ} = 1.8 A total. ***Figure 2*** shows typical gain, output power at 1 dB compression and efficiency vs. frequency.

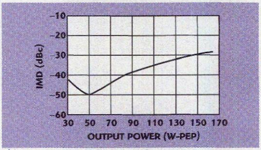


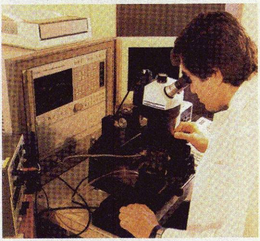
Fig. 3 Intermodulation distortion vs. output power.

One of the more significant features of the PTF 10100 device is its superior linearity performance. In class AB operation, the third-order intermodulation distortion is an impressive –50 dBc at 50 W peak envelope power (PEP) and just –30 dBc at 150 W PEP. ***Figure 3*** shows the device's intermodulation distortion vs. output power for two adjacent input signals at 880 and 880.1 MHz under the bias conditions described previously.

As with other GOLDMOS™ FETs from this family, this device employs ion implantation, nitride surface passivation and full gold metallization to ensure maximum device lifetime and reliability. In addition, 100 percent lot traceability is standard, providing compliance with quality assurance programs.

Ericsson RF Power Products,
Morgan Hill, CA (408) 776-0633.

Circle No. 302



ADVANCED LARGE-SIGNAL MODELS FOR TRANSISTOR PARAMETER EXTRACTION SOFTWARE

Accurate model generation is becoming a progressively more important part of the computer-aided-design process. Of special importance are large-signal models capable of accurately predicting the performance of nonlinear circuits. LASIMO large- and small-signal modeling software[1] facilitates the development of large-signal models by simplifying procedures for the extraction of MESFET and high electron mobility transistor (HEMT) model parameters. The program provides the designer with a set of proven transistor models[2] as well as the capability to incorporate user-defined models and subsequently modify these as required.[3]

Model parameters are optimized to match actual transistors by fitting the measured and modeled bias dependence of the device characteristics. In the user-defined model version of LASIMO, provisions were made for five DC and five capacitance user-defined large-signal models. The user-defined models were implemented as dynamic link libraries (DLL) created and added outside the program and linked at run time. Each of the DLLs is generated from a set of project files written in the C language and loaded into a C compiler. The default DC model is the Curtice model, and the default capacitance model is the Basic Semi-Junction Model. The designer has only to edit a single function that computes the nonlinear parameters. This function receives a set of arguments from the program and returns the required nonlinear parameters. The user is able to define and access up to 13 large-signal parameter coefficients to be optimized for each DC model and up to 15 large-signal parameters for each capacitance model. These DC and capacitance large-signal parameters can be selected by the user to suit various nonlinear simulators.

[Continued on page 114]

OPTOTEK LTD.
Kanata, Ontario, Canada

THE LASIMO UPGRADE

An upgrade to LASIMO — version 2.1 — has been released that incorporates additional advanced models, including the Alpha Own Model (AOM); TriQuint Own Model, Level 3 (TOM3); and TOM3, Modified. These models are implemented in the user-defined configuration to accommodate future refinement or user modification. The program's model complement is listed in ***Table 1***. The reconfigurable models can be modified by the user, or other user-defined models can be substituted.

The Alpha Own Model

AOM is a comprehensive model for GaAs MESFETs, which expands upon aspects of the TOM to account for dispersion, self-heating effects and charge conservation. A set of capacitance and charge equations are used for consistent small- and large-signal models. Transconductance and output conductance dispersion are modeled by combining a feedback network and subcircuit that describes the self-heating effects. The new model accurately predicts the I-V, CV, bias-dependent S-parameter, waveform, power and linearity characteristics of the MESFET. This model has been implemented in PSPICE.[4,5]

The TriQuint Own Model, Level 3

TOM3 is also a comprehensive model for GaAs MESFETs. It was developed to improve existing MESFET capacitance models for SPICE using conservation of charge in the implanted layer.[6] The capacitance model calculates the gate charge from the drain current and gate capacitances from the drain conductances. Relating the gate charge to the channel current creates gate capacitances dependent upon the channel current derivatives linking the small-signal model to the large-signal equations. Drain dispersion and self-heating effects are modeled by a GD model using a set of device equations and a specific subcircuit in SPICE.[7,8]

The TriQuint Own Model, Level 3, Modified

A variant of the TOM3 model is also provided where the parameters assigned to temperature are not included. For many applications the model can be used quite effectively without the temperature parameters. In addition, speed of extraction is improved.

A LARGE-SIGNAL MODEL EXTRACTION EXAMPLE

As an example of the use of the new user-defined models, the fitting of the AOM to a discrete GaAs MESFET is demonstrated. The transistor, a low power, low noise device,[9] was selected from the process control monitor in a three-inch GaAs wafer. Relevant data include a gate width of 300 μm (four interdigitated 75 μm fingers), gate length of 0.5 μm, ion implantation energy of 150 Kev and open channel current after recess of 100 mA. The transistor was measured using an on-wafer probe station and a Wiltron 360 vector network analyzer

TABLE I

LASIMO NONLINEAR MODELS

Built-in Standard Models	
I_{ds} MESFET Models	
Model 1:	Curtice
Model 2:	Statz (Raytheon)
Model 3:	Materka-Kacprzak
Model 4:	TriQuint Own Model (TOM)
Model 5:	Advanced Curtice
Model 6:	Curtice-Ettenberg
Model 7:	Lehovic Zuleeg
C_{gs} and C_{gd} MESFET Models	
Model 1:	Junction Model
Model 2:	Statz (Raytheon)
Model 3:	a physically based model
I_{ds} HEMT Models	
Model 1:	Curtice
Model 2:	Advanced Curtice
C_{gs} and C_{gd} HEMT Models	
Model 1:	a physically based model
Reconfigurable Models	
Model 1:	Curtice and Basic Semi-Junction Capacitance
Model 2:	TOM3 (no temperature dependence)
Model 3:	Alpha Own Model (AOM)
Model 4:	TOM3 (with temperature dependence)
User-defined Models	
Models 1–5:	User assignable as substitutes for the reconfigurable models

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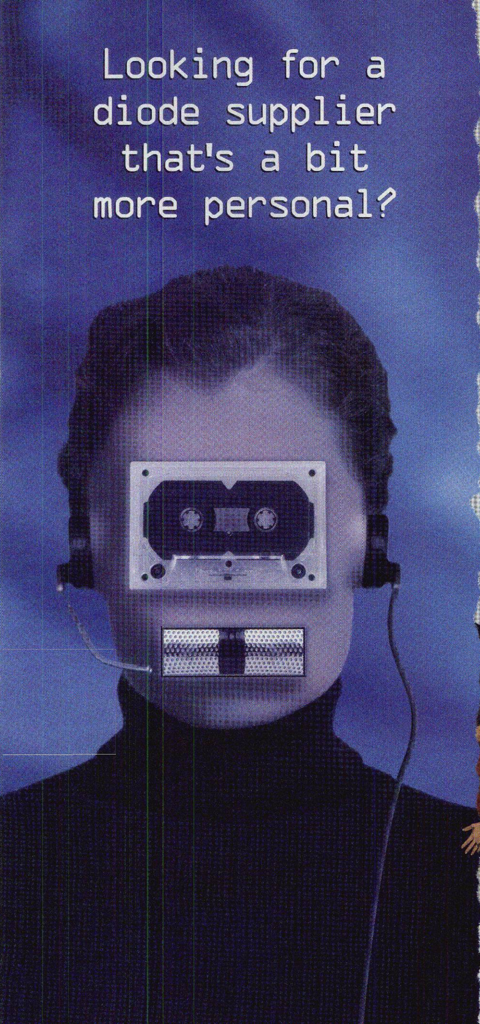
Looking for a
diode supplier
that's a bit
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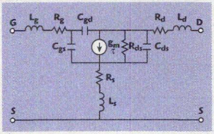
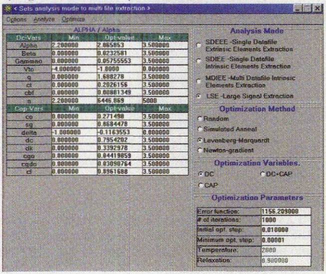


▲ *Fig. 1 The transistor small-signal model.*

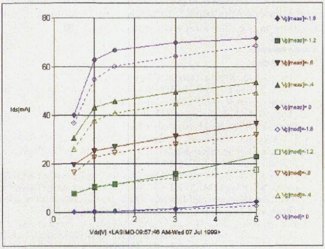
▼ *Fig. 2 The AOM model parameters.*



Dc-Vars	Min	Opt-value	Max
Alpha	2.200000	2.065853	3.500000
Beta	0.000000	0.0232581	3.500000
Gammao	0.000000	0.05755553	3.500000
Vto	-4.000000	-1.8000	0.000000
q	0.000000	1.688278	3.500000
ct	0.000000	0.2026156	3.500000
cbf	0.000000	0.00881349	3.500000
a	2.200000	6446.869	5000
Cap-Vars	**Min**	**Opt-value**	**Max**
co	0.000000	0.271498	3.500000
sg	0.000000	0.8684478	3.500000
delta	-1.000000	-0.1163553	0.000000
dc	0.000000	0.7954202	3.500000
dk	0.000000	0.3392978	3.500000
cgo	0.000000	0.04419859	3.500000
cgdo	0.000000	0.03090764	3.500000
cf	0.000000	0.8961688	3.500000

Error function:	1156.209000
# of iterations:	1000
Initial opt. step:	0.010000
Minimum opt. step:	0.00001
Temperature:	2000
Relaxation:	0.900000

▼ *Fig. 3 Measured vs. modeled I_{ds}.*



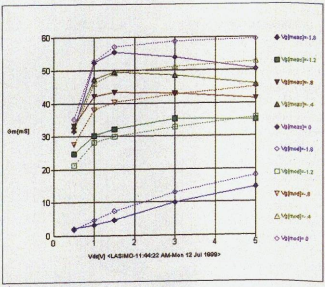
(VNA). The device was powered using two Keithley model 236 programmable power supplies. The VNA and power supplies were controlled via the IEEE-488 GPIB bus using the program's data acquisition module. The FET's S parameters and drain current were measured at V_{ds} = 0.5, 1.0, 1.5, 3.0 and 5.0 V and V_{gs} = –1.8, –1.2, –0.8, –0.4 and 0 V. A total of 25 data points were thus generated to represent the device's I-V curve. ***Figure 1*** shows the small-signal model chosen to represent the device.

The device parasitic resistances were measured using in-house PCM characterization procedures,[10] resulting in R_s = 1.3 Ω, R_d = 2.7 Ω and R_g = 1.1 Ω. The parasitic inductances were then extracted using the program, producing L_s = 36.35 pH, L_d = 4.21 pH and L_g = 77.46 pH. With the bias-invariant parasitics, LASIMO was used to extract the intrinsic device models at all bias points. In this process, the program gathers in memory the arrays of transconductance G_m, output conductance G_{ds}, gate source capacitance C_{gs} and gate drain capacitance C_{gd}. These arrays are a function of the intrinsic biases V_{gsi} and V_{dsi}. The intrinsic biases are calculated by subtracting the impressed voltages from the parasitics.

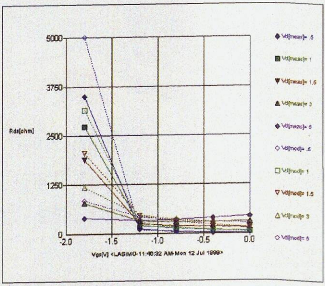
The program then is used to optimize these small-signal data arrays to the AOM equations representing the nonlinear I_{ds}, G_m, G_{ds}, C_{gs} and C_{gd}. The initial DC model values for optimization were chosen with care so that the optimization process converges rapidly. As an example, key DC parameter values were roughly calculated to produce the device's saturation current I_{dss}. The rest of the model parameters were chosen from default values. A combination of random and Levenberg-Marquardt optimizers were selected and care was exercised to ensure the values were realistic and within limits. The initial and final AOM model parameters are shown in ***Figure 2***.

LASIMO graphs of the fitted DC parameters demonstrate the versatility of the new AOM model in achieving a best fit for I_{ds}, G_m and R_{ds}, as shown in ***Figures 3***,

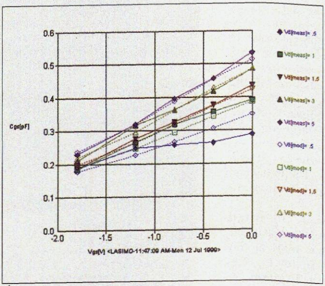
[Continued on page 118]



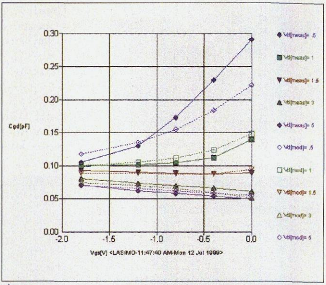
▲ *Fig. 4 Measured vs. modeled G_m.*



▲ *Fig. 5 Measured vs. modeled R_{ds}.*



▲ *Fig. 6 Measured vs. modeled C_{gs}.*



▲ *Fig. 7 Measured vs. modeled C_{gd}.*

4 and *5*, respectively. Similarly, the AOM model demonstrates a good capacitance fit for the transistor, as shown in ***Figures 6*** and *7*.

CONCLUSION

LASIMO software can be used to conveniently acquire MESFET measurements and fit these data to advanced large-signal models. The system requirements to operate the program properly include a Pentium PC with Windows 3.1/95/98/NT and a minimum of 16 MB of RAM. LASIMO Version 2.1 is priced from $7500 and is available immediately. Additional information can be obtained from the company's Web site: www.optotek.com. ■

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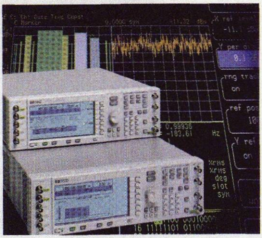
Optotek Ltd.,
Kanata, Ontario, Canada
(613) 591-0336.

Circle No. 303

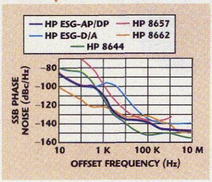


ANALOG AND DIGITAL SIGNAL GENERATORS WITH HIGH SPECTRAL PURITY

Due to the increasingly stringent requirements for communications channels, today's signal generators must have extremely low phase noise to determine if a device, component or subsystem meets test specifications. A new series of spectrally pure signal generators has been developed to meet these tight demands that also provides flexible digital modulation capabilities for current and future communications requirements.

The HP ESG family of RF signal generators has been expanded with the addition of new high spectral purity models that include the HP ESG-AP series of four analog model RF generators and the HP ESG-DP series of four digital models. The new generators are designed specifically to provide a source of high spectral purity RF signals with built-in modulation functionality for both analog and digital applications that previously required external test equipment or multiple generators. The new instruments provide good phase noise performance for general-purpose bench-top testing of modern communications devices and equipment. **Figure 1** shows a comparison of the typical single-sideband (SSB) phase noise performance of the new HP ESG-AP and -DP series vs. HP ESG-D and -A signal generators and other common signal generator types.

Fig. 1 A phase noise performance comparison at 1 GHz.



Good spectral purity is essential for achieving low phase noise. A spectrally clean signal when used as an LO for up- and downconversion prevents the masking of low level desired signals by phase noise. The high spectral purity of the HP ESG-AP and -DP generators also makes possible receiver performance testing that meets the phase noise and spurious content specifications of today's communications standards for both in-channel and out-of-channel receiver testing. In addition, radar testing traditionally requires a spectrally clean signal source. For example, airborne Doppler radar measures small shifts in frequency that return echoes undergo in order to determine the velocity of a target. Unfortunately, the return signal includes additional frequency-shifted echoes from the ground. This problem is significantly increased if the transmitter oscillator or receiver LO adds phase noise to the desired

[Continued on page 122]

HEWLETT-PACKARD CO.
Santa Rosa, CA

TABLE I

THE HP ESG RF SIGNAL GENERATORS

	High Spectral Purity Models			
Frequency Range	Digital/Analog	Analog Only	Digital/Analog	Analog Only
250 kHz to 1 GHz	HP E4434B	HP E4423B	HP E4430B	HP E4400B
250 kHz to 2 GHz	HP E4435B	HP E4424B	HP E4431B	HP E4420B
250 kHz to 3 GHz	HP E4436B	HP E4425B	HP E4432B	HP E4421B
250 kHz to 4 GHz	HP E4437B	HP E4426B	HP E4433B	HP E4422B

signal. The HP ESG-AP and -DP generators reduce the instrument-contributed phase noise on the received signal so that the real target signal is more readily distinguished.

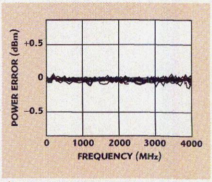
ANALOG AND DIGITAL MODULATION CAPABILITIES

The HP ESG-A and -AP series generators provide comprehensive analog modulation capabilities that include AM, FM, and phase and pulse modulation. The units also have built-in sweep features and a versatile function generator.

The HP ESG-D and -DP series generators provide broadband I/Q modulation with all of the major communications formats, such as wideband CDMA (W-CDMA), cdma2000, EDGE and GSM. Flexible digital modulation capabilities allow modification of existing standards or creation of new standards. In addition, the digital series generators include analog model features and many digital options, such as a dual arbitrary waveform generator for creating complex digitally modulated signals and a bit error rate (BER) analyzer for measuring sensitivity and selectivity. A real-time I/Q baseband generator permits mixing and matching of modulation types, data rates and filter types to create custom signals.

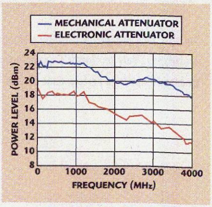
HP ESG FAMILY FEATURES

In addition to the choice of spectral purity performance levels and analog and digital vs. analog-only models, frequency coverage can be specified from 250 kHz to 1, 2, 3 or 4 GHz, as listed in ***Table 1***. The generator family also features an output power range of –136 to +17 dBm with superior output level accuracy of ±0.5 dB (> –127 dBm) below 2 GHz and ±0.9 dB above 2 GHz. The typical level accuracy is much better, as shown in ***Figure 2***. Even with modulation applied, the output level accuracy is better than ±1.2 dB, thus allowing the most sensitive receivers to be measured. In addition, the generators incorporate an electronic attenuator that easily handles continuous output power cycling with highly repeatable results to 4 GHz and offers outstanding reliability. An optional mechanical attenuator provides an increase in output power by as much as 6 dB for overcoming insertion losses from cabling and switch matrices or for components that require high drive levels. ***Figure 3*** shows typical output power vs. frequency.



▲ *Fig. 2 The generator's typical output level accuracy.*

Fig. 3 Typical maximum output power performance. ▼



[Continued on page 124]

FM deviations up to 40 MHz at rates to 10 MHz permit a variety of measurements to be made. The stable DC FM precisely reproduces digital signaling for FM receivers with selective squelch control. Wideband phase modulation capabilities offer deviations up to 360 radians and 4 MHz rates for use in satellite communications applications.

Complex modulation formats such as binary phase-shift keying, quadrature phase-shift keying and 64 quadrature amplitude modulation required for testing RF digital communications systems may be accomplished by driving the I/Q inputs with analog signals. A built-in quadrature modulator processes the I/Q input signals to provide superior modulation accuracy and stability over a 30 MHz RF bandwidth (15 MHz baseband I/Q). In addition, internal I/Q modulator calibration routines generate precisely controlled and repeatable signals that minimize measurement errors; the calibration results remain valid for 30 days when the instrument is operated within ±5°C of the calibration temperature.

The generators also provide a coherent carrier output to simplify the detection of digital baseband signals. (The coherent carrier output provides frequency and phase information about the transmitted carrier.) Using this signal as a reference eliminates the need for complex demodulation techniques.

BUILT-IN FUNCTIONALITY

The HP ESG generator family provides built-in multiple functionality that has traditionally required external test equipment or multiple generators. For example, an internal dual arbitrary waveform generator that combines flexible baseband generation and I/Q modulation in a single generator is available. This capability provides a multicarrier CDMA signal to stress active components with multiple carriers or allows the signals to perform intermodulation distortion measurements on amplifiers. An internal BER analyzer allows quick and easy sensitivity and selectivity measurements of communications subsystems and components. The BER analyzer also indicates pass or fail conditions for user-specified test limits. GSM loopback BER base station tests are made possible using an HP VSA series transmitter tester in conjunction with an HP ESG generator.

In general, the HP ESG-D and -DP's built-in flexible baseband generator provides complete control over a transmitted signal. The user can supply data, I/Q modulation waveforms or no data at all and generate digitally modulated signals, I and Q baseband outputs or data streams. This signal may then be used with an arbitrary digital transmitter at any of the major interfaces to test components to full receivers. A proprietary application-specific IC performs symbol building and finite-duration impulse-response filtering, thus giving the user complete flexibility in modulation generation. One-button generation of IS-95 Walsh-coded signals with up to 256 configurable channels for each carrier and up to 12 carriers is available, thus providing a complete CDMA personality. In addition, the instrument can keep pace with the emerging 3G wireless standards by providing W-CDMA, cdma2000 and EDGE personalities.

Finally, the generator is lightweight and portable and may be mounted in a five-inch-high rack space. An expandable, modular architecture makes the instrument a versatile tool for future growth. As digital communications advance, the programmable hardware of the HP ESG-D and -DP models will allow complete modification of the existing standards to create new formats. Updated firmware from the HP ESG Web site will provide support for future measurement personalities and performance options. For more information, consult the company's Web site at www.hp.com/go/esg.

Hewlett-Packard Co.,
Santa Rosa, CA (800) 452-4844.

Circle No. 301

An Educational Antenna Measurement System

The AL-2000-EDC Educational Antenna Measurement System is a low cost, yet versatile, automated antenna measurement system that allows a variety of antenna measurements to be accomplished in a small facility for a variety of antennas. The system is configurable for all the research needs of universities, allowing for measurements to be accomplished in all the standard antenna measurement modes, including far field, planar near field, cylindrical near field and spherical near field.

As a result of its multimode measurement capability, the system can be used for characterization of antennas encompassing a wide variety of performance characteristics, including pencil-beam, fan-beam, omnidirectional, low sidelobe and high front-to-back ratio antennas. Applications for the system include antenna measurements related to wireless systems, automotive-based systems, satellites and aerospace.

The system is designed to be located in a space-limited test environment, such as a small laboratory or anechoic chamber. It is capable of rapid reconfiguration, both from a hardware and software standpoint. The measurement mode and hardware parameters are easily saved and recalled from test parameter files that contain all necessary setup and test information. Many of the required test setup parameters can be automatically calculated for the user when desired.

The system maintains the required accuracies for RF measurements from 700 MHz to 44 GHz (110 GHz with an extended system). It features a gain accuracy of ±0.25 dB and sidelobe accuracy of ±1.5 dB per 10 dB (to 30 dB down) at 10 GHz. Measurement time per polarization is 20 minutes. Beam pointing is 0.5° and maximum antenna size (±45° pattern) is 32" × 32". The basic system includes a low profile roll-over-azimuth positioner for antenna-under-test orientation, 3' × 3' rigid box-frame high accuracy planar scanner, DC amplifier and cabling for control and feedback for all axes of motion, mounting hardware and RF probe. Also included are a data acquisition system (including personal computer and all necessary boards); software package for automated data acquisition, analysis and plotting for all measurement modes; and system documentation and manuals.

The system allows interface to standard RF equipment. This interface is accomplished through selectable device drivers that provide flexibility in reconfiguring the system for a variety of measurement applications as well as

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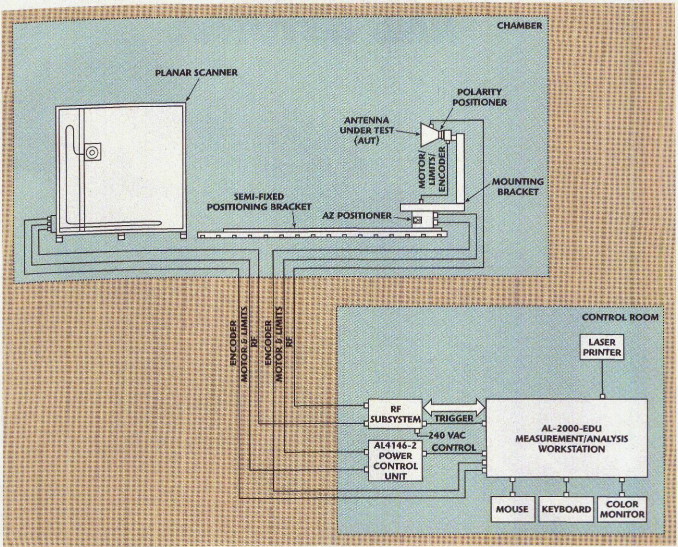
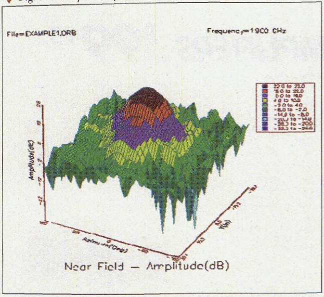
ORBIT/FR
Horsham, PA



▲ *Fig. 1 The antenna measurement system's block diagram.*

▼ *Fig. 2 A sample 3-D plot.*



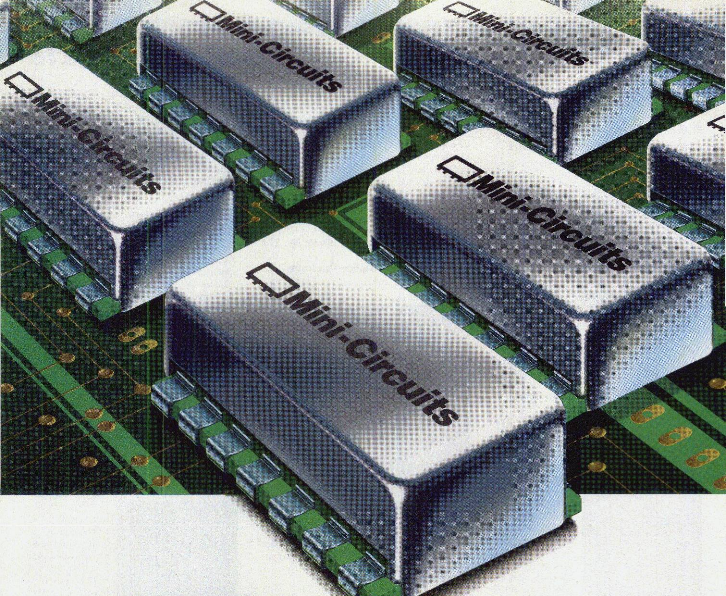
frequency ranges. The block diagram, shown in ***Figure 1***, illustrates the flexibility of measurement scenarios accommodated by the system.

Data acquisition and data analysis/plotting are implemented in separate packages to allow for off-line processing and data display. Both packages feature a graphical user interface implementation designed to allow for logical automated task definitions. Built-in contour and three-dimensional (3-D) plotting permit overviews and rapid visualization of both raw and processed data. A sample 3-D plot is shown in ***Figure 2***.

Automated tests can be executed in a user-defined order of multi-axis movements with the primary test axis scanned in either continuous or stepped motion. This flexibility allows the data collection sequence to be optimized for a given test application, minimizing required measurement time. All motions in the system are closed loop using encoder-based position feedback, thus providing confirmation of all requested data acquisition points. The system can be reconfigured rapidly for different measurement modes, thereby providing an extremely cost-effective investment for organizations, such as universities, where a single system can accommodate a wide variety of research projects and laboratory testing.

ORBIT/FR Inc., Horsham, PA (215) 674-5100.

Circle No. 300



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JTOS/JCOS SPECIFICATIONS

	Model	Freq. Range (MHz)	Phase Noise (dBc/Hz) SSB@ 10kHzTyp.	Harmonics (dBc) Typ.	V_{tune}** 1V to:	Current (mA) @+12V DC Max.	Price $ea. (5-49)*
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	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	-106	-23	16V	20	13.95
	JTOS-200	100-200	-105	-25	16V	20	13.95
	JTOS-300	150-280	-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	485-765	-98	-30	16V	20	16.95
NEW	JTOS-1000W	500-1000	-94	-26	18V	25	21.95
	JTOS-1025	685-1025	-94	-28	16V	22	18.95
	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	-95	-11	22V	30 (@8V)	19.95
	JTOS-3000	2300-3000	-90	-22	***	25 (@5V)	20.95
	JCOS-820WLN	780-860	-112	-13	***	25 (@9V)	49.95
	JCOS-820BLN	807-832	-112	-24	14V	25 (@10V)	49.95
	JCOS-1100LN	1079-1114	-110	-15	***	25 (@8V)	49.95

Notes: *Prices for JCOS models are for 1 to 9 quantity. **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 5V tuning models available, consult RF/IF Designer's Guide or call Mini-Circuits.

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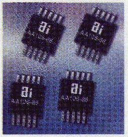
COMPONENTS

■ 0.5 - 3 GHz Miniature Digital Attenuators

The models AA105-86 and AA106-86 single positive control GaAs IC FET digital attenuators are four and five bit, respectively. The AA105-86 offers high attenuation accuracy at 1 dB steps to 15 dB; the AA106-86 features high attenuation accuracy at 0.5 dB steps to 15.5 dB. Both units feature low DC power consumption and are designed in a miniature low cost MSOP-10 plastic package. Typical applications include cellular radio, wireless data and wireless local loop gain level control circuits. Price: $4.40 (10,000).

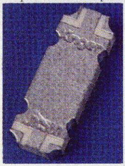


Alpha Industries,
Woburn, MA (800) 290-7200, ext. 306
or (508) 894-1904.

Circle No. 214

■ Directional Coupler

The model JX510 mini Xinger® surface-mount, low profile, 10 dB coupler for the 1.7 to 2 GHz band has been designed for UMTS, wideband CDMA and IMT-2000 applications. It features directivity of 20 dB (min) and insertion loss of 0.2 dB (max). The coupler has a peak-to-peak frequency sensitivity of ±0.1 dB, and SWR is better than 1.18. Maximum average power is 70 W. The JX510 is manufactured using materials with x and y thermal expansion coefficients compatible with many common substrates, including FR4, G-10 and polyimide. Size: 0.56" × 0.2" × 0.075".



Anaren Microwave Inc.,
E. Syracuse, NY (315) 432-8909.

Circle No. 215

■ Convection-cooled Attenuators

The FFI series 5 and 10 W convection-cooled attenuators use an interseries adapter kit to mate with a variety of RF connectors. The units operate over the frequency range of DC to 4 GHz, which allows usage in cellular, data, ISM, land mobile, paging, PCS or SMR/ESMR applications. The attenuators are 50 Ω devices that operate in any position. The 5 W model is rated for 5 W at 40°C ambient temperature and 6 W at 25°C. The 10 W model's power rating is 10 W at 40°C or 12 W at 25°C. Standard attenuation values for the FFI series are 1, 2, 3, 6, 10, 20 and 30 dB. Maximum SWR for both versions is 1.10 at DC to 1 GHz and 1.25 at 1 to 4 GHz. These values may be derated by the company's interseries adapters or customer-supplied adapters. Custom values are available on quantity purchases.

Bird Component Products Inc.,
Franklin, IN (317) 346-6600.

Circle No. 217

■ Integrated Isolator Package

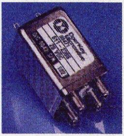
This integrated isolator package performs the work of both isolator and coupler and offers 0.4 dB (max) insertion loss and 50 dB isolation over the 925 to 960 MHz frequency range. It also incorporates two forward monitor ports and a fully functioning reverse coupler with 30 dB directivity to provide highly accurate system monitoring capability. The high power termination is supplied with a cable to ensure maximum heat dissipation away from the isolator assembly to enhance long-term reliability of the system. The isolator is magnetically shielded to allow close assembly of multiple devices.

Densitron Microwave Ltd.,
Southend-on-Sea, Essex, UK
44 (0) 1702-463440.

Circle No. 218

■ Miniature Magnetic Coaxial Transfer Switches

The 611 series low cost, miniature, magnetic coaxial transfer switches operate from DC to 18 GHz. Standard with SMA connectors, the 50 Ω impedance switches with actuating voltage of 12 or 28 V DC are intended for test applications. The units can handle up to 100 W CW and offer up to five million operations without performance degradation. Insertion loss is 0.5 dB (max) and isolation is 60 dB (min). Operating voltage is 12 and 28 V DC and switching time is 15 ms.



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

Circle No. 219

■ 38 GHz Diplexer

This diplexer provides low insertion loss with high harmonic rejection. The passbands can be tuned in the range of 37 to 39.5 GHz with a bandwidth of 640 MHz and a transmit to receive spacing of 1260 MHz. Harmonic rejection exceeds 40 dB. The operating temperature range is from –30° to +70°C. Size: 4.13" × 1.27" in WR-28 waveguide.

Filtel Microwave Inc.,
Vaudreuil-Dorion, Quebec, Canada
(450) 455-6082.

Circle No. 220

■ High Frequency Fundamental Crystals

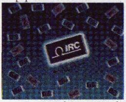
The models HC-45/u and HC-49/u high frequency fundamental crystals are suitable for applications like voltage-controlled crystal oscillators (VCXO) that require the ability to move frequency by a large amount. They are produced up to 50 MHz for VCXO, temperature-compensated crystal oscillator and filter applications, and reduce the number of multiplier stages in transceivers. The high frequency fundamental crystals with ±10 ppm calibration tolerance and ±10 ppm temperature tolerance from 0° to +50°C are available in small custom quantities. Delivery: two to three weeks.

International Crystal
Manufacturing Co. Inc.,
Oklahoma City, OK (405) 236-3741.

Circle No. 221

■ Resistor-capacitor Chip

The RC1206 series thick-film resistor-capacitor chip provides an economical solution for noise filtering and snubber circuits in telecommunications and computer applications. The thick-film resistive element features a resistance range of 10 Ω to 1 kΩ with tolerances to 10 percent, a voltage rating of 5 V (max) and temperature coefficients of resistance (TCR) to 200 ppm/°C. The capacitive element features a capacitance range from 10 to 200 pF with tolerances to 20 percent, voltage rating of 50 V (max) and TCR of +20/–55 percent. The device's operating temperature is rated from –55° to +125°C. The surface-mount 1206 chip is compatible with automated assembly equipment and wave or reflow soldering processes. Price: 18¢ (500,000). Delivery: stock to six weeks.

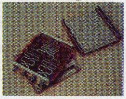


International Resistive
Company Inc. (IRC),
Corpus Christi, TX (888) 472-3282
or (512) 992-7900.

Circle No. 222

■ Four-way Power Divider/Combiner

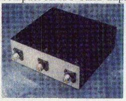
The model D317NS four-way power divider/combiner is designed for cellular and PCS applications. The unit operates over the 800 to 2000 MHz frequency range with typical band isolations of 30 dB between ports. It is amplitude and phase balanced within 0.3 dB and ±2°, respectively, and SWR is < 1.25 at any port. In-



put power is ±20 dBm (max). The D317NS is supplied with stainless-steel SMA connectors in a 3.00" × 3.00" × 0.58" package. Weight: 3.5 oz. Price: $50. Delivery: stock.
KDI/triangle Corp.,
Whippany, NJ (973) 887-8100, ext. 500.
Circle No. 223

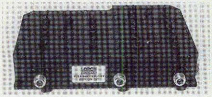
AMPS Duplexer

The model WSD-00136 high performance compact AMPS-band duplexer is configured



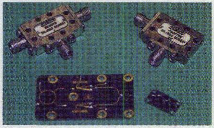
with a receive passband of 824 to 849 MHz and transmit passband of 869 to 894 MHz. Insertion loss and ripple within the passbands are specified at 1 dB (max) and 0.4 dB p-p (max), respectively, and passband return loss is specified at 17 dB (min), 20 dB (typ). The unit offers good passband-to-passband isolation of 85 dB (min) with antenna-to-receive rejection of 60 dB (min) from DC to 784 MHz, 85 dB (min) from 869 to 894 MHz and 50 dB (min) from 894 to 2547 MHz. Transmit-to-antenna rejection is 60 dB (min) from DC to 824 MHz, 85 dB (min) from 824 to 849 MHz and 50 dB (min) from 934 to 2682 MHz. Power handling is 45 W CW and 450 W peak instantaneous. Operating temperature range is 0° to +50°C. Size: 6.75" × 6.32" × 2.75", excluding connectors. Connectors are N-F at all ports. Delivery: six to eight weeks (ARO).
K&L Microwave Inc.,
Salisbury, MD (410) 749-2424.
Circle No. 224

PCS Duplexer



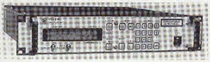
This PCS narrowband duplexer for CDMA applications has < 0.7 dB of insertion loss across the 25 MHz bandwidth. The high Q ceramically loaded cavity duplexer is factory tunable to any of the PCS bands. The high Q transmit portion of the duplexer provides greater than 8 dB of attenuation 2.25 MHz from the band edge and greater than 60 dB of co-channel isolation. Size: 9.81" × 6.35" × 2.00".
Lorch Microwave,
Salisbury, MD (410) 860-5100.
Circle No. 225

Double- and Triple-balanced Mixers



These double- and triple-balanced mixers (along with image-reject, dual (IF) and (IQ) mixers) cover RF and LO frequencies from 500 MHz to 26.5 GHz in varying bandwidths up to 180 percent. Double-balanced IFs vary from DC to 4 GHz and triple-balanced up to 8 GHz. The mixers are designed for low conversion loss and good IP3 performance. Open carrier, pin pack, surface-mount, TO8 and coaxial packages are available.
MICA Microwave Corp.,
San Jose, CA (408) 363-9200.
Circle No. 227

Ka-band Synthesized Converters



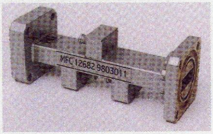
This series of Ka-band converters offers upconverters in the 27.5 to 31 GHz frequency bands and downconverters in the 17.7 to 21.2 GHz bands both for existing Ka-band satellites and satellites currently being planned. Frequency tuning is in a 125 kHz (min) step size. Both frequency and level control are available via the front-panel keypad or remote interface. Phase noise is data quality.
MITEQ, Hauppauge, NY (516) 436-7400.
Circle No. 230

Ka-band Mixer

The model MSR-1A-30G double-balanced mixer uses two pairs of GaAs Schottky diodes configured in a star pattern. The RF and LO signals are coupled to the diodes by means of

modified Marchand baluns. The IF port is DC coupled and the low parasitic inductance of the star configuration allows an IF bandwidth of 11 GHz. The mixer operates from 15 to 30 GHz with an IF as high as 11 GHz. However, the data show respectable conversion loss performance from 10 to 35 GHz. Typical applications include the high speed data satellite market as well as local multipoint distribution systems.
Merrimac Industries Inc., West Caldwell, NJ (888) 434-6636.
Circle No. 298

24 GHz Notch Filter



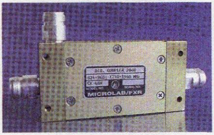
The model 12682 notch filter removes unwanted frequencies with a 50 dB (min) notch depth at 24.9 GHz and a passband loss of 0.5 dB (max). Used in a transmission system passing 24.25 to 24.45 GHz, the unit has a passband return loss of 16 dB (min), operating temperature range of –10° to +60°C and humidity of 99 percent noncondensing. The unit comes with WR-42 cover flanges, but other connectors are available upon request. Length: 2.45 inches (max).
Microwave Filter Company Inc. (MFC), East Syracuse, NY (800) 448-1666 or (315) 438-4747.
Circle No. 229

High Ratio Isolator

The model 0086IHD high ratio isolator is designed to provide 50 dB (min) isolation at 865 to 900 MHz with 250 W forward and 65 W reverse power handling. The circuit tabs are designed to

be part of the center conductor to provide maximum lead strength for the soldering process. The isolator presents a low insertion loss of 0.4 dB with a temperature range of –20° to +85°C. SWR is 1.2 on all ports. High isolation circulators/isolators in other frequency bands are available in similar packages with a maximum thickness of 0.3 inch.
Nova Microwave, Morgan Hill, CA (408) 778-2746.
Circle No. 231

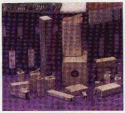
Dual-band Couplers



The CK series dual-band directional couplers are designed for base station and wireless service providers. The couplers feature main line loss below 0.1 dB and low passive intermodulation of –140 dBc. The series is available in 6, 10, 20 and 30 dB coupling values using N female connectors. Similar units are available with a variety of common connectors for frequencies up to 18 GHz. All are rated to 200 W (avg), 3 kW peak power.
Microlab/FXR, Livingston, NJ (973) 992-7700.
Circle No. 228

Ceramic Resonators, Inductors and Elements

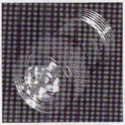
These ceramic resonators operate over the frequency range of 200 to 8500 MHz and come in



a variety of sizes from under 2 mm to over 12 mm for larger base station applications. Various metallizations are tailored to individual requirements. These low cost, high volume resonators, inductors and custom elements find applications in VCOs, filters, high Q inductors and frequency applications. Dielectric resonator pucks are also available upon request.
PicoFarad/Val Jackson & Associates Inc., Scotts Valley, CA (831) 438-5442.
Circle No. 232

Adapters

The 7-16 DIN adapter series has been expanded to include the RFD-1640-2, a 7-16 DIN

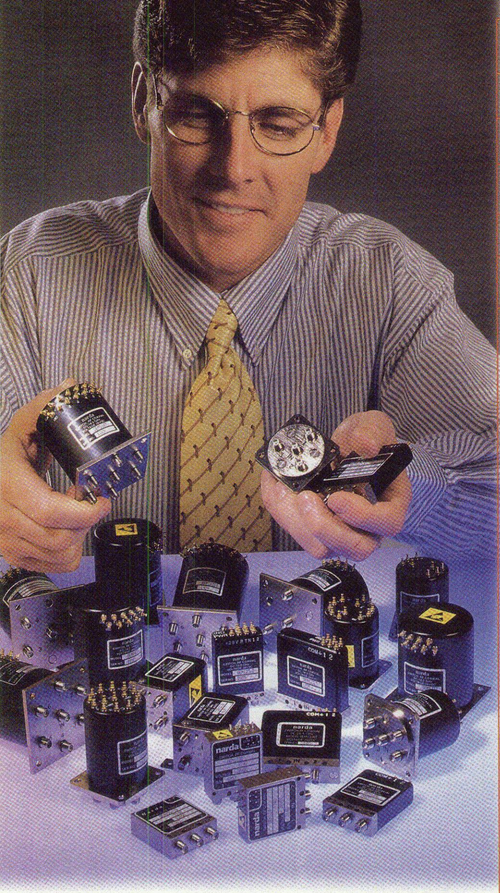


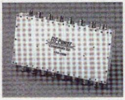
male to 7-16 DIN female straight adapter that is good for use in PCS, cellular and instrumentation applications. The 7-16 DIN connector line features PTFE insulation and silver-plated bodies and contacts, which provide high conductivity, optimal intermodulation distortion characteristics and corrosion resistance. All 7-16 DIN connectors conform to DIN 47223, IEC 169-4 and CECC 22 190 standards and are designed for use in medium to high power communication systems applications.
RF Connectors, a division of RF Industries, San Diego, CA (800) 233-1728 or (619) 549-6340.
Circle No. 233

8 × 8 200 W Butler Matrix

The model RFP-4339 high power 200 W 8 × 8 Butler matrix is designed for cellular and wire-

[Continued on page 134]





less applications. It operates in the 815 to 890 MHz frequency range with an amplitude balance of +65 dB and phase balance of ±5°. Insertion loss is < 1 dB and SWR is < 1.25. Amplitude and phase balance are ±0.65 dB and ±5°, respectively. Operating temperature is 55° to 85°C. Size: 9.0" × 4.5" × 1.0". Delivery: stock to five weeks.
RF Power Components Inc.,
Bohemia, NY (877) 737-2462.
Circle No. 234

Programmable Digital Attenuator

The model P-DATT-9200 six-bit programmable digital attenuator is an integrated IC housed in a 1.0" × 1.8" × 0.475" hermetic case that offers 0.5 dB resolution. Attenuation levels are 1, 2, 4, 8, 16 and 32 dB, and the unit operates over the frequency range of 10 to 500 MHz with a switching speed of 100 ns and attenuation accuracy of ±0.2. SWR is 1.4. The insertion loss is 3 dB and the unit handles +20 dBm of power. Custom models are available. Price: $1100 (10–24).

Signal Technology Corp.,
Beverly, MA (978) 524-7444.
Circle No. 236

Miniature Chip Dual-band Diplexer

The LTF3216D-F series chip dual-band diplexer operates over the carrier frequency range from 800 to 2000 MHz and has a 1206 footprint (3.2 mm × 1.6 mm) with a low profile of only 1.0 mm. The chip dual-band diplexers have a low insertion loss of < 0.5 dB and an average minimum attenuation of 20 dB in either the high or low band. They are specifically recommended to cost-effectively separate frequency bands downstream of the antenna for optimal flexibility in dual-band RF cellular design. The units are packaged on tape and reel in 2000-piece quantities. Price: 75¢ (10,000).
Toko America Inc.,
Mt. Prospect, IL (847) 297-0070.
Circle No. 238

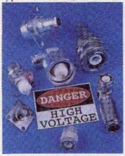
Miniature, High Performance Flexible Cable

The 421-677 series flexible cable measures 0.088" in diameter, has a static bend radius of 0.25" (min) and is suitable for use with SMP connectors. The velocity of propagation is a high 81 percent and a quadraform shield design provides good shielding effectiveness of > 85 dB through 18 GHz.
Storm Products Co.,
Advanced Technology Group,
Hinsdale, IL (888) 347-8676.
Circle No. 237

Single Directional Couplers

The models HCHP-12180, -18265 and -26540 single directional couplers operate over the frequency range of 12 to 18 GHz, 18 to 26.5 GHz and 26.5 to 40 GHz, respectively. The HCHP-12180 features directivity of 15 dB, insertion loss of 0.3 dB and power of 100 W. The HCHP-18265 features directivity of 13 dB, insertion loss of 0.5 dB and power of 80 W. The HCHP-26540 features directivity of 11 dB, insertion loss of 0.7 dB and power of 60 W. All three versions have impedance of 50 Ω and coupling of 20 or 30 dB (nom).
RLC Electronics Inc.,
Mount Kisco, NY (914) 241-1334.
Circle No. 235

RF Coaxial Connectors

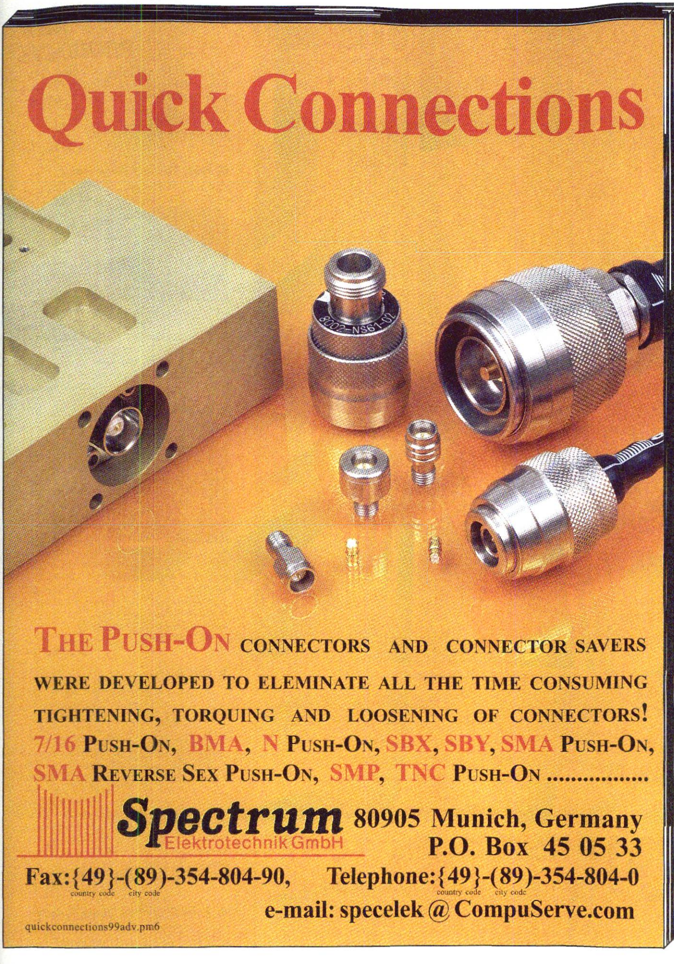


These RF coaxial connectors are variations of type C, SC, LT, LC and SQS connectors but feature enlarged center conductors and insulators to provide longer leakage paths along with step-cut back ends. Capable of withstanding up to 10,000 V peak (C and SC 4000 V), the connectors conform to MIL-C-3650 and MIL-C-39012 specifications. Applications include laser-, sputtering and process systems and medical electronics, radar and pulse equipment.
Tru-Connector Corp.,
Peabody, MA (978) 532-0775.
Circle No. 239

5 pF Multiturn Miniature Trimmer Capacitor

The A4 series trimmer capacitor tunes from 0.6 to 5 pF with five full turns for fine resolution. Voltage rating is 125 V DC with a high voltage option of 1000 DC working volts and 2000 DC withstanding volts. Q is over 2000 at 100 MHz with a self-resonant frequency of 1.8 GHz at 5 pF. The patented solid PTFE dielectric offers linear tuning and no chance of shorting. There are positive stops at minimum and maximum capacitance. Nonmagnetic versions for MRI and NMR are available. A desired ca-

[Continued on page 136]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pacitance value can be preset within ±1 percent so that no or minimal tuning will be required by the user. Price: $1.69 (10,000). Delivery: six weeks.
Voltronics Corp.,
Denville, NJ (973) 586-8585.
Circle No. 240

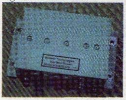
High Power Attenuator

The model WA29 high power attenuator operates over the frequency range of DC to 8.5 GHz. The nominal impedance is 50 Ω with natural convection cooling. Unidirectional power rating is 75 W (avg) from –55° to +125°C, derated linearly to 0 W at 125°C, 5 kW peak power. Maximum SWR is 1.2 (DC to 4 GHz) and 1.3 (4 to 8.5 GHz). Size: 5.70" × 3.50" × 2.25". Weight: 24 oz. Price: $275. Delivery: 60 days (ARO).

Weinschel, Bruno Associates,
Gaithersburg, MD (301) 948-8342.
Circle No. 241

Dual-band Diplexer

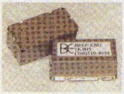
The model W9180 dual-band diplexer is designed for the 900 MHz GSM and 1.8 GHz DCS signals and eliminates the need for two tower feed cables at the base station. The diplexer covers the full DCS and GSM bands with < 0.5 dB insertion loss. Between-band isolation is > 60 dB. Return loss is > –18 dB, all ports. The power capability is > 50 W (both bands). Size: 2" × 4" × 6". Price: less than $255 (small quantities). Delivery: stock to two weeks.



Wireless Technologies Corp.,
Springdale, AR (877) 420-7983
or (501) 750-1046.
Circle No. 242

GPS Diplexer

The company offers a series of filters, which includes a surface-mount GPS diplexer. The configuration has a low loss of 0.7 dBa at the L1 and L2 passbands with channel-to-channel isolation of 30 dBa, and the unit will survive an Sn62 reflow environment. The location of the miniature input and output pads can be specified to accomodate many board configurations. Size: 1.0 × 0.5 × 0.4.



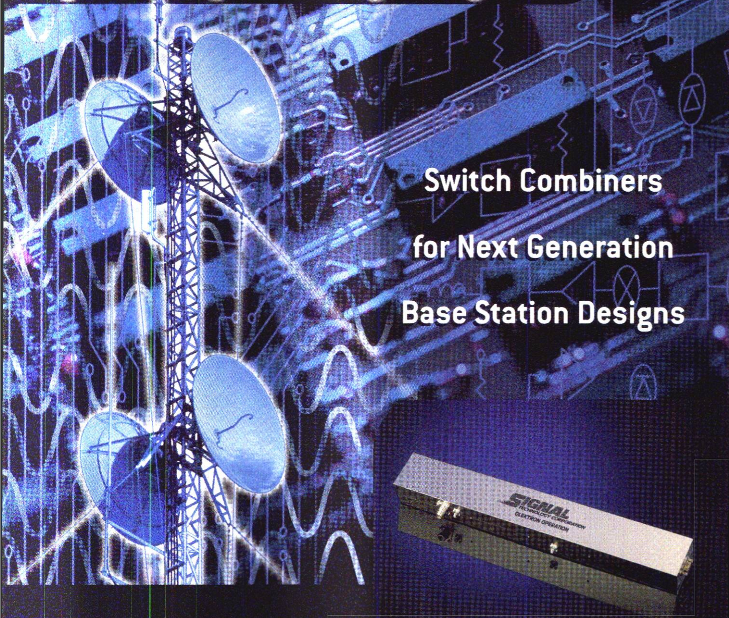
Bree Engineering,
San Marcos, CA (760) 510-4950.
Circle No. 277

7 kW SPDT PIN Diode Switch

The model ES0101 SPDT PIN diode switch is rated for 7 kW (peak), 35 W (average) power

[Continued on page 138]

Engineering a Stronger Signal



To meet the needs of base station designers who are developing multicarrier solutions, Signal Technology's Olektron Operation has developed a series of advanced Switch/Divider/Combiner modules. The SDU series provides full function logic controlled switching of up to four modular amplifiers. This approach allows power summation without the loss associated when using common combiners. Advanced engineering also guarantees the lowest insertion loss, and ensures premier phase and amplitude characteristics. By choosing the SDU series you will receive the highest performance at the lowest cost of any similar product available on the market today. To learn more, visit our SDU series web page at www.sigtech.com/olektron/sdu1

SDU Series Switch Combiners

Frequencies Available: (CDMA, TDMA, DECT, PCS)	800 - 2000 MHz
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VSWR:	<1.25:1*
Amplitude Balance:	0.3 dB
Phase Balance:	±2° max.
Power Summation:	150 watts channel
Random Peak Power:	1800 watts for 1 μS
Isolation from Combiner to Divider:	90 dB min.

* In 3 or 4 port live condition.

www.sigtech.com/olektron/sdu1

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NEW PRODUCTS

over the 5 to 6 GHz frequency band and operates on +5 V at 400 mA and –150 V at 5 mA. Insertion loss is < 1 dB (0.8, typ), isolation is > 40 dB and SWR is 1.5 with a switching speed of 3 μs.
Enon Microwave Inc.,
Topsfield, MA (978) 887-8234.
Circle No. 278

Voltage Regulators

The GMT-72XX LDO series micropower, low dropout voltage regulators are specifically designed to operate in noise-prone, switch-mode environments and provide reliable, low cost solutions for mobile telephones, palm computers, pagers, global positioning equipment and other portable applications. The units feature a logic-enabled sleep mode that produces a sleep-state current of only 0.5 μA. Typical quiescent current is 180 μA, independent of the load. The regulators are available in adjustable and 5.0, 4.85 and 3.3 V fixed output voltage options and are offered in eight-pin SOIC and DIP packages. Price: 75¢ each (1000). Delivery: four weeks.

GMT Microelectronics Corp.,
Norristown, PA (888) 468-4771.
Circle No. 280

50 Ω Dustcap Terminations

The model 3200 ultra-low cost 50 Ω dustcap terminations are designed for applications requiring SMA, BNC, TNC and type-N connectors. The 1 W terminations operate from DC to 4 GHz (DC to 8 GHz for SMA units). Although the SWR performance of these terminations is good, their primary focus is high volume applications where a "throw-away termination" is desired. Price (1000): \$5.30 (SMA male), \$4.00 (BNC male) and \$8.50 (TNC male or N male).

Inmet Corp.,
Ann Arbor, MI (888) 244-6638.
Circle No. 281

850 - 870 MHz Coupler/Filter Assembly

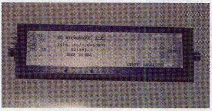
The model 80017 hybrid coupler is a customized two-channel unit with type-N female connectors designed for the cellular base station transmitter combiner application. It operates over the 850 to 870 MHz frequency band and provides insertion loss of 3.5 dB (typ) and 4.0 (max) with isolation of 80 dB (typ) and 70 dB (min) and SWR of 1.25 (max). Maximum power input is 200 W (avg) and 500 W (peak).
Renaissance Electronics Corp.,
Boxborough, MA (978) 263-4994.
Circle No. 282

SMD Mixers

The MXR/2000 series surface-mount device (SMD) mixers are primarily used in base stations or handsets and are available in 10 to 3000 MHz frequencies. The mixers have a good IP3 at +16 dBm (typ) with a +7 dBm input LO input power and isolation at 40 dB (typ). The units are available on tape and reel for easy installation. Size: 0.175" × 0.125" × 0.100".

TRAK Microwave Corp.,
a Tech-Sym company,
Tampa, FL (813) 884-1411.
Circle No. 283

Switched Iso-filter Banks



[Continued on page 146]

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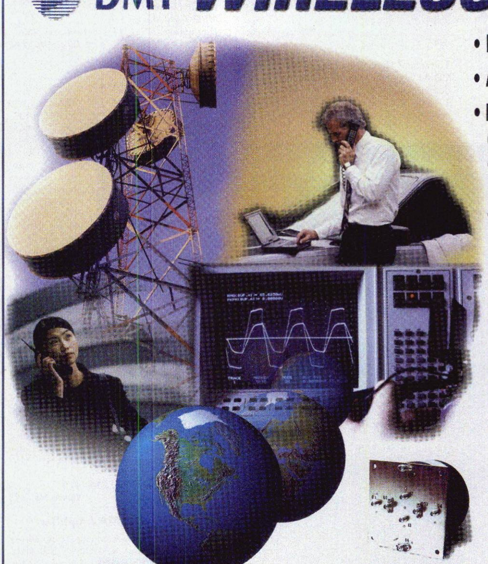
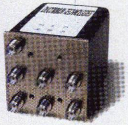
DMT *WIRELESS* PACKAGE

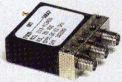
- DC to 40 GHz
- ATE Switch Matrix
- Base Station Applications
  (High Power, Multi Channel, Backup)
  - *5P4T (MM5) & 4P3T (MM4) Switches*
  - *SPDT (D13) & SPST (RA) Switches*





Multi-Channel Switch

ATE Switch Matrix



SPDT Switch

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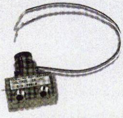

SPST Switch

DUCOMMUN TECHNOLOGIES, INC.

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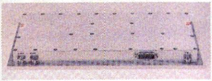
CIRCLE 22 ON READER SERVICE CARD

These switched iso-filter banks with removable SMA connectors have center frequencies of 960, 1000 and 1040 MHz and a 3 dB bandwidth of 50 MHz and 25 MHz at 1.0 dB. Insertion loss is 7.5 dB and SWR is 1.7. Additional features include reverse isolation of > 40 dB; ripples of 0.25 dB and a group delay of 4 ns (max) at ±14 MHz.
ES Microwave LLC, Gaithersburg, MD (301) 519-9407.
Circle No. 279

AMPLIFIERS

PCS 13 W CDMA High Power Amplifier



The model HPA1920-13 highly linear 13 W CDMA high power amplifier has a solid-state design that covers the PCS transmit band of 1930 to 1990 MHz. Gain is 30 dB with other options available. The unit is suitable for single-channel tower-top or base station applications. The rugged amplifier design meets all specifications over a DC input range of 26 to 29 V DC with an operational current of < 5.5 AMPS. The operational baseplate temperature range is –30° to +85°C. Circulator protection is provided for transmission into any load mismatch. Size: 12" × 5.8" × 1.1". An optional 1819 to 1870 MHz model is available.
MPD Technologies Inc., Hauppauge, NY (516) 231-1400, ext. 452.
Circle No. 246

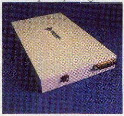
Tower-mounted Amplifier System

The model TMA 1900-DD tower-mounted amplifier system increases the receive sensitivity of PCS base stations. The system consists of three components: the tower-mounted amplifier, amplifier interface unit and system status panel. The tower-mounted amplifier boosts receive signals by 12 to 15 dB and can be used in transmit/receive or receive-only configurations. Two performance levels are available: The low noise version provides good receive sensitivity performance with a 1.8 dB noise figure; the standard version maintains good receive sensitivity with a 2.2 dB noise figure and features a high third-order intercept point for additional immunity from interference in co-located sites. The amplifier interface unit functions as a bias-T with full remote fault reporting through open collector or relay contacts. The system status panel provides central power distribution and fusing, alarm interfacing and visual status monitoring for up to six tower-mounted amplifiers.

Andrew Corp., Orland Park, IL (800) 255-1479
Circle No. 243

18 W PCS CDMA Amplifier

This 18 W PCS CDMA amplifier operates over the frequency range of 1930 to 1990 MHz. Housed in a single, rugged, reliable assembly, the GaAs FET class AB linear amplifier serves the forward-channel transmission requirement of a typical PCS system. The amplifier has a gain of 45 dB (typ) at 25°C and an output power flatness of ±1 dB (max). The operating temperature range is –40° to +85°C baseplate. The standard forward power detection is 0 to 4 V DC and reverse detection is an option. Features include an optional integral heat sink for forced air cooling, an onboard microprocessor for remote on/off control and health status monitoring, and an integral output isolator. Size: 10.50" × 5.00" × 1.75".



Chesapeake Microwave Technologies Inc., Glen Rock, PA (717) 235-1655, ext. 112.
Circle No. 245

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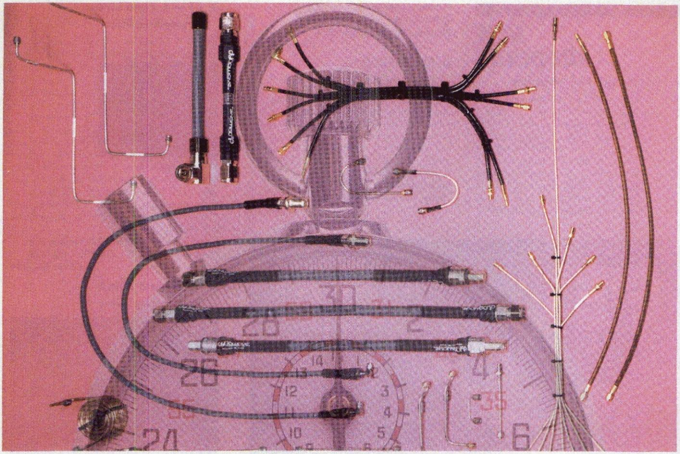

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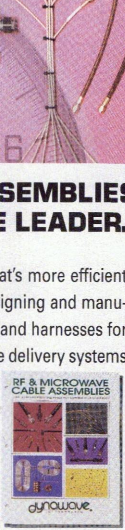

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NEW PRODUCTS

Tower-mounted Amplifier

The model ATM192012-2 tower-mounted amplifier provides extended PCS base station coverage by reducing overall system noise. The use of the new amplifier reportedly can potentially reduce the number of sites required to operate a system by up to 40 percent. Models are available to cover the frequency assignments of A Block, B Block or C Block carriers. The unit's noise figure of 1.8 dB promotes improved receiver performance. Transmit loss is 0.2 dB.

Celwave, a division of Radio Frequency Systems Inc., Phoenix, AZ (800) 235-9283.

Circle No. 244

55 - 60 GHz Low Noise Amplifier

The model CHA2157 low noise, medium power amplifier operates in the frequency range of 55 to 60 GHz. Noise figure is 4 dB, output power is 15 dBm at the 1 dB compression point and gain is 12 dB. A temperature sensor is implemented on the chip. Chip size is 1.78 mm^2.

United Monolithic Semiconductors SAS (UMS), Orsay, France +33 1-69-33-03-08.

Circle No. 247

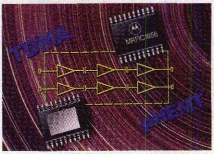
25 W L-band Linear Power Amplifier

This 25 W L-band linear power amplifier has a frequency range of 1500 to 1750 MHz, gain of 24 dB (nom), input/output SWR of 1.5 and input/output impedance of 50 Ω. Designed for QPSK, BPSK and CDMA spread spectrum applications, the unit features CW or burst operational modes and an optional heat sink. P1dB is 44 dBm (typ), 43.5 dBm (min) over temperature, efficiency is 45 percent, spurious is < –70 dBc and operating temperature range is –40° to +85°C.

Chesapeake Microwave Technologies Inc., Glen Rock, PA (717) 235-1655, ext. 112.

Circle No. 284

Dual-band TDMA Power Amplifiers



The model MRFIC1856 dual-band, dual-mode TDMA power amplifiers are designed to operate in the frequency ranges of 824 to 849 MHz for TDMA and AMPS handsets and 1850 to 1910 MHz for PCS TDMA telephones. The units have adjacent-channel power and alternate-channel power specifications of –29 and –48 dBc, respectively, operate with a supply voltage of 3.6 V and are packaged in a high power, low profile TSSOP-20EP surface-mount package with a backside metal contact. The high thermal conductivity of the TSSOP-20EP provides RF output of at least 30 dBm without consuming excessive board space. Price: $5.65 each (10,000).

Motorola, Semiconductor Products Sector, Phoenix, AZ (602) 413-4991.

Circle No. 285

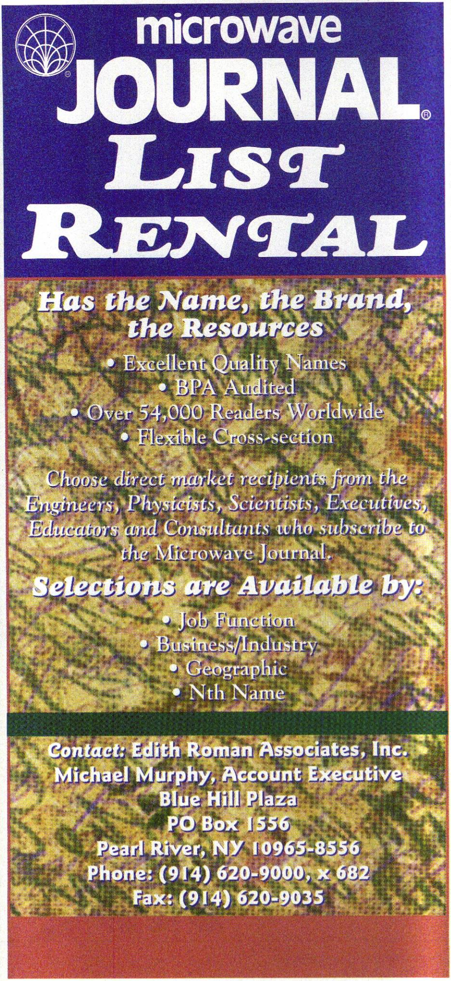
Power Amplifier Module

The RF3101 high power, high efficiency linear amplifier module is designed for 3 V digital cellular and spread spectrum systems in the 1850 to 1910 MHz frequency band. The self-contained unit delivers 29 dBm linear output power and 24 dB linear gain while operating at 35 percent efficiency. Offered in a LGA package, the RF3101 is believed to be the smallest PCS amplifier module in the industry. Both the input and output are matched to 50 Ω internally and require no additional components externally. Size: 5 mm × 6 mm × 1.7 mm.

RF Micro Devices, Greensboro, NC (336) 664-1233, ext. 6652.

Circle No. 248

[Continued on page 150]



NEW PRODUCTS

ANTENNAS

250 V/m Field Antenna

The model AT4002A microwave horn antenna is capable of generating fields of up to 250 V/m with a gain of 11 dB (max) over isotropic. It accepts 250 W of input power from 0.8 to 5 GHz and supplies the high intensity fields necessary for electromagnetic/RF interference field testing in shielded rooms. Specifically designed septums are installed to focus beamwidth and ensure field intensity at three meters. The unit mounts easily on a tripod or back plate. Size: 46.3 × 46.3 × 69.2 cm. Weight: 6 kg.

Amplifier Research (AR), Souderton, PA (215) 723-8181.

Circle No. 250

Antenna Mount

This point-to-point antenna mount, the Quick Align Mount (QAM), simplifies the installation and alignment of an antenna. The mount adapts to mast pipes ranging in size from 1.9 to 4.5 inches. The QAM requires only a wrench and screwdriver for on-site installation of antennas. The new mount is currently being supplied with the company's new antenna models SSP2-23A and SSP2-52B. It is also available on select directional flat-panel antennas.

Gabriel Electronics Inc., Scarborough, ME (207) 883-5161.

Circle No. 252

LMDS Subscriber and Base Station Antennas

These local point-to-multipoint distribution system (LMDS) subscriber antennas and base

[Continued on page 152]

NEW PRODUCTS

station horns operate over a frequency range of 24 to 38 GHz for indoor or outdoor applications. Single or dual polarization is available as well as a coax or waveguide interface. Gain is 35 to 43 dBi, and operating temperature range is –40° to +80°C. Size: 10" to 21" in diameter; 4" to 8" in depth.
Rantec Microwave & Electronics Inc., Calabasas, CA (818) 223-5202.

Circle No. 286

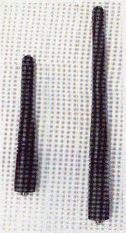
Ceramic Antennas

The model CSA-1900 ceramic antennas operate over a frequency range of 1.85 to 1.99 GHz. Impedance is 50 Ω with power input of 2 W (max). The antennas have an omnidirectional radiation pattern and vertical polarization. Operating temperature is –100° to +150°C and SWR is < 1.9.
Ace Antenna, Chatsworth, CA (818) 718-1534.

Circle No. 249

Wireless Antenna

The SX series portable antennas operate over the frequency bandwidth of 150 to 161 MHz

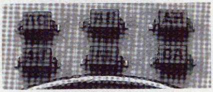


and can be up to 20 percent shorter at the same frequency as industry-standard injection-molded antennas. The antenna's patented capless sheath construction increases its durability. SWR is < 1.5 at resonant frequency. The SX series is offered with a standard MX connector and an assortment of SMA female connectors. It is available in UHF and VHF. Length: 5.5 inches (140 mm).
Centurion International Inc., Lincoln, NE (402) 467-4491.

Circle No. 251

DEVICES

Tuner Diodes

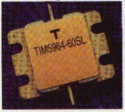


The model SOD323 packaged varactor diodes require 50 percent less board space than their larger SOT23 packaged alternatives and have a reverse breakdown voltage of 25 V. The diodes offer users a nominal capacitance range between 8.2 and 68 pF for a V_R of 2 V and a frequency of 1 MHz, assuring them a wide range of applications. A minimum quality factor Q at test conditions of 50 MHz and a low V_R of 3 or 4 V are guaranteed. Depending on the device type, the ZMV series displays a minimum Q of 80 to 350. Price: 46¢ to 54¢ each (5000). Delivery: eight weeks (max).
Zetex Inc., Commack, NY (516) 543-7100.

Circle No. 254

60 W C-band GaAs FET

The model TIM5964-60SL 60 W C-band GaAs FET is designed for use in solid-state power



amplifiers for satellite earth station communication transmitters (SATCOM) and very small aperature terminals (VSAT) and has output power of 48 dBm (typ) at a frequency range of 5.9 to 6.4 GHz. The company implemented its new heterojunction field effect transistor (HFET) process technology, which is a promising candidate for microwave higher power devices due to its performance and the increase in power and gain. Price: $1100 (100).
Toshiba America Electronic Components Inc., Irvine, CA (800) 879-4963, ext. 212.

Circle No. 287

[Continued on page 154]

NEW PRODUCTS

HARDWARE

Two-part EMI Shield

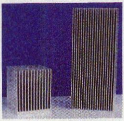
The BOLDT SHIELD II™ is a standard off-the-shelf, two-part electromagnetic interference shield packaged in standard EIA410 tape-and-reel formats for automated circuit board-level installation. Its unique design (with removable lid) provides easy access to inspect or repair important electronic components without having to detach the surface-mount technology shield. Available in many JEDEC sizes, including 52-pin quad flat pack (TQFP), 256-position ball-grid array (BGA) and 84-pin plastic leadless chip carrier (PLCC) packages, the shield combines high shielding performance and reliability with added flexibility for prototype adjustment.

Boldt Metronics,
a business unit of BMI,
Palatine, IL (847) 934-4700.

Circle No. 256

High Fin Density Heat Sinks

The HT series heat sinks provide high cooling power for various devices and are suitable for



applications with high volume air flow. The bonded fin heat sink features ~ 13 fins/inch. Size: 3" × 3" × 2" up to 8" × 10" × 4". Price: from $10 each (500). The machined heat sink features ~ 10 fins/inch. Size: 1.0" × 1.0" × 0.5" up to 3" × 7" × 2". Price: from $5 each (500) with gang-saw technique.

ACK Technology Inc.,
Buena Park, CA (714) 739-5797.

Circle No. 255

INTEGRATED CIRCUITS

3 V Receiver

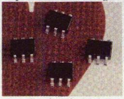
The model AWR8004 wireless receiver is designed for 3 V operation and features conversion gain of 17 dB (typ) and noise figure of 3.5 dB (max). The unit offers low power consumption and a very small footprint and is highly integrated, allowing wireless system manufacturers to lower component counts and, thereby, reduce costs. It delivers a –8 dBm (typ) third-order intercept point and requires a power supply current of 12 mA (typ) biased from a single +3 V DC supply. Acting as a monolithic downconverter, the AWR8004 integrates a low noise amplifier, mixer, LO buffer and IF amplifier. Size: 8.64 × 3.91 mm. Price: $2 (10,000).

ANADIGICS Inc.,
Warren, NJ (908) 668-5000.

Circle No. 257

5 V Wideband Amplifier ICs

The models UPC2708TB and UPC2710TB amplifier ICs are designed to serve as a gain



stage device in cellular, GPS and PCS receivers and DBS tuners and to serve as a PA driver in cellular, GPS and PCS receivers, respectively. The UPC2708TB features high output power for wideband operation and good gain and noise performance of 15 and 6.5 dB, respectively. The UPC2710TB features high output power for wideband operation and delivers high gain of 33 dB and high saturated power with good noise performance of 3.5 dB. Price: 48¢ (100,000).

California Eastern Laboratories (CEL),
Santa Clara, CA (408) 988-3500.

Circle No. 258

RF Front-end Receiver IC

The model SA3600 highly integrated RF front-end receiver IC integrates 800 MHz cellular and 1900 MHz PCS-band low noise amplifiers and downconversion mixers and provides the gain, noise figure and linearity needed to meet the receiver sensitivity and intermodulation requirements for TDMA (IS-136 and GSM) dual-band, multimode digital cellular telephones. The on-chip LO frequency doubler, input/output buffer amplifiers, matching cir-

[Continued on page 156]

cuitry and control-made logic reduce external glue components. By integrating all key RF functions in a single chip, the SA3600 provides a complete dual-band receiver solution that saves board space and time. Samples are available in a 24-pin plastic thin shrink small outline package. Price: $2.29 (10,000).
Philips Semiconductors, Sunnyvale, CA (408) 991-2332.
Circle No. 289

Negative LDO Regulator

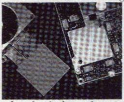
The model MIC5270 IttyBitty™ negative low dropout (LDO) regulator is available in the SOT-23-5 package and can supply up to 100 mA. Designed for GaAs FET bias, LCD and CCD array, and battery-operated equipment applications, the MIC5270 features a two percent tolerance over temperature, thermal shutdown and current limit. Quiescent current is 80 μA, and a –20 V (max) input voltage range ensures the part will survive power supply spikes that would be fatal for many other low power LDO regulators. Price: $1.22 (1000). Delivery: stock to eight weeks (ARO).

Micrel Inc., San Jose, CA (408) 944-0800.
Circle No. 288

MATERIALS

Reinforced Gap Filler

The THERMA-A-GAP™ F574 thermally conductive elastomer is designed for efficiently transferring heat from components into various heat spreading devices. The material's thermal impedance ranges from 0.6° to 2.6°C-in²/W for thickness from 0.02 to 0.10 inch. The material consists of a soft silicone elastomer loaded with a blend of ceramic particles and for mechanical strength, the material is reinforced with an internal fiberglass mesh. Its flexible nature allows it to blanket highly uneven surfaces across components and circuit boards. The material has a tacky surface and does not require any mounting adhesives. Sizes: standard sheets are 9" × 9" or 18" × 18". Price: 25¢/square inch.



Chomerics division of Parker Hannifin Corp., Woburn, MA (781) 935-4850.
Circle No. 259

SOFTWARE

Translator Software

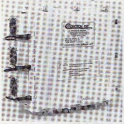
AnsoftLinks for the HP EEsof Series IV is a smart translator software utility that migrates entire high frequency circuit designs from series IV to the company's Serenade Design Environment. Designs are automatically converted into Serenade projects using IFF files and a specialized neutral format. Linear and nonlinear translations are supported, providing users all the advantages of Serenade, including greater accuracy, an easy-to-use Windows® interface and advanced design utilities. Special features of the series include seamless transport of the entire design, automatic transport of linear and nonlinear circuits, preservation of full circuit hierarchy through translation and an intuitive pull-down menu within Serenade.
Ansoft Corp., Pittsburgh, PA (412) 261-3200.
Circle No. 260

[Continued on page 158]

NEW PRODUCTS

SOURCES

Weatherproof S-band Transmitter



The model CHC29218-250/5650 class C power amplifier system operates over the 2025 to 2120 MHz NASA frequency band with 250 W (min) output power, and is circulator protected. The amplifier system is housed in two weatherproof NEMA enclosures (amplifier and power supply) for direct mounting to an outdoor antenna. Operating temperature is 0° to +50°C with 100 percent condensing humidity. An RF input level of 0 dBm is required for full power output. A low power mode (25 W) is also selectable locally. Prime operating power is 120 VAC single phase 50/60 Hz. Size: 25" × 24" × 12".
Comtech PST,
Melville, NY (516) 777-8900.
Circle No. 261

12.5 - 25 MHz VCO

The model JTOS-25 surface-mount VCO is the performance solution for measurement instrumentation and phase lock loop circuit applications spanning the 12.5 to 25 MHz frequency range. The thermally rugged VCO features linear tuning characteristics, –26 dBc (typ) harmonic suppression and 1 to 11 V tuning voltage and displays low –115 dBc/Hz (typ) phase noise at 10 kHz offset over the band. Tape-and-reel packaging is available. Price: $18.95 each (5–49).
Mini-Circuits,
Brooklyn, NY (718) 934-4500.
Circle No. 262

TCXO

The model MTXL25 TCXO is available with frequency stabilities of ±1.5 ppm over –20° to +70°C, ±2.5 ppm over the –30° to +75°C and ±5 ppm over –40° to +85°C operating temperature ranges. Frequency adjustment is by means of an internal trimmer. Output is HCMOS/TLL compatible. The model MTVXL25 has the same stability options as the MTXL25 but incorporates voltage tuning. These oscillators are good for PCS, cellular, GPS, test instrumentation and mobile ra-

[Continued on page 160]

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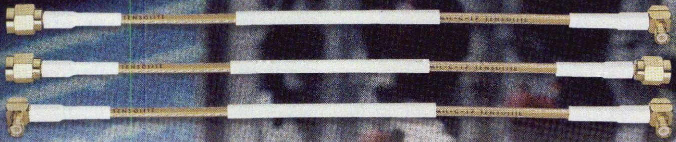

GUARANTEED SPECIFICATIONS

	Impedance Nominal (Ohms)	Capacitance Nominal (pf/FT)	Relative Shielding (1FT assembly) (db Min.)	Velocity of Propagation, Nominal (%)	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
MCX RT on 187 Cable	50	29.4	>-40	70	1000	900	1.44	120	500	0.5	187
										1	134
										2	95
										3	78
SMA MALE on 187 Cable	50	29.4	>-40	70	1000	900	1.44	120	500	0.5	187
										1	134
										2	95
										3	78
SMA MALE to SMA Male	50	29.4	>-40	70	1000	900	1.44	120	500	0.5	187
										1	134
										2	95
										3	75

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

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CIRCLE 111 ON READER SERVICE CARD

NEW PRODUCTS

dio base station applications, and are available in a small leadless surface-mount 9.6 × 11.4 × 2.5 mm package.
M-tron Industries Inc.,
Yankton, SD (800) 762-8800
or (605) 665-9321.
Circle No. 263

■ Surface-mount TCXO

The model RTVY-174 TCXO offers ±2.5 ppm stability over the temperature range of –30° to +80°C as a standard feature. It is powered by a 3 V supply and the current drain is 2 mA (max). Output voltage is 0.9 V p-p (min), clipped sinewave, capable of driving a 10 kΩ load shunted by 10 pF. The unit is available in standard frequencies from 12.6 to 19.8 MHz. The TCXO incorporates a custom IC chip, not a hybrid, and has a footprint of only 6.0 × 3.5 mm. Price: $5.95 each (10,000).
Raltron Electronics Corp.,
Miami, FL (305) 593-6033.
Circle No. 265

■ mm-wave Active Doublers

The models AK-2X and AKa-2X active doublers operate from 18 to 26 GHz and 26 to 40 GHz, respectively.

Input power can be in the range of 10 to 17 dBm and output power options are 15 dBm (min) or 20 dBm (min). Customized input and output power requirements are available. Fundamental and harmonic rejection is 20 dBc (typ), 15 dBc (min). Input connectors are K-type (F) and output connectors are either K-type (F) or waveguide.
Spacek Labs Inc.,
Santa Barbara, CA (805) 564-4404.
Circle No. 266

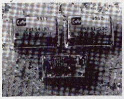
■ 1500 - 1600 MHz VCO

The model CLV1550E VCO operates over the frequency range of 1500 to 1600 MHz with a

tuning voltage of 0.5 to 5 V DC. The phase noise is –106 dBc/Hz at 10 kHz offset with harmonic suppression of –35 dBc. Load impedance is 50 Ω, and the unit operates over the temperature range of –40° to +85°C. Applications include digital radios, base stations and mobile communications.
Z-Communications Inc.,
San Diego, CA (619) 621-2700.
Circle No. 267

■ 3.3 V VCXO

The PVL541 series 3.3 V voltage-controlled crystal oscillator (VCXO) is a low jitter oscilla-

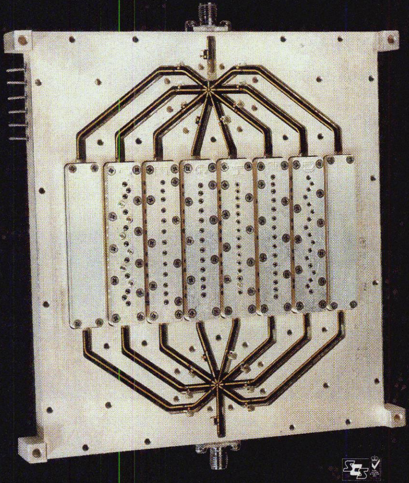


tor designed to meet the stringent SONET chip specifications for SONET, SDH and ATM applications. The oscillator is ideal for the AMCC S3041 and S3043 OC-48 transmitter chips and has a total frequency tolerance of less than 20 ppm. Jitter performance is guaranteed to be less than 1 ps in the 12 kHz to 20 MHz band. (Use of a fundamental frequency source rather than a multiplier to reach the output frequency achieves this low jitter.) Center frequency is 30 to 155.52 MHz, temperature range is 0° to +70°C, output load is 50 Ω and linearity is ±10 percent (max).
Connor-Winfield Corp.,
Aurora, IL (603) 851-4722.
Circle No. 290

■ LMDS Phased-locked DRO

The model HP E5500 DRO operates over the frequency range of 12 to 16 GHz with a power output of +13 dBm. Harmonics are –20 dBc

[Continued on page 162]



ISO 9001 Certified certification #960161

and spurious is –80 dBc. Temperature range is –10° to +65°C and operation is +12 V at 160 mA. The DRO is reliable with a rugged design and low microphonics.
Nexyn Corp.,
Sunnyvale, CA
(408) 732-0793.

Circle No. 253

Broadband VCO

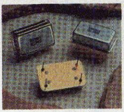
The model PV-1103 low noise VCO is designed for cable modems and other applications, and works over a frequency range of 1100 to 2000 MHz with a 10 V supply. The phase noise of the VCO is –100 dBc/Hz at 10 kHz offset and –120 dBc/Hz at 100 kHz offset from the center frequency. The tuning voltage is 1 to 20 V, and the unit operates over the temperature range of –30° to +70°C. Size: 0.5" × 0.5".

Princeton Electronic Systems Inc. (PES),
Princeton, NJ (609) 275-6500.

Circle No. 264

Crystal Oscillator

The model SEL 3400 crystal clock oscillator is designed for high resolution graphics, top-line workstations, and imaging and telecommunications applications and has a frequency range from 7 to 250 MHz, including SONET 155.52 MHz. The SEL 3400 is available in 5, –5.2 and 3.3 V positive/pseudo emitter-coupled logic supply voltages. (The 3.3 V complementary version is also compatible with low voltage differential signaling.) Open emitter outputs allow the user to select the load termination to optimize performance and crystal technology allows for economical and rapid turnaround of custom frequencies. Delivery: stock to 10 weeks.



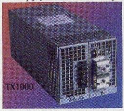
SaRonix,
Menlo Park, CA (800) 227-8974
or (650) 470-7700.

Circle No. 292

SUBSYSTEMS

1000 W Power Supply

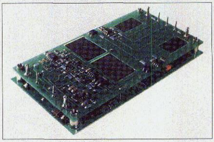
The TX1000 series single-output, 1000 W power supply with active input power factor correction circuitry accommodates a 90 to 264 VAC input for global applications. Standard output configurations include 3.3, 5, 12, 15, 18, 20, 24, 28, 36 and 48 V models to support a wide range of needs including front ends for distributed power architectures. All models (except the 3.3 and 5 V) have an optional ORing diode, which, when combined with the active current sharing feature, provides an N+1 redundant platform for fault-tolerant applications. Standard features include power fail warning, remote inhibit, DC OK signal, current share, over-voltage protection, output over current/short circuit protection and remote sense. The logic signals can be configured either active high or active low.



C&D Technologies Inc.,
Power Electronics Division,
Tucson, AZ (800) 547-2537.

Circle No. 268

DC/DC Converters



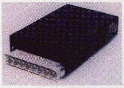
The VWx series DC/DC converters includes the 100, 150 and 300 W VWS and VWB boosters. The series uses advanced planar magnetics and open frame packaging to deliver good thermal performance and high reliability. The VWx converters are available in wide range 24 or 48 V nominal input voltages. Output voltages avail-

[Continued on page 164]

NEW PRODUCTS

able include 3.3, 5, 12, 15, 24, 28 or 48 V. The series is rated for 100°C baseplate operation and has 1500 V DC of isolation. Price: $110.
International Power Devices,
Boston, MA (617) 746-5135.
Circle No. 269

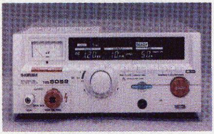
100 W DC-to-DC Converter



The Statronics Power Supplies E100 series DC-to-DC converters have an input voltage range of 17.5 to 150 V DC. The input/output isolation is 2 kV rms and the DC output power is 100 W continuous, 110 W surge. The remote sense compensation is up to 1 V total lead drop with step-load response of 25 to 75 percent on output. Size: 4.0" × 1.0" × 6.7".
Power Plus Technical Distributors Inc.,
Canoga Park, CA (818) 703-8088.
Circle No. 270

TEST EQUIPMENT

Voltage Tester

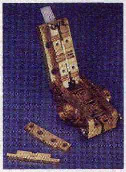


Kikusui Electronics Corp.'s model TOS5052 withstanding voltage tester is designed for use with electronic equipment or components and features a rise-time control that automatically increases test voltage to specified levels as required by UL-type and IEC safety standards. It offers a high capacity power supply with an output of 5 kV AC (max) at 100 mA. Preset output voltage, select output frequency of 50 or 60 Hz, digital voltmeter, ammeter and timer functions are standard. The tester provides dual-axis operation of the test voltage range selector switch and voltage setting knob and separate up/down keys to determine current and timer settings.
IFR Americas Inc.,
Wichita, KS (316) 522-4981.
Circle No. 273

Portable CDMA Scanner

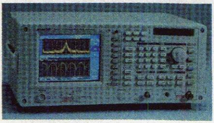
The Hummingbird™ portable CDMA scanner is available in both PCS and cellular models. It features low cost, speed, sensitivity and the ability to measure indoors or outdoors. The unit is self-contained and does not require GPS reception because it includes sync channel demodulation for positive base station identification and has removable data storage. Playback allows engineers to review problem spots with markers.
Berkeley Varitronics Systems Inc.,
Metuchen, NJ (732) 548-3737.
Circle No. 271

Short Lead Transistor Test Fixture



The model MT950G short lead transistor test fixture includes short lead transistor inserts that are designed to work with the company's short lead transistor packages or similar package designs. The short lead fixture can work with the company's existing transistor inserts as well. The manual for the inserts contains circuit models, which can be used to develop de-embedding parameters.
Maury Microwave Corp.,
Ontario, CA (909) 987-4715.
Circle No. 274

Spectrum Analyzers



[Continued on page 166]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Tel: (561) 840-1800 • Fax: (561) 844-8551
CIRCLE 131 ON READER SERVICE CARD

NEW PRODUCTS

The model R3132/R3132N and R3162 spectrum analyzers are designed for high throughput wireless, RF and television production test applications. The instruments are competitively priced and equipped with a simplified user interface and automated measurements.
Tektronix Inc., Beaverton, OR (503) 627-5757.

Circle No. 275

Timer/Counters

The models 901, 901R and 900 timer/counters provide state-of-the-art timer/counter mea-surements for time interval, frequency, phase and jitter. The model 901 has an ultra-high time interval resolution of 50 ps (single shot) and 1 ps (averaged), plus a speed of up to 8000 measurements per second. The frequency range can be extended from 300 MHz to 2.7 GHz. The model 901R is equipped with an atomic rubidium timebase frequency reference. The economy model 900 is identical to the model 901, except for a 250 ps single-shot time interval resolution, 225 MHz basic frequency range and a speed of 2000 measurements per second.

Wavetek Corp., San Diego, CA (619) 279-2200.

Circle No. 276

Radiation Hazard Measuring Instrument

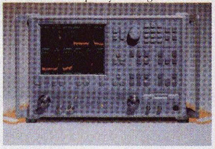
The model 2001 radiation hazard measuring instrument (RAHAM) is constructed in a ruggedized housing and is designed to be utilized by personnel who may be exposed to potentially hazardous levels of nonionizing RF and microwave radiation. It covers the frequency range of 3 MHz to 1 GHz, measures the E-field over the wide dynamic range of 10 to 1000 V/m and features a three-element diode detector that provides an isotropic (omnidirectional) response. The alarm level threshold is set to 200 V/m, but can be factory reprogrammed to meet specific customer needs. The instrument and probe are enclosed within a single rugged housing designed to be rainproof and survive a more-than-three-foot drop onto a solid surface. Operator controls are easily accessible and suitable for gloved users. Size: 9.58" × 2.80" × 1.75". Weight: 1 lb.

General Microwave Corp., Amityville, NY (516) 226-8900, ext. 236.

Circle No. 272

Self-contained 65 GHz VNA

The model 37X97 single-unit, self-contained vector network analyzer (VNA) with a frequency coverage to 65 GHz is designed to meet the testing needs of higher frequency systems such as wireless networking, low earth orbit satellite communications systems and intelligent transportation systems. The VNA features electrical performance of > 70 dB dynamic range and > –5 dBm leveled output power. High performance doubler and quadrupler modules with GaAs MMIC output amplifier stages provide the VNA with the capability to make active device measurements over a wide range of input levels. Standard features include a four-channel display for viewing all four S parameters at once. A standard four-sampler architecture offers the highest degree of accuracy and stability. Price: $130,000.



Anritsu Co., Microwave Measurement Division, Morgan Hill, CA (408) 778-2000.

Circle No. 293

NEW LITERATURE

■ RF ON FIBER™ DESIGN GUIDE

This eight-page guide reviews RF on Fiber product technology, including the company's two-path, three-path and four-path WDM transceivers; systems design parameters; fiber-optic link performance; and product specifications.
Anacom Systems Corp.,
New Brunswick, NJ (732) 846-2680.
Circle No. 200

■ CAPABILITY GUIDE

This eight-page guide contains information on the company's comprehensive line of multifunction programmable assemblies specifically designed for cell system fading emulation and cellular traffic simulation applications, fixed attenuators, terminations, programmable attenuators, power dividers/combiners, connectors, and RF switches and test accessories. Product photographs and specifications are included.
JFW Industries Inc.,
Indianapolis, IN (877) 887-4539
or (317) 887-1340.
Circle No. 202

■ COMPANY NEWSLETTER

This two-page newsletter contains information on the company's ball-grid arrays, tape transfer technology for military, industrial and telecommunication applications, gold etching process and other manufacturing and design capabilities. Product photographs included.
Advanced Packaging Technology
of America (APTA),
San Diego, CA (619) 452-2700.
Circle No. 203

■ ENGINEERING BULLETIN

This 20-page engineering bulletin provides detailed descriptions about the company's new line of SURFCOIL® surface-mount technology, fixed and variable surface-mount inductors, coils and transformers designed for application in RF, EMI, power and other industrial circuits that need individual or coupled resonant components. Features, specifications, outline drawings, application notes and an application guide are included.
Sprague-Goodman Electronics Inc.,
Westbury, NY (516) 334-8700.
Circle No. 204

CLASSIFIED

■ FULL-LINE CERMET RESISTOR PRODUCT CATALOG

This 56-page catalog contains information about the company's complete line of surface-mount chip resistors and chip resistor arrays, surface-mount leaded and leadless resistor networks, through-hole resistor networks, surge/power resistor networks, and TrackStik® strain gage pointing devices.
CTS Corp., Elkhart, IN (219) 293-7511.
Circle No. 205

■ RF AND MICROWAVE PRODUCT GUIDE

This 16-page guide highlights custom RF and microwave power transistors, MMICs and power amplifiers and provides key product specifications for general-purpose amplifiers, FM broadcast amplifiers, HF and VHF amplifier pallets and modules, UHF-TV and wireless amplifier pallets, cellular/mobile/paging amplifier pallets and low noise amplifiers.
Richardson Electronics Ltd.,
RF Gain Division,
LaFox, IL (800) 737-6937
or (630) 208-2200.
Circle No. 206

■ CUSTOMER MAGAZINE

This 16-page magazine (*Alliance*) highlights the capabilities of the company's Advanced Design System and contains information about Toshiba's GSM chipset, which uses the Advanced Design System. Expanding opportunities in third-generation wireless communications are also discussed.
HP EEsof,
Santa Clara, CA (800) 452-4844.
Circle No. 207

■ ADVANCED SYNCHRONIZATION TECHNIQUES APPLICATION NOTE

This application note is a step-by-step tutorial that demonstrates how PXI modular instrumentation and the company's data acquisition combine to easily address the needs of the most common test systems requiring timing and synchronization of input/output functions.
National Instruments Corp.,
Austin, TX (800) 258-7022.
Circle No. 208

■ TECHNICAL BULLETIN

This technical bulletin features the 2625D silver conductor for printing both standard and very thick prints in hybrid circuits and provides information about typical fired conductor properties, composition properties and recommended processing procedures for thick printing.
Emca-Remex Co.,
Montgomeryville, PA (215) 855-1000.
Circle No. 209

■ PRODUCT GUIDE

This seven-page guide contains information about the company's MicroPen™ precision writing system, which produces an image directly from computer-generated data without using any hard tooling for a wide range of applications. Product photographs and specifications included.
OhmCraft,
Honeoye Falls, NY (716) 624-2610.
Circle No. 210

■ PULSED EMI HANDBOOK

This revised pulsed electromagnetic interference (EMI) handbook contains information about threatening pulsed phenomena such as electrostatic discharge, electrical fast transients, surges resulting from lightning or switching in the power grid and power quality failure. The sources of each threat, levels found in the environment, test methods and standard compliance levels are described.
KeyTek, a Thermo Voltek company,
Lowell, MA (978) 275-0800.
Circle No. 211

■ CHIP ATTENUATOR BROCHURE

This eight-page brochure discusses the installation of the company's line of chip attenuator pads for use in military and commercial MIC applications. Specifications and features are listed. Performance graphs are included.
DAV Technology,
Tyngsborough, MA (508) 649-4231.
Circle No. 212

■ LONG LIFE SWITCH BROCHURE

This six-page brochure highlights the company's low cost, long life magnetic switches specifically designed for test equipment applications. The switches, which use a magnetic linear solenoid, offer up to five million operations while handling 100 W CW and can be used in a wide variety of commercial applications where frequent switching is required.
Dow-Key Microwave Corp.,
Ventura, CA (805) 650-0260.
Circle No. 213

■ CERAMIC INDUSTRY ROADMAP

The Ceramic Interconnect Initiative of the International Microelectronics and Packaging Society (IMAPS) has developed a ceramic industry "roadmap" that describes how the features of ceramic technology deliver benefits for a variety of electronic packaging and interconnect applications. The document analyzes the current state and forecasts future requirements of the use of ceramic in electronic packaging.
IMAPS, Reston, VA (888) 464-6277.
Circle No. 295

■ DC POWER SUPPLY BROCHURE

This 10-page brochure describes Kikusui Electronics Corp.'s PAN-A series DC power supplies designed for use in research and development, burn-in, quality control and production environments. Product photographs and specifications are included.
IFR, Wichita, KS (316) 522-4981, ext. 406.
Circle No. 296

■ COAXIAL CABLE BROCHURE

This six-page brochure describes the features and benefits of the company's line of flexible high performance low loss LMR® coaxial cables, connectors, installation tools and accessories designed for use in wireless communications systems such as cellular, PCS, paging, two-way radio, LMDS, WLL, CLEC, ISM, wireless data and telemetry.
Times Microwave Systems,
Wallingford, CT (203) 949-8489.
Circle No. 297

Basic Engineering Circuit Analysis

J. David Irwin and Chwan-Hwa Wu
John Wiley & Sons
976 pages; $99.95
ISBN: 0-471-36574-2

The sixth edition of this text includes some important changes resulting from the way introductory circuits are currently being taught and includes contributions from Chwan-Hwa Wu as a new co-author. The book is designed to serve as a core text for students majoring in electrical and computer engineering as well as a basic introduction to electronic circuits for students in other disciplines.

"...a good first exposure to basic electronic circuit analysis..."

The book begins with a discussion of circuit elements followed by resistive circuits, including operational amplifiers, transients, sinusoidal steady state and complex frequency, and ends with Laplace and Fourier methods. It is written for students who have completed introductory physics and calculus college courses. The goal is to provide an effective and efficient environment for students to obtain a thorough understanding of circuit analysis as well as an introduction to the design of linear electronic circuits.

Each chapter begins with a preview of the topics covered and a side column containing comments to help shorten the learning curve. A large number of examples are supplied to aid in understanding the material. Practical examples, referred to as applications, frequently deal with design issues. Drill problems and exercises are intended to be assessment tools, which help to guide the student in the proper problem-solving techniques.

Problem-solving strategies are placed throughout the book to aid the student in selecting the proper solution techniques applicable to particular situations. Computer-aided design tools, such as PSPICE® and Matlab® are applied to the analysis and design of electronic circuits. In addition, a study guide is available containing a CD ROM that includes circuit simulations and five easy-to-use video segments demonstrating PSPICE solutions. This study guide also contains 100 representative problems with complete solutions.

This book is a good first exposure to basic electronic circuit analysis and forms a solid foundation for further study. It is very clearly presented and an easy guide to learning in this area.

To order this book, contact: John Wiley & Sons Inc., 605 Third Avenue, New York, NY 10158 (212) 850-6336 or (800) 225-5945.

RF and Microwave Coupled-line Circuits

Rajesh Mongia, Inder Bahl and Prakash Bhartia
Artech House Inc.
520 pages; $89, £67
ISBN: 0-89006-830-5

Coupled transmission structures are critical components in distributed RF and microwave passive circuits. This book is primarily intended for design engineers and research and development specialists involved in coupled-line circuit design, analysis, development and fabrication. The first chapter covers the nature of coupled structures and their importance in microwave circuits. Chapter 2 establishes the basic circuit parameters and representation of microwave networks. The fundamental building blocks for coupled-line circuits are covered in Chapter 3, including the characteristics of planar lines, such as microstrip, coplanar and striplines, and coupled lines using broadside coupling, edge coupling or, in the case of waveguides, coupling with shields present.

Chapter 5 describes the design and performance of forward-directional couplers using asymmetrical coupled lines. Parallel-coupled backward TEM directional couplers are described in Chapter 6 and, in Chapter 7, the design and synthesis procedure for such couplers is outlined together with some techniques to obtain broadband performance. Chapter 8 presents the tight coupler, which can be designed and fabricated in a number of configurations.

"Coupled transmission structures are critical components in distributed RF and microwave passive circuits."

The most commonly used form of coupled-line circuit is the filter. Chapter 9 extensively covers filter parameters, filter synthesis, design and realization. Modern miniature filters are also discussed and a number of software packages for filter design are assessed.

Chapter 10 covers the analysis and design of DC blocks, coupled-line transformers, interdigital capacitors, spiral inductors and transformers, while Chapter 11 describes the design and analysis of baluns. Chapter 12 covers the topic of high speed digital interconnects and the problem of crosstalk. Finally, Chapter 13 provides information on the use of multiconductor lines as building blocks for coupled-line circuits.

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.

Frank Bashore

Frank Bashore is a member of the Microwave Journal *staff.*

International Microwave Symposium
Boston, Massachusetts
IEEE Microwave Theory and Techniques Society
June 11–16, 2000

CALL FOR PAPERS

The IEEE MTT-S International Microwave Symposium 2000 (IMS2000) will be held in Boston, MA June 11–16, 2000 as the centerpiece of Microwave Week 2000. Technical papers describing original work on the advancement and application of RF & microwave theory and techniques are solicited.

Electronic Communications

Preparation for this year's meeting will rely primarily on e-mail and our Web site (www.ims2000.org) in order to make communication, submission and review more accurate, efficient and timely. Prospective authors are required to "register" electronically and are encouraged to use electronic communication for submitting papers. This process will permit us to include authors and attendees in the meeting preparation, push back submission deadlines, send faster acknowledgments and provide last-minute updates on symposium events.

Proposals Invited

Workshop, special session (focused and honorary) and panel/rump session proposals are also invited. The IMS2000 Web site (www.ims2000.org) will be used to allow participation of the MTT community in defining the workshops and special session topics. Make suggestions for topics or volunteer to help organize or participate in a workshop or special session.

Submission Process

Submit either electronic ***or*** hard copy summary, ***not*** both

For electronic submission (highly recommended),
use www.ims2000.org
Deadline: December 6, 1999
e-submissions will be acknowledged instantly.

For hard copy submission,
send three copies of paper summary to:
International Microwave Symposium 2000
c/o LRW Associates
468 Walden Trail
Waxhaw, NC 28173
Telephone: (704) 841-1915
Deadline: November 29, 1999 (receipt of paper summary and electronic author registration form)

For acknowledgment of hard copy receipt, please include self-addressed, stamped envelope or card.

Faxed or late submissions *will not* be accepted.

Submission Deadlines	*Electronic*	*Hard Copy*
Proposals for Workshops, Panel and Special Sessions	7 Sept. 1999	30 Aug. 1999
Technical Paper Summaries	6 Dec. 1999	29 Nov. 1999
Final Manuscripts for the Digest	1 March 2000	1 March 2000

Microwave Week

A microwave exhibition, an historical exhibit, the RFIC Symposium and the ARFTG Conference will also be held during Microwave Week. Joint IMS/RFIC and IMS/ARFTG sessions will continue to be held on Tuesday and Thursday, respectively, as part of the technical sessions. Papers of general and special interest for the joint IMS/RFIC and IMS/ARFTG sessions are also solicited.

For the latest information, visit the IMS2000 Web site at www.ims2000.org

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4	American Technical Ceramics	81	516-622-4700	516-622-4748	http://www.atceramics.com
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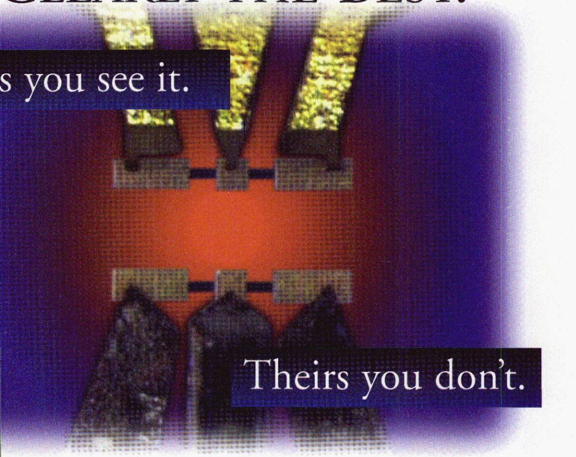

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