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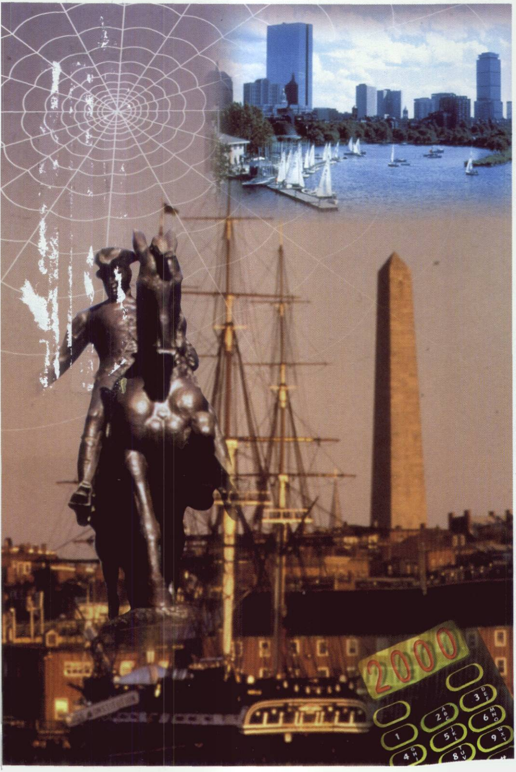

MTT-S SYMPOSIUM AND EXHIBITION

MTT-S IMS SHOW GUIDE

DC LINEAR AND NONLINEAR AC STABILITY ANALYSIS

MODULATION IMPERFECTIONS IN IS54/136 DUAL-MODE CELLULAR RADIOS

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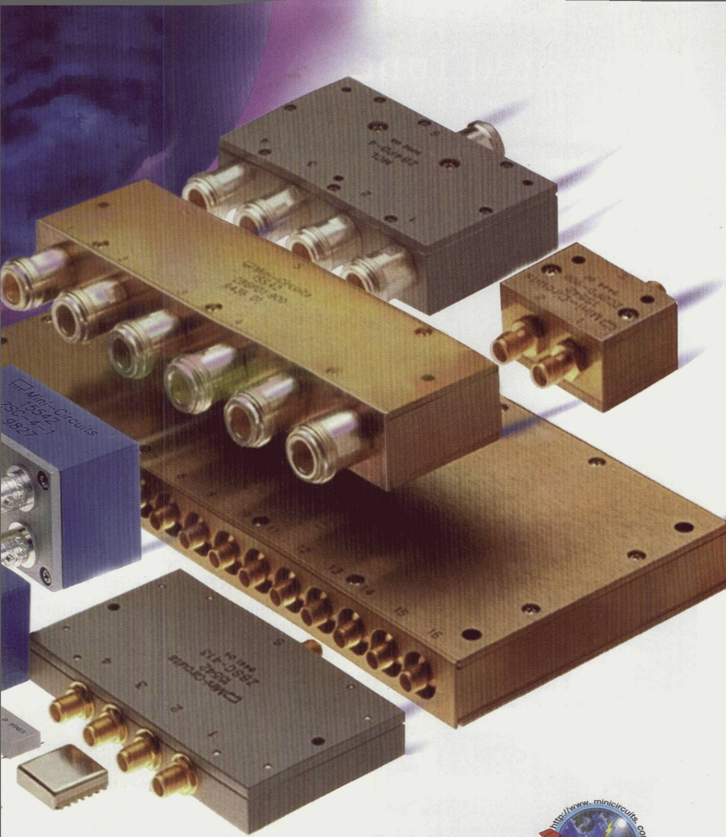
horizon house


Mini-Circuits
15542
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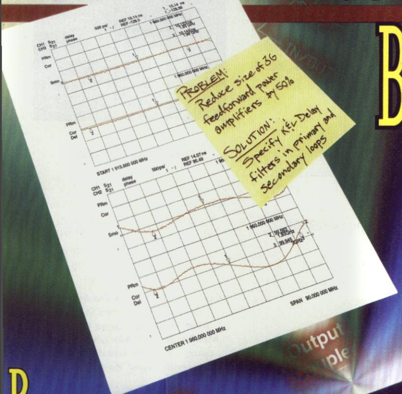
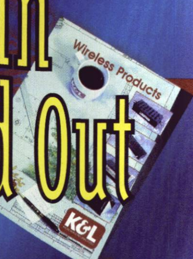
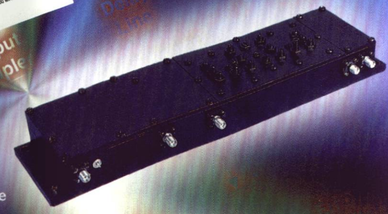
9827

3G

Design In Build Out







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2000 IEEE MTT-S International Microwave Symposium & Exhibition

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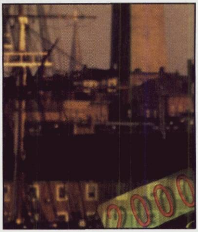

ON THE COVER

This month's cover features scenes from the historic city of Boston, site of the 2000 IEEE MTT-S International Microwave Symposium and Exhibition to be held June 11–16

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A new generation of mixers with outstanding intermodulation performance, minimum space requirements and remarkably low LO power levels

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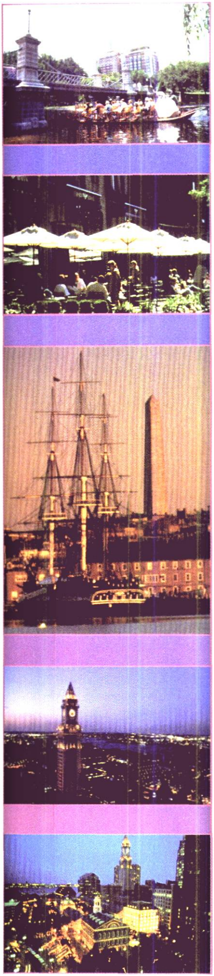

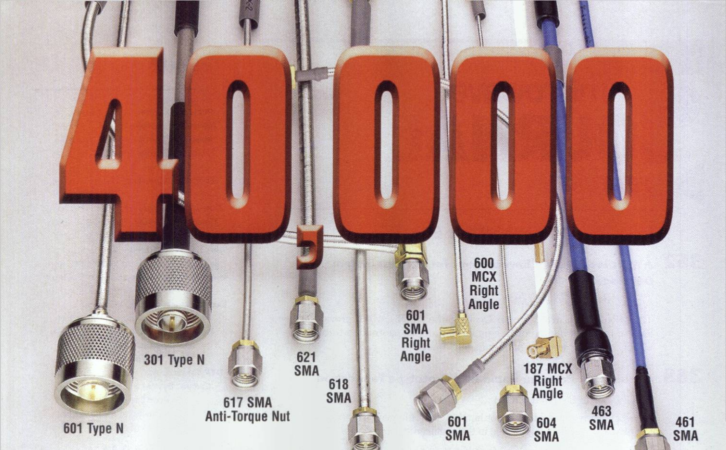

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685 Canton Street, Norwood, MA 02062
Tel: (781) 769-9750
Fax: (781) 769-5037
e-mail: mwj@mwjournal.com

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IEEE International Conference on Third-generation Wireless Communications
June 14–19, 2000
Silicon Valley, CA

Topics: Third-generation (3G) mobile communications, including CDMA and wireless Internet access and protocol, cdmaOne and cdma2000, General Packet Radio Service network planning and wireless mobile asynchronous transfer mode; resource management in Universal Mobile Telecommunications Systems; low cost mobile receivers, bit error rate analysis and joint phase-lock detection; and 3G satellite multiple accesses. Contact: Willie Lu, 1960 Linden Lane, Milpitas, CA 95035 or e-mail: wwlu@ieee.org. Additional information is available at www.3Gwireless.com.

Topical Meeting on MEMS for High Q Filters
July 17–18, 2000
University of Surrey, UK

Sponsors: IEEE UK and Republic of Ireland MTT/AP/LEO/ED Joint Chapter Administrative Committee, University of Surrey and IEEE MTT-S. Topics: High Q filter design; micromachined electromechanical systems (MEMS); application-specific ICs; MMICS; flip-chip, hybrid and multichip module boards; ultraminiature transmit/receive systems; and commercial simulation tools. Contact: Steve Marsh, Marconi Caswell Ltd. +44 (0) 1327 356 426 or e-mail: steve.marsh@ieee.org.

2000 IEEE International Symposium on Electromagnetic Compatibility
August 21–25, 2000
Washington, DC

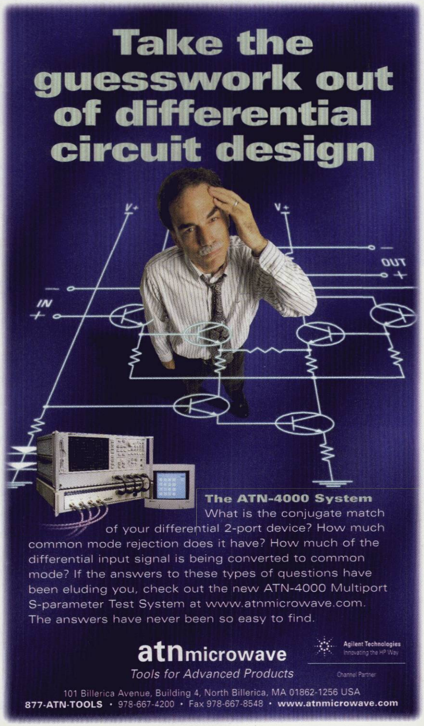
Sponsor: IEEE EMC Society. Topics: Electromagnetic compatibility management, certification and accreditation, testing, shielding and grounding, electrostatic discharge, spectrum efficiency and monitoring, product and environmental safety, international government standards, new product designs, commercial and military trends, new personnel and laboratory ideas for electromagnetic compatibility corporate management. Contact: William Duff, Computer Sciences Corp. (703) 914-8450 or e-mail: wduff@csc.com.

2000 IEEE Radio and Wireless Conference (RAWCON 2000)
September 10–13, 2000
Denver, CO

Sponsor: IEEE MTT-S. Topics: Interdisciplinary aspects of RF technology and communications system design, including system architecture and performance, antennas and propagation, active/passive devices, wireless data, smart antennas, ultrawideband systems and software radio architectures. Contact: Michael Heutmaker, Lucent Technologies (609) 639-3116, fax (609) 639-3197 or e-mail: heutmaker @lucent.com. Visit www.rawcon.org for additional conference information and updates.

Wireless Workshop
October 22–25, 2000
Sedona, AZ

Sponsors: Rogers Corp. and Merix Corp. Topics: Innovative applications and designs, design and simulation considerations and issues, software tools for design and simulation, interdependence of high frequency packaging requirements and system design, MMIC and hybrid circuits, new packaging techniques and structures, advancements in high frequency-compatible materials, materials testing and characterization, circuit fabrication challenges and innovations, interconnection and assembly considerations, system and component reliability, and high volume manufacturing. Contact: Sharon Aspden, Rogers Corp. (480) 961-8206



or e-mail: sharon.aspden@rogers-corp.com. Additional information is available at www.az-ww.com.

Connector and Interconnection Technology Symposium
October 23–25, 2000
Orlando, FL

Sponsors: International Institute of Connector and Interconnection Technology Inc. and the Electronic Components, Assemblies Equipment and Supplies Association. Topics: Radio frequency interconnection, including design/new interface style; quality; automation; surface-mount technology; automotive interconnects; space flight connector technology; medical applications; materials, finishes and plating; and test methods. Contact: Steve Ulett, Avnet, 6321 San Ignacio Ave., San Jose, CA 95119 (408) 360-4113, fax (408) 281-8722 or e-mail: steve.ulett@avnet.com.

2000 IEEE GaAs IC Symposium
November 5–8, 2000
Seattle, WA

Sponsors: IEEE, EDS, MTT and SSCS. Topics: Developments in integrated circuits using GaAs, InP and other compound semiconductor devices, including innovative RFIC device and circuit concepts, circuit design and fabrication techniques, manufacturing technology and cost issues, CAD/CAM/CAT tools and techniques, IC testing and methodology, packaging technology, reliability, advanced design applications, system applications (commercial and military), optoelectronic applications and fiber system ICs. A short course on linear power amplifiers will also be presented. Contact: Kevin Kobayashi, TRW (310) 814-1857 or e-mail: kevin.kobayashi@trw.com. Additional information is available at www.gaasic.org/.

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 communications 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 for wireless communication; antenna CAD; human interaction with antennas; MEMS for wireless communication applications; and indoor/outdoor propagation and channel models. For additional information, contact the conference office at (781) 890-5290 or e-mail: bostonieee@aol.com.

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

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

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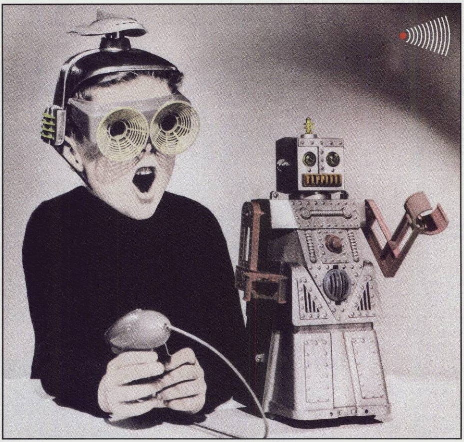


CAPABILITIES

WORKSHOPS & COURSES

3G Wireless Solutions

■ **Topics:** A complete RF chip set for wideband CDMA and Universal Mobile Telecom Systems, third-generation (3G) system requirements and system solutions, and technology road maps. (To be held in conjunction with the IEEE MTT-S International Microwave Symposium.) Fee: free.
■ **Site:** Boston, MA
■ **Dates:** June 13 and 14, 2000
■ **Contact:** Melanie Cook, RF Micro Devices (336) 931-7114, fax (336) 931-7371 or e-mail: mcook@rfmd.com.

Phased-array Radar

■ **Topics:** Principles and technology of phased-array antennas as well as overall system significance, design and performance.
■ **Sites:** Various
■ **Dates:** Various
■ **Contact:** Research Associates of Syracuse Inc. (RAS), 6780 Northern Blvd., Suite 100, East Syracuse, NY 13057 (315) 463-2266, fax (315) 463-8261 or e-mail: seminars@ras.com.

CMOS Analog Integrated Circuits

Topics: CMOS and BiCMOS analog IC design, electrical modeling, process parameter characetization and test ability considerations. Fee: $1295.
■ **Site:** Atlanta, GA
■ **Date:** August 7–11, 2000
■ **Contact:** Georgia Institute of Technology, Continuing Education, Atlanta, GA 30332 (404) 385-3502, fax (404) 894-7398 or e-mail: conted @gatech.edu.

Near-field Antenna Measurements and Microwave Holography

■ **Topics:** Near-field ranges (planar surface, cylindrical surface and spherical surface); basic theory, procedures and techniques for all three systems as well as for microwave holography; and a tour of the National Institute of Standards and Technology near-field ranges. Fee: $1495.
■ **Site:** Boulder, CO
■ **Date:** Aug. 28 - Sept. 1, 2000
■ **Contact:** Georgia Institute of Technology, Continuing Education, Atlanta, GA 30332 (404) 385-3502, fax (404) 894-7398 or e-mail: conted @gatech.edu.

Interactions between Microwave and Optics

■ **Topics:** Optical processing of microwave signals.
■ **Site:** Grenoble, France
■ **Date:** Aug. 28 - Sept. 1, 2000
■ **Contact:** OMW Secretariat, LEMO-ENSERG, 23 rue des Martyrs - BP 257, 38 016 Grenoble, France +33 4 76 85 60 13 or e-mail: OMW@ enserg.fr. Additonal information can be obtained at www.enserg.fr/ecole/ labos/lemo/.

High Efficiency Amplifiers for Wireless Communications Systems

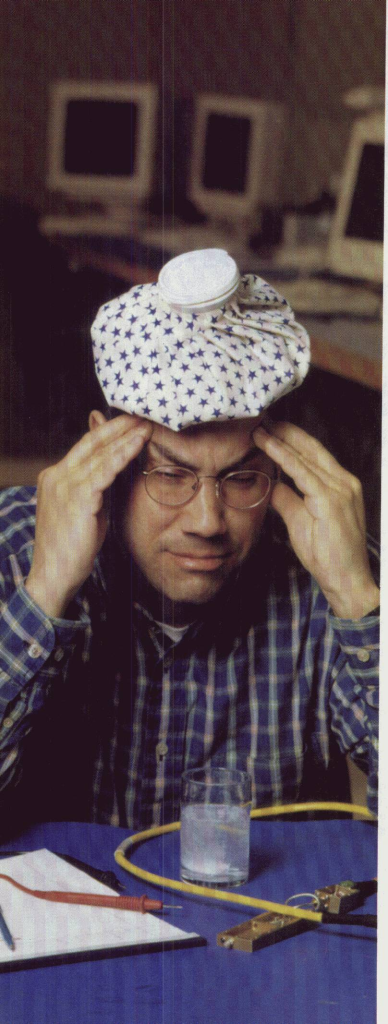
■ **Topics:** Linear power amplifier design, gain/power match, load pull and high efficiency techniques, harmonic effects, linearization and PA system issues, efficiency-enhancement techniques and design examples.
■ **Site:** Dublin, Ireland
■ **Date:** September 18–20, 2000
■ **Contact:** Continuing Education Institute (CEI)-Europe, PO Box 912, S-612 25 Finspong, Sweden +46 122 175 70 or e-mail: cei.europe@cei.se. Additional information can be obtained at www.cei.se.

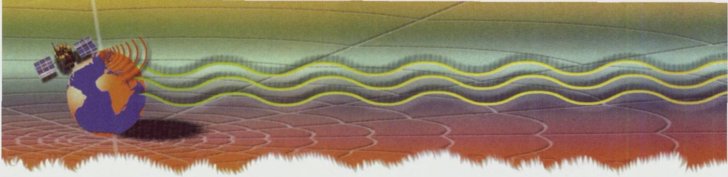
RF and Wireless Component Design Using Electromagnetic Simulation

■ **Topics:** Advantages and disadvantages of 2-D, 2.5-D and 3-D simulators; commercially available tools; circuit vs. field simulators; convergance problems; high speed circuit issues; and illustrative examples.
■ **Site:** Dublin, Ireland
■ **Date:** September 21–22, 2000
■ **Contact:** CEI-Europe, PO Box 912, S-612 25 Finspong, Sweden +46 122 175 70 or e-mail: cei.europe @cei.se. Additional information can be obtained at www.cei.se.

Self-study Radar Course

■ **Topics:** Radar principles, functions and parameters, the radar equation, target detection, tracking and track-while-scan, radar hardware, signal processing and case studies. Textbook included. Fee: $384.
■ **Contact:** IEEE Customer Service Dept., 445 Hoes Lane, PO Box 1331, Piscataway, NJ 08855 (800) 678-4333 or e-mail: customer-service@ieee.org.





WELCOME TO THE INTERNATIONAL MICROWAVE SYMPOSIUM 2000

Dr. Glenn Thoren *holds bachelors and masters degrees in applied engineering in physics and a PhD in electrical engineering (solid-state physics), all from Cornell University. He has been with Sanders, a Lockheed Martin company, since 1987 and is currently the director of intellectual property exploitation. From 1991 to 1998, Thoren was the director of strategic technology development where he designed, developed, coordinated and implemented Sanders' Strategic Technology Plan. He was also director of engineering for Sanders' Microwave Technology Center, which included the GaAs MMIC foundry. From 1987 to 1988, he managed the microwave technology department, which provided microwave subsystem, antenna, receive and component design and development for a variety of programs including the F-22 EW array program. Prior to his work at Sanders, Thoren worked at Raytheon Company for 15 years in various development and leadership roles.*

Thoren has also served as advisor to the National Science Foundation, chairman of the board of directors of the Cornell Society of Engineers and chairman of the Worcester Polytechnic Institute Liaison Committee, and has authored more than 45 technical and managerial papers and presentations. He is a frequent lecturer on technology, business planning and core competency strategy, and the co-holder and principal in four patents on solid-state power combining technology. In addition, Thoren was awarded the IEEE Professional Leadership Award and the IEEE Millennium Medal.

Boston is again extending a hearty and warm welcome to the International Microwave Symposium (IMS). We had no way of knowing, seven years ago when we proposed Boston for the year 2000, that this symposium would become such an astounding success and such a landmark event. It is likely that all previous attendance records will be broken. New records also have been set for the number of papers submitted (945) and the number of exhibitors and booths. We are literally bursting at the seams. The John B. Hynes Convention Center will host our exhibits and technical papers on all floors and even in the corridors. The Marriott and the Westin joined forces to become our co-headquarters hotels because no one hotel could contain all the additional functions. A number of additional hotels were made available because of the large, early demand for rooms. This symposium is quite an adventure.

The Boston Symposium has taken on many challenges in the past and IMS2000 is no exception. The hardcover Digest and the Open Forum began here. Now we have taken the giant step to implement the electronic submission and peer review of papers. In addition, we plan to broadcast the Plenary Session over the Web. Agilent's Byron Anderson will reveal a vision of the future wireless world and the revolution in "information mobility" as our keynote speaker.

The Technical Program Committee, led by Peter Staecker and Fred Schindler, has succeeded in its "information mobility" challenge. We have entered the new era of electronic submittals and reviews. Thanks also go to Jeff Pond, who provided the expertise and countless hours necessary to make this transition successful. Well done, gentlemen, to you and your stellar team. You will find an outstanding program of microwave, RFIC, and ARFTG papers and workshops. Please take a moment to thank the individuals who have made it all possible – they've earned it.

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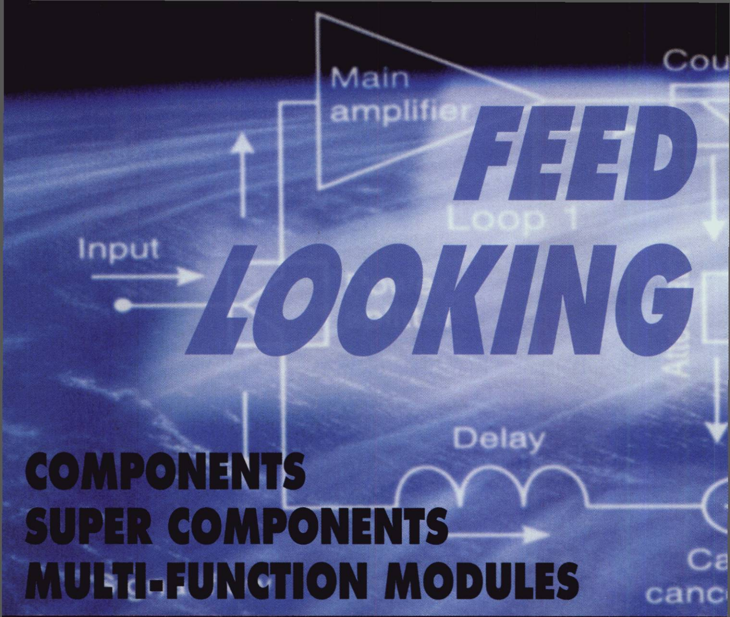
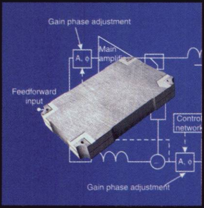
GLENN THOREN
General Chair, 2000 International Microwave Symposium



FEED LOOKING

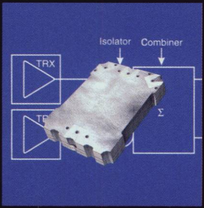
COMPONENTS
SUPER COMPONENTS
MULTI-FUNCTION MODULES

DIRECTIONAL COUPLERS



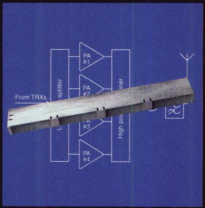
- LOW LOSS
- HIGH DIRECTIVITY
- WIDE OR NARROW BAND
- WRAP AROUND GROUND

DIVIDERS/COMBINERS



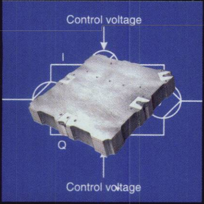
- IN PHASE DESIGNS
- 2 & 3 WAY
- LOW LOSS
- INTEGRATED RESISTORS

INLINE MULTICOUPLERS



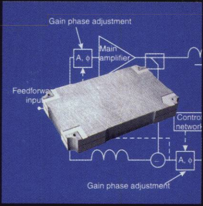
- LOW LOSS
- 3 TO 8 COUPLERS PER MODULE
- INTEGRATED COMPACT PACKAGE

VECTOR MODULATORS



- WIDE DYNAMIC RANGE
- HIGH LINEARITY
- LOW NOISE FIGURE
- FLAT RESPONSE

QUAD HYBRIDS



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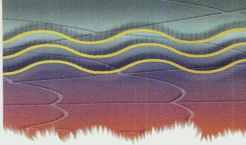


A lighthouse has been a symbol worldwide for identifying landmarks and pointing the way. We have selected a lighthouse logo to represent IMS2000 in Boston. The wave you see in the background adds to the symbolism that expresses our industry "from DC to light."

Boston is rich in history and thrives on entertaining all visitors. The guest program has been expanded with more tours each day and a "something for everyone" set of events on Tuesday night (another first). I know you and your family will enjoy your visit, so please register early for these events. I guarantee you will have fun.

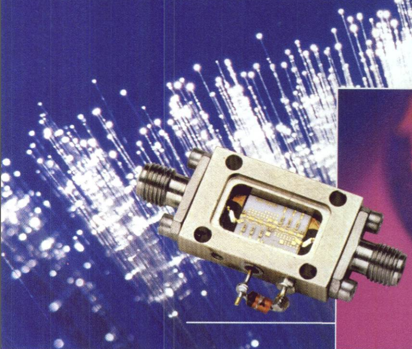
Microwave Week can be truly overwhelming. From the dozens of workshops on Sunday and Monday; to the RFIC Symposium on Monday and Tuesday; to the exhibits, tours, Plenary Session, banquet, ARFTG Conference and workshops on Friday, there will be hardly a moment to catch your breath. Plan your time well and enjoy reestablishing old friendships as well as making new acquaintances.

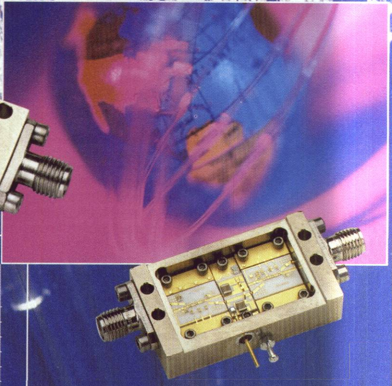
It takes a team of literally dozens of volunteers (52 in our case) working for more than five years to make this symposium work. I can describe only a few of the challenges, potholes, surprises and outright annoying things that occur. If asked, I'm sure the Steering Committee members will share the rest. But this is a labor of love for our profession, for our peers and for the legacy of those who have done so well in symposiums before us. These men and women, and their families, have worked hard and sacrificed their personal time for IMS2000. Their companies also deserve recognition for their support and encouragement. Please take a moment to thank them — again, they've earned it.

Welcome, and welcome back, to Boston for the International Microwave Symposium 2000. You are about to make history. ■

AMPLIFIERS

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





MODEL NUMBER	FREQ. RANGE GHZ	GAIN dB MIN	NOISE FIG. dB MAX	GAIN FLATNESS +/-dB	1dB COMP. PT. dB MIN	3RD ORDER ICP TYP.	VSWR IN/OUT MAX	DC CURRENT MA
JCA008-201	.01-8.0	25	*5	2.0	0	10	2.0:1	175
JCA008-202	.01-8.0	24	*5	2.0	5	15	2.0:1	200
JCA008-203	.01-8.0	22	*5	2.0	10	20	2.0:1	225
JCA008-301	.01-8.0	35	*5	2.5	0	10	2.0:1	300
JCA008-302	.01-8.0	34	*5	2.5	5	15	2.0:1	325
JCA008-303	.01-8.0	32	*5	2.5	10	20	2.0:1	350
CA0010-201	.01-10.0	24	*5	2.0	0	10	2.0:1	175
CA0010-202	.01-10.0	22	*5	2.0	5	15	2.0:1	200
CA0010-203	.01-10.0	20	*5	2.0	10	20	2.0:1	225
CA0010-301	.01-10.0	34	*5	2.5	0	10	2.0:1	300
CA0010-302	.01-10.0	32	*5	2.5	5	15	2.0:1	325
CA0010-303	.01-10.0	30	*5	2.5	10	20	2.0:1	350
CA0012-201	.01-12.0	23	*5	2.0	0	10	2.0:1	175
CA0012-202	.01-12.0	21	*5	2.0	5	15	2.0:1	200
CA0012-203	.01-12.0	20	*5	2.0	10	20	2.0:1	225
CA0012-301	.01-12.0	33	*5	2.5	0	10	2.0:1	300
CA0012-302	.01-12.0	31	*5	2.5	5	15	2.0:1	325
CA0012-303	.01-12.0	30	*5	2.5	10	20	2.0:1	350
CA0118-201	.1-18.0	22	**5	2.5	3	13	2.0:1	200
CA0118-202	.1-18.0	20	**5	2.5	5	15	2.0:1	250
CA0118-203	.1-18.0	20	**5	2.5	7	17	2.0:1	300
CA0118-301	.1-18.0	31	**5	2.5	3	13	2.0:1	250
CA0118-302	.1-18.0	29	**5	2.5	5	15	2.0:1	300
CA0118-303	.1-18.0	29	**5	2.5	7	17	2.0:1	350

* Noise Figure is specified above 300 Mhz
** Noise Figure is specified above 500 Mhz

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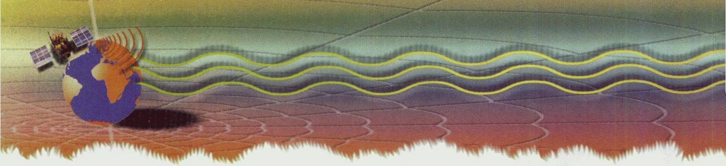


ATTENDING THE CONFERENCE

The IEEE International Microwave Symposium (IMS) and Exhibition has moved back to the East Coast this year for a stop in the historical city of Boston. Symposium attendees are virtually guaranteed an action-packed visit filled with informative technical sessions highlighted by a mind-numbing array of social events intended to familiarize them with the best that "Beantown" has to offer. Symposium activities are scheduled to begin Sunday, June 11 and continue through Friday, June 16. The Hynes Convention Center will house most of the week's activities, including all technical sessions and the industry exhibition.

During the six days that compose "Microwave Week," the latest advances in microwave technology and applications will be presented through a number of technical sessions, workshops, panel sessions and open forums. In addition, the Radio Frequency Integrated Circuits (RFIC) Symposium and the Automatic RF Techniques Group (ARFTG) Conference will again be held concurrently with the many IMS activities that are planned. A schedule of the week's events can be found on pages 34 and 35.

TRAVEL TO BOSTON

June is a very good time to fly to Boston. The crowds at Boston's Logan International Airport will be seasonally smaller as many of the college students leave town for the summer. The Massachusetts Port Authority (Massport) also operates a number of regional airports. The next closest airport with good commercial service is Manchester, NH (approximately one hour from Boston by bus). An excellent source of information on transportation to and from Logan can be found at www.massport.com/logan/getti.html. Most of the show hotels operate an airport shuttle bus/van service. Check with your hotel for courtesy service, but there is a curbside bus service that runs to all hotels for US$7.50.

Taxi stands are located in front of each airport terminal at Logan Airport. A fast-moving queue is the way to catch a cab. It is not recommended to stand in the roadways around Logan and hail a taxi independently. Fare to downtown will be approximately US$10–$15.

Driving and parking in the city of Boston can be a challenge even for the most seasoned traveler. If you must rent a car, car rental desks are located in the baggage claim areas of the airport. The hotels do have parking garages and/or valet parking service.

Walking in combination with rides on the MBTA subway (the "T") is a great way to see Boston, and many maps are available. A subway map may be obtained online at www.mbta.com. The Hynes Convention Center is located on the Green Line at the stop marked Hynes Convention Center/ICA.

[Text continued on page 39]
[Schedule of Events continued on page 34]

AMY E. NORCROSS
Microwave Journal Staff

2000 IEEE MTT-S INTERNATIONAL MICROWAVE SYMPOSIUM

SATURDAY, JUNE 10, 2000

2:00 TO 6:00 PM
Registration

SUNDAY, JUNE 11, 2000

7:00 AM TO 6:00 PM
Registration

8:00 AM TO 5:00 PM

WSA: Silicon/Silicon Germanium BiCMOS Processes and Circuit Techniques for RFICs
WSB: Efficiency & Linearity Enhancement Methods for Portable RF/MW Power Amplifiers
WSC: Microwave Filter Synthesis and Equivalent Circuit Extractions
WSD: BLUETOOTH Technology: From Concept to Implementation
WSE: Millimeter-wave Packaging: Industry Practices and Emerging Technology
WSF: An Introduction to the Theory and Practice of Numerical Electromagnetics
WSG: Spatial and Quasi-optical Power Combining Arrays
WSH: Antennas and Propagation for Wireless Communication

1:00 TO 5:00 PM

WSI: Emerging Technology for High Power (> 100 W) Power Amplifiers
WSJ: New Developments in Mixed-mode Techniques for Nonlinear Circuit Design
WSK: Micro-/Millimeter-wave Transceivers for Mass Production: Design, Technology, Implementation

7:00 TO 10:00 PM
RFIC Reception, *Colonnade*

MONDAY, JUNE 12, 2000

7:00 AM TO 5:00 PM
Registration

8:00 AM TO 5:00 PM

RFIC Symposium, *Hynes Convention Center*
WMA: RF Power Amplifiers, Classes A through S: How the Circuits Operate, How to Design Them and When to Use Each
WMB: Wavelets for EM, Device and Circuit Modeling
WMC: Applications of Artificial Neural Networks to RF and Microwave Design
WMD: Future Trends in Ferrite Devices and Technology
WME: Advances in Ceramic Interconnect Technologies for Wireless, RF and Microwave Applications
WMF: EM-based CAD of Printed Circuit Components, Waveguide Networks and Antennas: State-of-the-art and Promising Techniques for the Next Decade
WMG: Space-based Radar Microwave Links
WMH: RF Front End Architectures

8:00 AM TO 12:00 PM	12:00 TO 1:15 PM	1:00 TO 5:00 PM
WMI: Digital Receivers for Military and Commercial Applications	**PMA:** Will SiGe Step on the GaAs?	***WMJ:*** Smart Antennas ***WMK:*** Ultrawideband Systems and Applications

6:00 TO 8:00 PM
Microwave Journal/MTT-S Reception, *Marriott*

TUESDAY, JUNE 13, 2000

7:00 AM TO 5:00 PM
Registration

8:30 AM TO 5:00 PM
RFIC Symposium, *Hynes Convention Center*

9:00 AM TO 5:00 PM
IMS Exhibition

10:10 AM TO 5:00 PM
μAPS

Room 304/306	Room 302	Room 312	Room 309	Room 313
		8:00 TO 9:40 AM ***TU1A:*** Plenary Session, *Hynes Convention Center, Ballrooms A/B/C*		
10:10 TO 11:50 AM ***TU2A:*** Low Noise Technology *(Joint IMS/RFIC)*	**10:10 TO 11:50 AM** ***TU2B:*** Millimeter-wave Signal Sources	**10:10 TO 11:50 AM** ***TU2C:*** Millimeter-wave Packaging	**10:10 TO 11:50 AM** ***TU2D:*** Advanced Topics in Nonlinear CAD	**10:10 TO 11:50 AM** ***TU2E:*** Advanced Concepts in Frequency Domain Numerical Techniques
		12:00 TO 1:15 PM ***PTB:*** High Data Rate Communication RF and Microwave Education Forum, *Marriott, Salon E*		
1:20 TO 3:00 PM ***TU3A:*** Wireless Circuit Techniques *(Joint IMS/RFIC)*	**1:20 TO 3:00 PM** ***TU3B:*** MEMS Switches/Phase Shifters	**1:20 TO 3:00 PM** ***TU3C:*** Filters (1)	**1:20 TO 3:00 PM** ***TU3D:*** Monolithic and Semiconductor Technology	**1:20 TO 3:00 PM** ***TU3E:*** Advances in Time Domain Modeling
		2:30 TO 5:00 PM ***TU1F:*** Interactive Forum, *Hynes Convention Center*		
3:30 TO 5:10 PM ***TU4A:*** Integrated Transceivers *(Joint IMS/RFIC)*	**3:30 TO 5:10 PM** ***TU4B:*** *Focus Session*—Micromachining and MEMS Technology	**3:30 TO 5:10 PM** ***TU4C:*** Filters (2)	**3:30 TO 5:10 PM** ***TU4D:*** Microwave Digital Circuits	**3:30 TO 5:10 PM** ***TU4E:*** Applications of Time
		7:00 TO 9:30 PM ***Rump Session:*** Wide Bandgap Microwave Power Transistors, *Marriott*		

SCHEDULE OF EVENTS

WEDNESDAY, JUNE 14, 2000

7:00 AM TO 5:00 PM
Registration

9:00 AM TO 5:00 PM
IMS Exhibition

9:30 AM TO 5:00 PM
µAPS

Room 304/306	Room 302	Room 312	Room 309	Room 313
8:00 TO 9:40 AM *WE1A:* New Transmission Line Elements	**8:00 TO 9:40 AM** *WE1B:* Mixer Techniques	**8:00 TO 9:40 AM** *WE1C:* Superconducting Components and Technology	**8:00 TO 9:40 AM** *WE1D:* Microwave Photonics: Devices and Systems	**8:00 TO 9:40 AM** *WE1E:* X-band T/R Modules: Semiconductors, Packaging and Assembly Issues*
10:10 TO 11:50 AM *WE2A:* Advances in Microwave Signal Generation	**10:10 TO 11:50 AM** *WE2B:* Nonlinear Transistor Modeling	**10:10 TO 11:50 AM** *WE2C:* HF/VHF/UHF Power Amplifiers and Linearizers	**10:10 TO 11:50 AM** *WE2D:* Active Quasi-optics and Spatial Power Combining	**10:10 TO 11:50 AM** *WE2E:* Phased Arrays

12:00 TO 1:15 PM
PWC: RF MEMS for Tunable Applications
PWD: Devices for High Speed Fiber Optics

Room 304/306	Room 302	Room 312	Room 309	Room 313
1:20 TO 3:00 PM *WE3A:* Power Amplifiers and Handsets	**1:20 TO 3:00 PM** *WE3B:* CAD, Modeling and Optimization Technology	**1:20 TO 3:00 PM** *WE3C:* Ferrite and SAW Devices	**1:20 TO 3:00 PM** *WE3D:* Biological Effects and Medical Applications*	

2:30 TO 5:00 PM
WE1F: Interactive Forum, *Hynes Convention Center*

Room 304/306	Room 302	Room 312	Room 309	Room 313
3:30 TO 5:10 PM *WE4A:* Power Amplifier Integrated Circuits	**3:30 TO 5:10 PM** *WE4B:* CAD Modeling of Passive Components	**3:30 TO 5:10 PM** *WE4C:* Advances in Millimeter Waves and Submillimeter Waves	**3:30 TO 5:10 PM** *WE4D:* Biological Effects and Medical Applications	**3:30 TO 5:10 PM** *WE4E:* Packaging and Interconnects

6:00 TO 7:30 PM
Industry-hosted Cocktail Reception, *Westin Copley*

7:30 TO 10:00 PM
Awards Banquet, *Westin Copley*

THURSDAY, JUNE 15, 2000

7:00 AM TO 3:00 PM
Registration

9:00 AM TO 3:00 PM
IMS Exhibition

9:30 AM TO 2:20 PM
µAPS

Room 304/306	Room 302	Room 312	Room 309	Room 313
8:00 TO 9:40 AM *TH1A:* Wireless and Cellular Communications	**8:00 TO 9:40 AM** *TH1B:* Couplers	**8:00 TO 9:40 AM** *TH1C:* Broadband and High Efficiency Amplifiers and Novel Hybrid Module Techniques	**8:00 TO 9:40 AM** *TH1D: Focus Session—* Ferroelectric Devices	**8:00 TO 9:40 AM** *TH1E:* Linear Models of Active Devices
10:10 TO 11:50 AM *TH2A:* Automotive Sensors and ID Systems	**10:10 TO 11:50 AM** *TH2B:* Passive Components	**10:10 TO 11:50 AM** *TH2C:* Linear and Nonlinear Network Measurements *(Joint IMS/ARFTG)*	**10:10 TO 11:50 AM** *TH2D: Focus Session*—Power Amplifier Linearization	**10:10 TO 11:50 AM** *TH2E:* Periodic Structures and New Techniques

12:00 TO 1:15 PM
Student Awards Luncheon
PTHE: Low Cost LMDS Terminals

Room 304/306	Room 302	Room 312	Room 309	Room 313
1:20 TO 3:00 PM *TH3A:* Applied Sensor Technology*	**1:20 TO 3:00 PM** *TH3B:* Trends in Frequency Multipliers and Switches	**1:20 TO 3:00 PM** *TH3C:* Optical Probing and Millimeter-wave Measurements	**1:20 TO 3:00 PM** *TH3D:* Filters (3)	**1:20 TO 3:00 PM** *TH3E:* New Propagation Effects on CPW and Microstrip

2:30 TO 5:00 PM
TH1F: Interactive Forum, *Hynes Convention Center*

Room 304/306	Room 302	Room 312	Room 309	Room 313
3:30 TO 5:10 PM *TH4A:* Novel Microwave Systems and Components	**3:30 TO 5:10 PM** *TH4B:* Very High Power Components	**3:30 TO 5:10 PM** *TH4C:* Photonic Synthesis of Microwave Signals*	**3:30 TO 5:10 PM** *TH4D:* Filters/Multiplexers (4)	

FRIDAY, JUNE 16, 2000

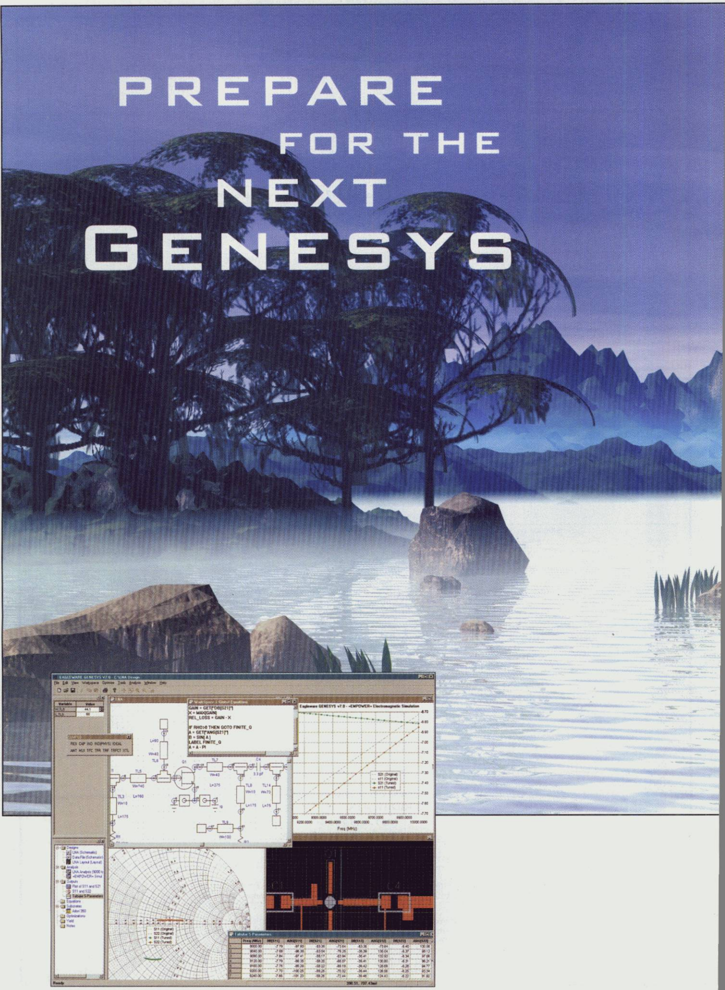
7:00 AM TO 9:00 AM
Workshop Registration

7:30 AM TO 5:30 PM
ARFTG Conference and Exhibition, *Hynes Convention Center*

8:00 AM TO 12:00 PM
WFC: Microwave Oscillators: Looking Back and Looking Forward
WFH: Printed Antenna Technology for Wireless and Satellite Communications

8:00 AM TO 5:00 PM
WFA: Integrated Transceiver Design Using Silicon-based Semiconductors
WFB: High Power Transmitter Systems and Related Subsystems for Wireless Base Stations
WFD: Microwave and Photonic Applications of MEMS
WFE: Ferroelectric Materials and Microwave Applications
WFF: Automated Circuit Optimization Using Electromagnetic Simulators
WFG: Biological Effects of EM Fields

**Special Session*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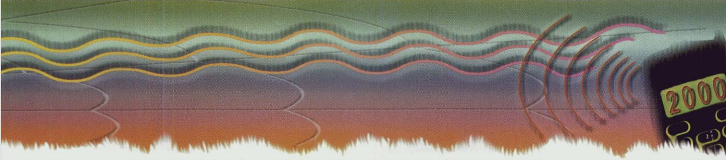
FOR THE
NEXT
GENESYS



Hotels

Blocks of rooms at several high quality hotels located within close proximity to the Hynes Convention Center have been reserved for Microwave Week attendees. The Boston Marriott Copley Place and the Westin Copley Place will serve as headquarters hotels.

Climate/Attire

Boston in June averages a high temperature of 76°F and a low temperature of 58°F. Unfortunately, humidity often detracts from the otherwise pleasant weather and will likely rear its ugly head at some point during Microwave Week.

Casual sportswear goes right along with the typically comfortable weather. Some restaurants may require a jacket and tie for dinner. Boston weather is always unpredictable, making it a good idea to bring along both shorts and slacks. Evenings will be cooler, so a sweater or light jacket should be packed.

Guest Program

Hospitality Suite

Guests of attendees are invited to visit the Hospitality Suite in the Staffordshire Room at the Westin Hotel. It will be open Sunday, Monday, Tuesday, Thursday and Friday from 7:30 AM to 4:30 PM and Wednesday from 7:30 AM to 2:30 PM. A free continental breakfast will be served in the morning and light refreshments will be available during the day. Information on Boston will be available and the concierges in each hotel are always eager to help. Knowledgeable tour guides and hosts also will be on hand to answer questions about the multitude of opportunities to enjoy Boston during your visit.

Tours

Many interesting tours have been arranged for the spouses and guests of Conference attendees. All are sold on a first-come, first-served basis, and advance registration is strongly encouraged. Choices include Exploring the Kennedy Legacy; A Walk in the Public Gardens; The Seaports of Salem and Marblehead; Relive the History of Lexington and Concord; An Early Morning Walk Along the Charles River; Newport, RI; On the Cambridge Trail; A Walk from Boylston Street to Beacon Hill; Literary Legends of the Greater Boston Area; Boston's Historic Marketplaces and North End; and Old Cape Cod. All tours depart from the lobby of the Marriott Hotel. Return times have

[Continued on page 45]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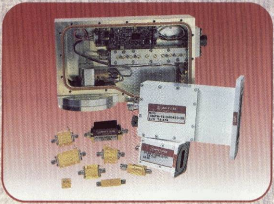
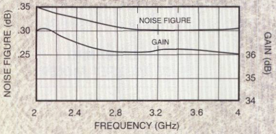
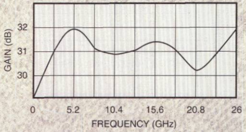


ULTRA-LOW NOISE 2 TO 4 GHz AMPLIFIER



NOISE FIGURE PERFORMANCE BASELINE	
2 to 4 GHz	**0.35 dB** noise figure
2 to 8 GHz	**0.8 dB** noise figure
6 to 18 GHz	**1.3 dB** noise figure
26 to 40 GHz	**2.5 dB** noise figure
C-band SATCOM LNA	**30 K** noise temperature
Ku-band SATCOM LNA	**65 K** noise temperature
2 to 4 GHz at 77 K ambient	**10 K** noise temperature
6 to 18 GHz at 77 K ambient	**50 K** noise temperature

100 MHz TO 26 GHz AMPLIFIER



Bandwidth Performance Baseline

2 kHz to 15 GHz for high data rate applications
2 to 40 GHz in one unit (broadband ELINT)

Output Power Performance Baseline

2 to 8 GHz	**2 watts** (at 1 dB compression)
6 to 18 GHz	**1 watt** (at 1 dB compression)
14 to 14.5 GHz (Ku-band)	**5 watts** (at 1 dB compression)

BIPOLAR AMPLIFIERS

- Frequency Range 10 kHz to 2 GHz
- Broadband **Low-Noise Amplifiers**
- Available from **Stock**

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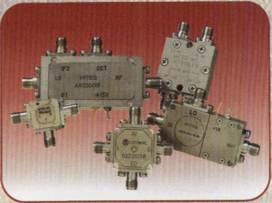
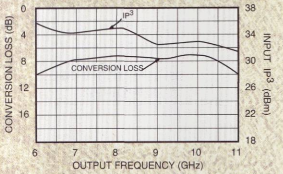
MIXERS AND FREQUENCY MULTIPLIERS TO 60 GHz

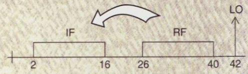
- Low Loss, Moderate to Octave Band **Balanced Mixers**
- Broadband **Double- and Triple-Balanced Mixers**
- **Image Rejection Mixers**
- **Single Sideband Modulators**
- Ultra High Dynamic Range **FET Based Mixers**
- Microwave **Phase Detectors and I/Q Mixers**
- Microwave **QAM, QPSK and Biphase Modulators**
- **Sampling Mixers** (Sampling Phase Detectors)
- Broadband Active and Passive **Multipliers**



HIGH DYNAMIC RANGE MESFET MIXER



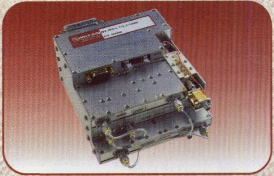
MILLIMETER-WAVE BLOCK CONVERSION



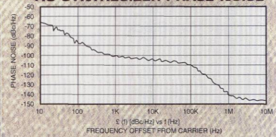
BLOCK CONVERSION MIXER TB0440LW1	
RF and LO	4 to 44 GHz
IF	0.5 to 20 GHz
Conversion loss	10.5 dB

FREQUENCY SOURCES TO 40 GHz

- **Frequency Synthesizers**
  Phase-locked loop communication band synthesizers
  Single-loop fast acquisition synthesizers
  Octave band YIG-based synthesizers
- **Free-Running and Phase-Locked VCOs**
  Cavity and coaxial resonator designs
    Fundamental to 4 GHz
    Multiplied to 40 GHz
  Octave band L-C VCOs
- **Free-Running and Phase-Locked DROs**
  Fundamental bipolar-based designs to 12 GHz
  FET designs to 25 GHz



4 TO 8 GHz YIG SYNTHESIZER PHASE NOISE



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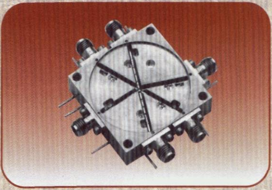
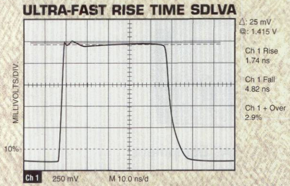
MICROWAVE CONTROL PRODUCTS TO 26 GHz

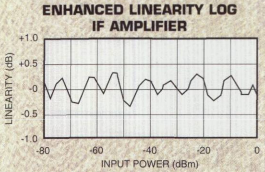
- **Pin Diode Switches,** Reflective and Nonreflective, SPST through SP7T with up to 80 dB Isolation
- **Pin Diode Attenuators,** Current Controlled 10% Bands
- **Power Dividers,** 2-Way to 16-Way Power Dividers to 26 GHz



IF SIGNAL PROCESSING COMPONENTS

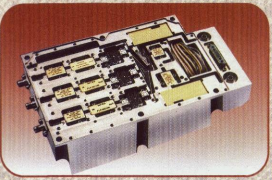
- **Logarithmic Amplifiers** to 2 GHz
- **SDLVA** and **DDLVA** High Speed Logarithmic Amplifiers to 6 GHz
- **Constant Phase Limiting IF Amplifiers** to 1200 MHz
- **Frequency Discriminators** to 2 GHz
- **Variable** and **Automatic Gain-Controlled Amplifiers**
- **AFC Processors**





INTEGRATED ASSEMBLIES AND CUSTOM-ENGINEERED EQUIPMENT

MITEQ concentrates on applying our overall corporate talents along with direct interface with the customer to solve engineering and manufacturing design problems.



- Remote Exciter Modules
- Monopulse Receivers
- SAR Exciter/Receiver Systems
- Research and Development Subsystems
- Space-Borne Components
- Three-Channel Monopulse Receiver Front Ends
- Five-Channel Phase Interferometer Receiver Systems

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been scheduled to allow for evening activities. Please bring comfortable walking shoes. Tour tickets and a complimentary guest badge will be included in the registration packets of those who have preregistered for the Symposium. The guest badge also allows access to the exhibition hall and the plenary session.

SOCIAL HIGHLIGHTS

MICROWAVE JOURNAL/MTT-S RECEPTION

All Microwave Week attendees and exhibitors are invited to attend a reception hosted by *Microwave Journal* and MTT-S on Monday, June 12 from 6:00 to 8:00 PM in the Grand Ballroom of the Marriott Copley. Beverages and hors d'oeurves will be served.

INDUSTRY-HOSTED COCKTAIL RECEPTION

Symposium exhibitors will host a cocktail reception on Wednesday, June 14 from 6:00 to 7:30 PM at the Westin Copley. Complimentary beverage tickets will be included in the registration packages.

IEEE MTT-S AWARDS BANQUET

The annual Awards Banquet will be held on Wednesday, June 14 from 7:30 to 10:00 PM in the Ballroom at the Westin Copley. Presentation of major MTT-S awards, Fellow awards and Student Paper Contest awards will be made before, during and after an elegant dinner. The banquet will feature dinner music provided by a string quartet and an after-dinner speech by Pultizer Prize-winner Doris Kearns Goodwin. Goodwin will discuss her experience writing biographies of Presidents Lyndon Johnson, John F. Kennedy and Franklin Roosevelt as well as her forthcoming biography of Abraham Lincoln. She will also touch on the process involved in writing her own memoir on growing up in the 1950s and her love of the Brooklyn Dodgers.

SPECIAL TUESDAY EVENING ACTIVITIES

As a special treat this year, several events have been scheduled for Microwave Week attendees on Tuesday evening. Transportation is included with all ticket prices. Choices include dinner at a North End eatery, a trip to see *Miss Saigon*, dinner at the Uniuon Oyster House followed by a visit to the Comedy Connection or a performance by the Boston Pops Orchestra. Reservations and ticket sales for Tuesday evening events only are being accepted by Evelyn Thoren. Confirmation and/or tickets can be mailed or picked up in the Hospitality Suite. Additional information will be available in the Hospitality Suite on Sunday, Monday and Tuesday, or contact Evelyn Thoren at (978) 256-1482 (home), fax (978) 244-9149 or e-mail: thoren@mediaone.com.

THE MTT-S IMS TECHNICAL PROGRAM

The 2000 IMS technical offerings are grouped similarly to previous years, with special sessions and workshops introducing new topics as well as providing the latest results or overviews in established areas. Highlighted topics include sensor technology and product applications; agile and novel optical synthesis of optical signals; biological effects and medical applications; X-band T/R module technology; MEMS and micromachining; amplifier linearization techniques; and ferroelectric materials, devices and components. In addition, 30 workshops will be held on Sunday, Monday and Friday of Microwave Week. These sessions offer detailed discussion in an interactive setting of current topics among nearly all of the technical disciplines encompassed by the Society. Included in this grouping are five short courses of tutorial nature: class A through S RF power amplifiers, applications of artificial neural networks to RF and microwave de-

[Continued on page 47]

sign, an introduction to the theory and practice of numerical electromagnetics, biological effects of EM fields, and antennas and propagation for wireless communication. The Interactive Forum will feature nearly 150 papers in a comfortable, informal setting on Tuesday, Wednesday and Thursday, allowing maximum discussion time between author and audience. To offer even more choices for stimulating luncheons, panel sessions have been planned for Monday, Tuesday, Wednesday (two) and Thursday to discuss topical and controversial issues in microwave design and applications. In addition, a rump session, conducted in panel format, is scheduled for Tuesday evening. These events add up to another very busy week in a delightful setting.

The Plenary Session

All Microwave Week registrants and guests are invited to attend the IMS2000 Plenary Session, which will begin at 8:00 AM on Tuesday, June 13 in Ballrooms A, B and C of the Hynes Convention Center with welcoming remarks by Symposium Chairman Glenn Thoren and MTT-S President Roger Sudbury. IEEE Award recipients will be recognized, including Class of 2000 IEEE Fellows; recipients of the IEEE Third Millennium Medals; Prof. Roger Harrington, recipient of the IEEE Electromagnetics Award; and Prof. Arthur Oliner, recipient of the IEEE Heinrich Hertz Medal. Byron J. Anderson, senior vice-president and general manager of Agilent Technologies, will present the keynote address, "Accelerating the Web-meets-Wireless Revolution." Anderson will explore the many formidable challenges caused by the convergence of the digital and wireless worlds with an insightful look into the elements driving this revolution and what "hot" technologies are available to help designers deliver on the high expectations that come with this latest wave of wireless innovation.

Student Paper Competition

The MTT-S Student Paper Competition encourages and recognizes excellence in research in microwave science and technology. One hundred and sixty-nine student papers were submitted to the competition this year. Among these submissions, 96 were accepted for presentation, and the technical program committee selected 24 semifinalists. All accepted student papers will be presented at their appropriate paper sessions. In addition, the 24 semifinalists will present their papers at the Student Paper Competition Interactive Forums on Tuesday, June 13 and Wednesday, June 14 from 3 to 5 PM.

Prizes will be awarded to the six best papers among the finalists. All student semifinalists will be given certificates and complimentary registration to IMS2000. Cash awards in the amount of $1900 have been donated by MTT-S, and additional prizes for this year's contest have been provided through generous donations from GHz Circuit Design Inc. Travel subsidies to the Symposium for all the finalists were sponsored by the National Science Foundation and MTT-S. A student awards luncheon will be held on Thursday of IMS Week during which the awards will be presented.

Exhibition

With more than 450 exhibitors (another record breaker), the 2000 exhibition promises to be a feast for the senses as companies from around the world converge on two levels in Halls A, B, C and D and Meeting Room 112 of the Hynes Convention Center to display the latest products and services available to the microwave industry. Exhibition hours are 9 AM to 5 PM on

[Continued on page 49]

Tuesday and Wednesday, June 13 and 14, and 9 AM to 3 PM on Thursday, June 15. For a list of exhibitors and booth numbers, see pages 168–174. A floor plan of the Hynes can be found on page 176.

µAPS

The Microwave Application and Product Seminars (µAPS) are technical, product-oriented sessions presented by selected IMS exhibitors. These seminars offer the latest technology for the wireless, SATCOM, military and medical markets. Six sessions will include discussions on EM simulation; nonlinear, circuit and system simulation measurements; millimeter waves and ferrites; filters, LTCC and PAs; fab, amplifiers, mixers and oscillators; and systems and subsystems. The sessions are scheduled to take place on Tuesday, June 13 from 10:10 AM to 5:00 PM, Wednesday, June 14 from 9:30 AM to 5:00 PM and Thursday, June 15 from 9:30 AM to 2:20 PM. All technical conference and exhibition attendees are welcome.

The Historical Exhibit

The Microwave Theory and Techniques Society Historical Exhibit will be located at the Hynes Convention Center. Symposium attendees are encouraged to visit the Historical Exhibit during the regular exhibition hours, Tuesday through Thursday. The Historical Exhibit includes the MTT-S library collection of books and documents with descriptions of early theoretical and experimental achievements in microwaves. A collection of historical artifacts will be on display, including electron devices from the early 1930s (klystrons, magnetrons and traveling-wave tubes), modern MMIC chips and T/R modules. There will also be scheduled showings of videotapes describing historic developments in microwaves. In addition, Professor Karl Stephan will give a historical talk entitled "Marconi and Microwaves" on Tuesday, Wednesday and Thursday at 1:30 PM in Room 310 of the Hynes Convention Center.

Historical Electronics Museum

Between symposia, the MTT-S Historical Collection has a permanent home at the Historical Electronics Museum in Linthicum, MD near the Baltimore-Washington International Airport. For more information, visit the Museum's Web site at www.erols.com/radarmus/index.html.

Awards

Microwave Career Award

The Microwave Career Award is the highest honor bestowed by MTT-S. It recognizes a career of meritorious achievement and outstanding technical contribution by an individual in the field of microwave theory and techniques. Dr. James C. Wiltse is honored in 2000 for a career of leadership, meritorious achievement, creativity and outstanding contributions in the field of microwave theory and techniques.

Distinguished Educator Award

This award was inspired by the untimely death of Prof. F.J. Rosenbaum (1937–1992), an outstanding teacher of microwave science and a dedicated Administrative Committee member and contributor. The award recognizes a distinguished educator in the field of microwave engineering and science who best exemplifies the special human qualities of Fred Rosenbaum, who considered teaching a high calling and demonstrated his dedication to the Society through tireless service. This year's recipient is Tatsuo Itoh for outstanding achievements as an educator, mentor and role model of microwave engineers and engineering students.

Microwave Pioneer Award

The Microwave Pioneer Award recognizes an individual or a team

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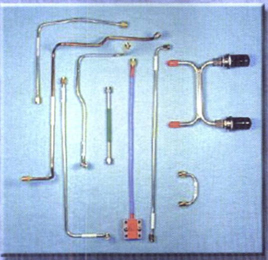

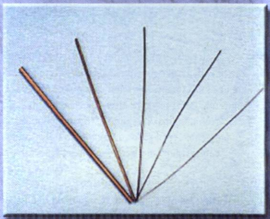

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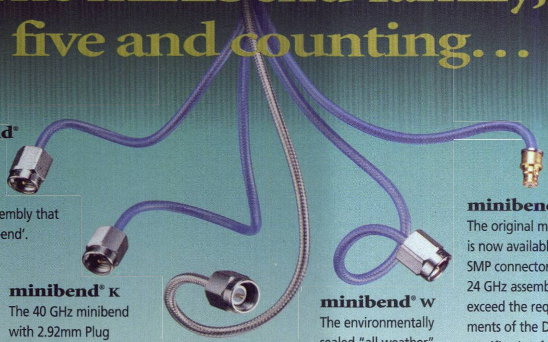

minibend®
The original True Flexible 24 GHz SMA Plug cable assembly that 'bends-to-the-end'.

minibend® K
The 40 GHz minibend with 2.92mm Plug connectors; now with extended temperature range from –55°C to +125°C.

minibend® L
The enhanced version of the original minibend for lower loss and higher phase stability with extended frequency range to 26.5 GHz.

minibend® W
The environmentally sealed "all weather" version of the original minibend with an extended frequency range to 26.5 GHz.

minibend® S
The original minibend is now available with SMP connectors; these 24 GHz assemblies exceed the requirements of the DESC specification for SMP and the interface standards of MIL-STD-348.

Astrolab's expanded line of patented minibend cable assemblies provide an excellent commercial-off-the-shelf (COTS) solution for your cable assembly needs. The minibend was designed for use in low profile, internal point-to-point interconnections between RF modules within communications systems. The minibend readily replaces custom, preformed semi-rigid cables with low cost, standard length flexible cables. Minibend has been successfully integrated in commercial, military and space applications.

The ease of installation of minibend reduces your assembly costs. Our express stock delivery program on standard lengths allows you to lower your inventory requirements. All minibend cable assemblies are 100% tested so you can be confident of their continuous performance.

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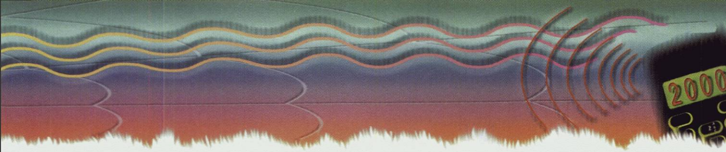


not exceeding three persons who has made outstanding pioneering technical contributions that advance microwave theory and techniques and are described in an archival paper published at least 20 years prior to the year of the award. This year's recipient is Dr. Yevgenii M. Kuleshov for development of a hollow-ribbed dielectric beamguide technology and quasi-optical measuring technique in the short-millimeter and sub-millimeter wavelength regions.

MICROWAVE APPLICATION AWARD

The Microwave Application Award recognizes an individual or team for outstanding application of microwave theory and techniques. The 2000 Microwave Application Award recipient is Dr. Arye Rosen for the application of RF/microwave techniques in medicine.

MICROWAVE PRIZE

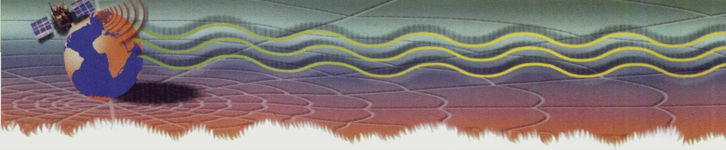
The Microwave Prize recognizes, on an annual basis, the most significant contribution by a published paper to the field of interest of the Microwave Theory and Techniques Society. Papers under consideration are those published during the period January 1 to December 31 of the year preceding the fall meeting of the Administrative Committee at which the award is considered. This year's recipients are Dr. N. Scott Barker and Professor Gabriel M. Rebeiz for a significant contribution to the field of endeavor of the IEEE MTT Society in the paper entitled "Distributed MEMS True-Time Delay Phase Shifters and Wide-Band Switches," *IEEE Transactions on Microwave Theory and Techniques*, MTT-46, pp. 1881-1890 (1998).

DISTINGUISHED SERVICE AWARD

The Distinguished Service Award recognizes an individual who has given outstanding service for the benefit and advancement of the Microwave Theory and Techniques Society. This year's recipient is Professor Eikichi Yamashita for outstanding and dedicated service to the Society.

IEEE HEINRICH HERTZ MEDAL

The IEEE Heinrich Hertz Medal was first awarded in 1989, and may be presented annually to an individual for outstanding contributions to electromagnetic waves. The award consists of a gold medal, a bronze replica, a certificate and an honorarium of $10,000. The 2000 IEEE Heinrich Hertz Medal is awarded to Arthur A. Oliner for many outstanding contributions to the theory of



guided waves and antennas, with emphasis on the fundamentals and applications of leaky waves.

IEEE Electromagnetics Award

The IEEE Electromagnetics Award was established in 1996, and is presented to an individual for outstanding contributions to electromagnetics in the areas of theory, application or education. The Award consists of a bronze medal, certificate and cash prize. This year's recipient is Professor Roger F. Harrington for pioneering the application of the method of moments to computational electromagnetics, and contributions to electromagnetics education.

Fellows

The grade of Fellow is conferred in recognition of unusual and outstanding professional distinction. It is awarded at the initiative of the IEEE Board of Directors following a rigorous nomination and evaluation process. Individuals receiving this distinction have demonstrated extraordinary contributions to one or more fields of electrical engineering, electronics, computer engineering and related sciences. This grade is not conferred automatically on nomination; only a fraction of those nominated are selected. Fifteen MTT-S members who were evaluated by the Society were elected to the grade of Fellow, effective January 1, including Werner Bächtold, Elliott Rowe Brown, Attilio Jose Giarola, Allen Katz, Chandra M. Kudsia, Lawrence Ernest Larson, Johann Friedrich Luy, Roger Bradley Marks, Vijay K. Nair, Yi-Ching Pao, James Clinton Rautio, Rainee Navin Simons, Daniel Gustav Swanson, Jr., Makoto Tsutsumi and Claude Malherbe Weil. In addition, 14 MTT-S members were elevated to the grade of Fellow by other societies, including Yahia Mohamed Moustafa Antar, Peter M. Asbeck, Andreas C. Cangellaris, Sverre T. Eng, Helmut Ermert, Hugh Duncan Griffiths, Randy L. Haupt, Lars G. Josefsson, Giuseppe Pelosi, Ronald Charles Petersen, Andrew Francis Peterson, Dale Louis Schuler, Federico Tosco and Hung Yu David Yang.

Millennium Medals

As part of its celebration of the Third Millennium, the IEEE will award 3000 IEEE Millennium Medals and certificates to individuals who have been selected by IEEE societies, sections and major boards for outstanding contributions in

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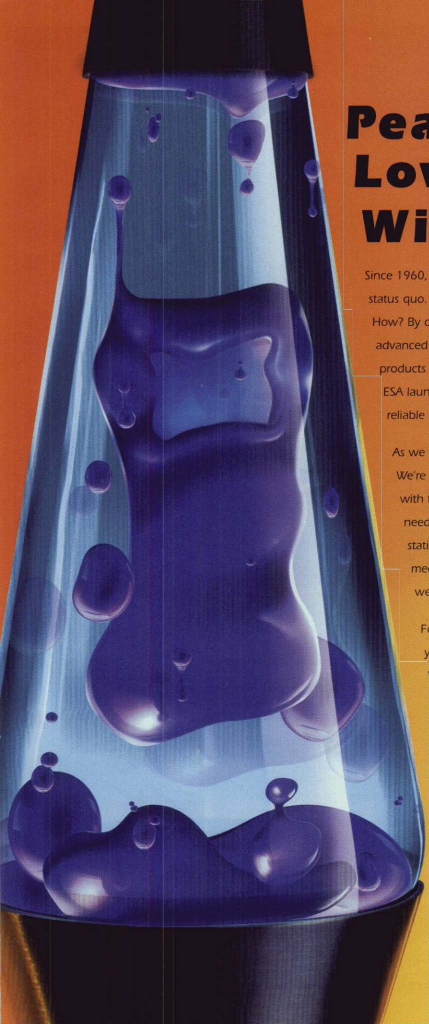
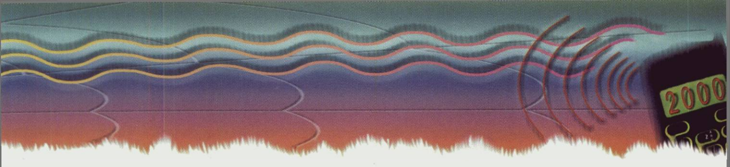



Just add
intelligence, discipline
and initiative.



their respective areas of activity. These medals will be distributed during the year 2000.

As of press time, the known list of MTT members chosen to receive Third Millennium Medals is as follows: Stephen F. Adam, Les Besser, Eliot D. Cohen, Seymour B. Cohn, E. James Crescenzi, Jr., Robert L. Eisenhart, Vladimir G. Gelnovatch, Kuldip C. Gupta, George I. Haddad, Peter R. Herczfeld, John B. Horton, Harlan Howe, Jr.,* Tatsuo Itoh, Rolf H. Jansen, Reynold S. Kagiwada, Linda P. B. Katehi, Reinhard H. Knerr, H. John Kuno, Ralph Levy, George L. Matthaei, James W. Mink, Edward C. Niehenke, Arthur A. Oliner, H. George Oltman, Jr., John Osepchuk,* Don Parker, Roger D. Pollard, Robert A. Pucel, Arye Rosen, David B. Rutledge, Martin V. Schneider, Harold Sobol, Roberto Sorrentino, Barry E. Spielman, Peter W. Staecker, Glenn R. Thoren,* Kiyo Tomiyasu,** Robert J. Trew, Theodore S. Saad,* Richard A. Sparks* and Leo Young** (*Evaluated by the Boston Section, **Evaluated by Board of Directors, No Mark: Evaluated by the MTT Society).

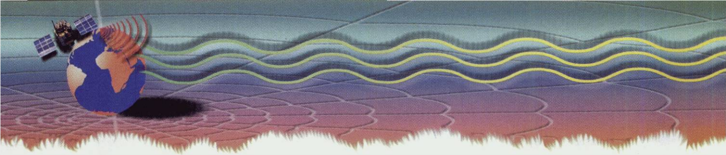
Other Technical Presentations

The RFIC Symposium

The Radio Frequency Integrated Circuits (RFIC) has established itself as a leading symposium dedicated to the advancement of monolithic ICs and subsystems for RF, microwave and millimeter-wave applications. Technical activities include two workshops on Sunday. Technical sessions will take place on Monday and Tuesday. Monday will also include a lunchtime panel session, which will address the advantages and disadvantages of both SiGe and GaAs in high frequency applications. The Symposium will be kicked off with an invited session on future wireless communications technologies and broadband wired and wireless data communications. This year's symposium also offers a special invited session focused on several new "Cutting Edge RFICs."

The ARFTG Conference

The Automatic RF Techniques Group (ARFTG) will hold its 55th conference at the Hynes Convention Center on Friday, June 16. This year's conference will explore new methodologies in large-signal techniques with the theme "Going Beyond S-Parameters." The papers selected deal with calibration of large-signal measurement systems, measurement of large-signal behavior, definition of large-signal network parameters, cre-



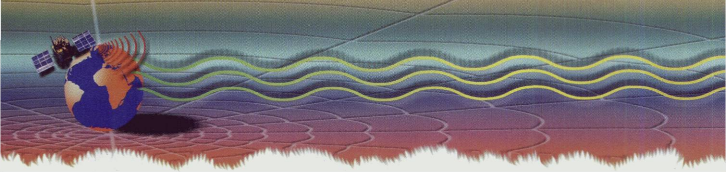
ation of large-signal models and simulation of high frequency, large-signal behavior. In addition to the Friday conference, registrants are invited to attend the ARFTG/MTT joint session on optical probing and millimeter-wave measurements to be held Thursday, June 15.

General Information

- Pamphlets and information on the Boston area will be available at a booth centrally located in the Main Lobby on the Plaza Level of the Hynes Convention Center. Representatives of the Boston Convention & Visitors Bureau will man the booth.
- An IEEE/MTT-S membership booth will be located in the registration area. Those who apply for membership on site will be eligible for the discounted member rates on registration fees. IEEE members (or on-site applicants) who register for the full Symposium and have not been MTT-S members in the past year will be offered a free one-year basic MTT-S membership good until the end of the year, which will include admission to the MTT-S members' breakfasts.
- Free coffee and soft drinks will be available during mid-morning and mid-afternoon breaks in the refreshment areas in the exhibition hall. Bottled water will be available in the Ballroom Reception area at the University booths.
- Smoking is not permitted in the Hynes Convention Center.
- Recording of technical presentations by video or audio recorders or cameras is not allowed without the permission of the speaker and notification of the session organizer.

Boston and Beyond

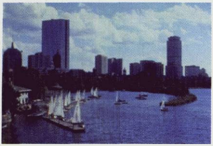
A far cry from the sunny Southern California setting of the 1999 IMS, Boston certainly holds its own in terms of history, culture and food. In addition, it's simply a fun city. For ideas on what to do and where to eat while in town, take a look at "Boston: Where It All Began" on page 60. That article also contains a list of Web sites that may prove helpful for obtaining information on any topic that we may have managed to neglect. Keep in mind Boston's close proximity to an endless array of attractions in the New England area should you be planning an extended stay before or after the Symposium. Once again, we look forward to seeing you in Boston! ■



BOSTON: WHERE IT ALL BEGAN

When it comes to American history and culture, Boston, the birthplace of American independence, is where it all began. From Paul Revere's House to the Boston Tea Party Ship to the Old North Church, history can be found on every corner. Today, Boston offers a mix of Old World charm and modern culture. From the observation deck atop a sleek skyscraper, you can look down on the charming colonial buildings situated along the gas-lit cobblestone streets that compose Beacon Hill. Minutes later you can wander through Faneuil Hall, where American colonists debated the abuses of British rule, then plow through the crowds thronging the renovated Quincy Market, one of Boston's favorite gathering places.

Boston is known as "America's Walking City." From the Hynes Convention Center, home of this year's IEEE MTT-S Symposium, you can reach on foot most of the major hotels and a tremendous assortment of restaurants and nightclubs, as well as galleries, museums and theaters. Walk down to the Public Gardens and check out the famous Swan Boats, or stroll along the Charles River Esplanade, a two-mile stretch of paths and parks that includes the Hatch Memorial Shell, site of summer Boston Pops concerts. For a truly unique adventure, follow the winding red line of the Freedom Trail, which traces the birth and early turbulent history of our nation over the course of two and a half miles and 16 historic sights.



Boston has also been referred to as the "Hub of the Universe" by its residents. While this statement may be considered a bit bold, Boston does serve as a hub to the six New England states, each with natural beauties of its own worth bragging about. The inviting beaches of Rhode Island and Cape Cod, the rugged coast of Maine or the Green Mountains of Vermont are all within an easy drive of Boston. If you're thinking of extending your visit to include some vacation time, New England in June is a great place to enjoy.

Don't forget about the Red Sox! While the team is out of town during most of the week of the show (playing the hated New York Yankees), they return to town on Friday, June 16. Fenway Park, site of home games, is a cultural experience in itself, and the Red Sox are expected to finally break the "Curse of the Bambino" this season and win the World Series. (We can always hope!)

We are especially proud to be hosting this year's show in the great state of Massachusetts, home to your *Microwave Journal*. Short descriptions of the numerous neighborhoods that compose the city as well as a sampling of restaurants and entertainment ideas for your visit have been provided on the following pages. If you have any specific questions, please e-mail us at mwj@mwjournal.com. We look forward to seeing you in Boston.

NEIGHBORHOODS

BACK BAY

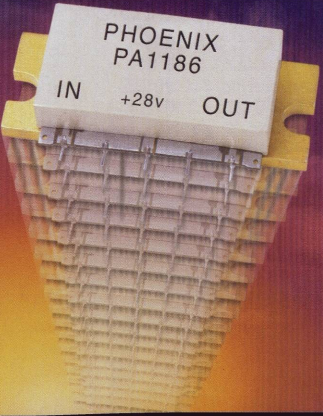
In the 19th century, this area encompassed a massive landfill project with the objective of filling in the bay, leveling the hills and shaping the city. Once the project was completed, the area soon became populated with elegant brownstone row houses and other stunning architectural structures such as the Boston Public Library and Trinity Church, which can still be seen today. Newbury Street, with its specialty shops and street-level cafes, is the East Coast version

[Text continued on page 64]
[Map continued on page 62]

ALLISON GRECO, CARL SHEFFRES AND MICHELLE DAVID
Microwave Journal *Staff*

Introducing High Power Linear Power Amplifier Modules

NEW!
+28volt single supply GaAs FET rugged modules



6 Watt Wireless Linear Power Amplifiers

Typical performance @ +25° C

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

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

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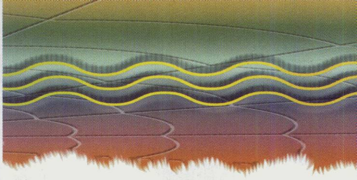
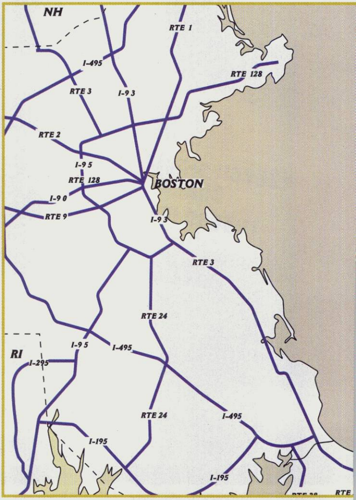
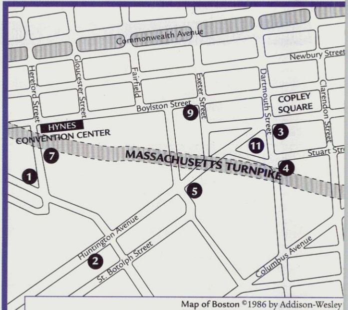
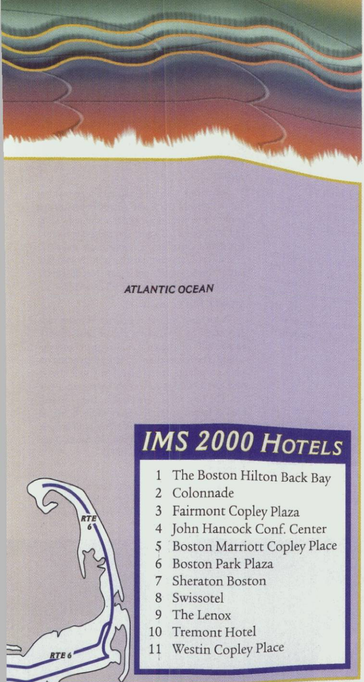




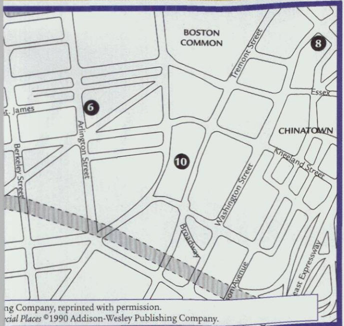


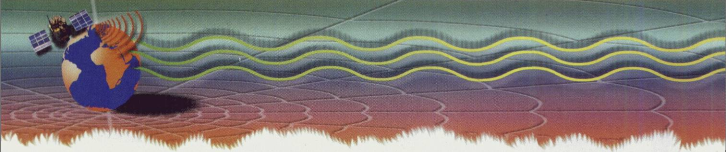
Map of Boston ©1986 by Addison-Wesley
From the book *UNCOMMON BOSTON: A Guide to Hidden Spac*



IMS 2000 Hotels

1. The Boston Hilton Back Bay
2. Colonnade
3. Fairmont Copley Plaza
4. John Hancock Conf. Center
5. Boston Marriott Copley Place
6. Boston Park Plaza
7. Sheraton Boston
8. Swissotel
9. The Lenox
10. Tremont Hotel
11. Westin Copley Place





of Rodeo Drive. The Prudential Center, Copley Place and the Hancock Tower embody the more modern side of the Back Bay.

Beacon Hill

Possibly the best known area of Boston, Beacon Hill is one of the few remaining hills in the city. Early in the 19th century, Charles Bulfinch, a federal-era architect, designed the State House and its gold leaf dome, which was the predecessor to the Capitol in Washington, DC. With its gas lampposts, cobblestone walkways and antique shops, Beacon Hill is an attractive neighborhood to explore on foot.

Cambridge

Actually a separate town from Boston, Cambridge is located just across the Charles River and serves as home to Harvard University, the famous Harvard Square and Massachusetts Institute of Technology. This spunky and off-beat but charming neighborhood offers something for everyone: theaters, museums, shopping, historic sites and fine dining.

North End

The North End is Boston's "Little Italy." Here you will find numerous bakeries with tasty treats, quaint cafes and cozy Italian restaurants. You will also find some of the historic remains of Revolutionary Boston such as the Paul Revere House (the oldest house in Boston) and the Old North Church. A stone's throw away is Faneuil Hall, where you can eat and shop some more. Many of the Freedom Trail's stops can be found in the North End.

South Boston

Home to a predominantly Irish population, South Boston extends east toward the harbor. The world's only Computer Museum is located here as well as the Boston Children's Museum. Visit A Street to take in the many art galleries and exclusive lofts that hundreds of artists helped to create from old, abandoned warehouses.

Restaurants

Abe & Louie's

Traditional steak house atmosphere. A la carte menu features any steak imaginable with a variety of seafood, complemented by a full bar and wine list, mouth-watering appetizers, salads, side dishes and desserts. Reservations are highly recommended as there is a wait for walk-ins nightly. Located close to the main hotels and the Hynes, it's a good place to take customers. Always a solid meal. Prices: range from $17.50 to 42.95 for an entrée. 793 Boylston Street (617) 536-6300.

Anago

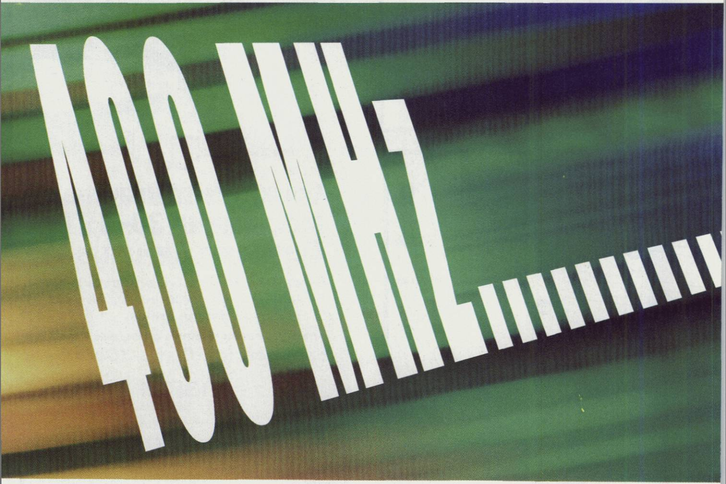
American. The husband-and-wife team of Susan Finegold and Bob Calderone operates in a grand venue with open kitchen, vaulted ceiling and provocative red walls. Try the lobster thermidor, grilled angus with foie gras sauce and a trio of soufflés for dessert. Sunday brunch with jazz buffet. Prices: moderate/expensive. 65 Exeter Street (in The Lenox Hotel) (617) 266-6222.

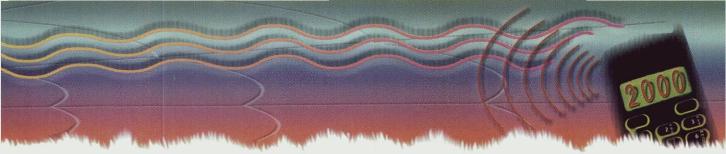
Atlantic Fish Company

Point your bow at this seafood restaurant decorated to look like a classic cruiser with barrel-vault ceilings and mahogany cherry detailing. The menu changes daily, depending on what's available at the pier, but you'll always find award-winning clam chowder and a raw bar. The best food here is plain fish: broiled, fried or baked. It's fresh and carefully prepared in the best Yankee, no-frills style. Excellent strawberry daiquiris. 761 Boylston Street (near Fairfield Street) (617) 267-4000.

Aujourd 'hui

This award-winning restaurant located in the Four Seasons Hotel offers one of the city's best views of the Public Gardens and one of





the most professional and refined wait staffs anywhere. A change of chefs has resulted in spotty reviews, but traditionally the food has been superb. Features include an outstanding visiting chefs series worth checking out. Try the iced tea. Prices: expensive. 200 Boylston Street (near Charles Street) (617) 451-1392.

Bay Tower

Ranked among the Top 100 restaurants in the US by Restaurants & Institutions. Ranked among the Top 40 restaurants in Boston by Zagat. Rated Three-stars "Excellent" by Mobil. French-fushion cuisine. Located on the 33rd floor adjacent to Faneuil Hall with breathtaking views of Boston Harbor. Prices: expensive. 60 State Street (617) 723-1666.

Back Bay Brewing Company

Downstairs are a small bar and seating for 40, while upstairs reveals a clubby room. The two floors have separate menus and reservation policies: The first floor offers sandwiches, salads, appetizers and no reservations; the second floor accepts reservations and offers grilled rare tuna, sirloin steak and smoked pork chops with collard greens. The five or so microbrews are usually excellent. Prices: moderate. 755 Boylston Street (near Exeter Street) (617) 424-8300.

Boodle's Restaurant

Located in the Back Bay Hilton, this steak and seafood emporium aims to please the hungry masses with plentiful portions and free-flowing beer. Boodle's serves approximately 90 different microbrews. Biweekly beer dinners and monthly brewers' dinners feature different beers matched with each course – and reasonable prices to boot. The cuisine lives up to as many Boston stereotypes as possible: baked beans, chowdah, etc. Prices: moderate. 40 Dalton Street (617) 266-3537.

Bull & Finch Pub (Cheers)

Visit the Bull & Finch Pub, the inspiration for the setting of the TV series *Cheers*. The pub offers a mouthwatering selection of traditional pub fare and an abundant beverage selection, which features award-winning Bloody Marys and a variety of draft beers. The Retail Gallery offers an assortment of officially licensed *Cheers* merchandise. Hours: 11 AM–2 AM. Food served until 11:30 PM. Prices: moderate. 84 Beacon Street (near the Public Gardens) (617) 227-9605.

Cactus Club

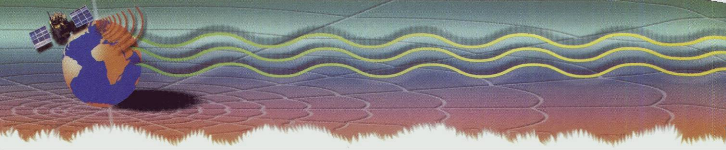
A stuffed buffalo and other gaudy Southwestern knickknacks dominate this lively yuppie hangout. Oddly enough, it's the atmosphere, not the cuisine, that attracts most customers. The venison stew is popular, and the chicken chimichanga is made with fresh, whole chicken breast. A good place for unwinding and people watching after the show. Prices: moderate. 939 Boylston Street (near the Hynes) (617) 236-0200.

Capital Grille

A classic upscale steak house, Capital is popular for its serious approach to red meat, good wine and all the visual and culinary accouterments. Ounce for ounce, the restaurant offers steak at a good value, but huge portions mean big tickets. The bar is a favorite watering hole for high end Back Bay professionals. Try the Stoli Doli. The cigar smoke and deep dark wood give the restaurant the ambiance of a men's club. Prices: expensive. 359 Newbury Street (near Mass. Ave.) (617) 262-8900.

Ciao Bella

Named for an Italian come-on line (Hey, beautiful!), this "yupscale" Northern Italian eatery serves capellini a la Newbury Street; that is, with bold flavors and chic-er than thou attitude. The veal chop, delicate pasta and wine selection all earn high praise. The atmos-



phere is romantic, polished and refined. Great location and nice outside patio. Prices: expensive. 240 Newbury Street (near Fairfield Street) (617) 536-2626.

Clios

French/American cuisine. Creamy taupe walls, white wood, a carpet of leopard spots and luxurious private space between tables make Clios the place to go for special occasions. Chef Ken Oringer paints plates with chilled Concord grape soup, roast baby goat and broiled hamachi. The cheese course changes weekly. Prices: expensive. 370A Commonwealth Avenue (Eliot Hotel) (617) 536-7200.

Cottonwood Cafe

The Cottonwood is an upscale restaurant offering both fine dining and casual menus. The cuisine is indigenous to the Southwest, using open-grill preparation for all meats, poultry and seafood. Highlights of the bar include award-winning margaritas. Semi-private and private dining spaces are available as well as a three-season patio. 222 Berkeley Street (617) 247-2225.

Davio's

Italian cuisine. Figure skater Nancy Kerrigan thought the food was good enough to have her rehearsal dinner here. The food – like grilled squid and chick pea crespelle or rabbit ravioli – is excellent and the atmosphere is smart but casual. Dine out front on the patio for great people watching. Located close to the Hynes Convention Center, Davio's is a good place to take clients for lunch during the show. 269 Newbury Street (617) 262-4810.

The Dining Room – Ritz Carleton

French cuisine. Venetian crystal chandeliers, cobalt-blue appointments and a view of the Public Gardens make dining here an occasion. Escargots, fresh Dover sole, native roasted duck in cassis, lobster with whiskey sauce and soufflé desserts are featured menu items. If you're looking to impress someone, this is your place. Jackets required. Prices: expensive. 15 Arlington Street (617) 536-5700.

Du Barry Restaurant

French cuisine. Excellent Chateaubriand, pate du chef and wine selection combined with a pleasant and warm atmosphere make for a great dining experience. Prices: expensive. 159 Newbury Street (near Dartmouth Street) (617) 262-2445.

Evoo

This restaurant will require a short car or cab ride, but is well worth the trip. The name is the acronym for extra virgin olive oil and features tea-smoked sea scallops (tremendous), baked halibut, Maine salmon and an over-the-top entrée called Duck, Duck, Goose. A small, unassuming restaurant with excellent service. One of our favorites. 118 Beacon Street, Somerville (617) 661-3866.

Grill 23 & Bar

American cuisine. A grand steak house on a grand scale located in the former Salada Tea building. Features include drinks, the usual carnivore accouterments, cilantro-crusted tuna, cedar-planked Maine salmon, rack of lamb and, of course, steak. Prices: expensive. 161 Berkeley Street (617) 542-2255.

Hamersley's Bistro

Chef Gordon Hamersley is highly regarded for his American-influenced country French fare. He and his sous chefs wear baseball caps in the open kitchen, taking the edge off any formality that might be felt in the beautifully appointed, light-filled dining room. A favorite of ours for special occasions. The food is superb, and the service is great. 553 Tremont Street (617) 423-2700.

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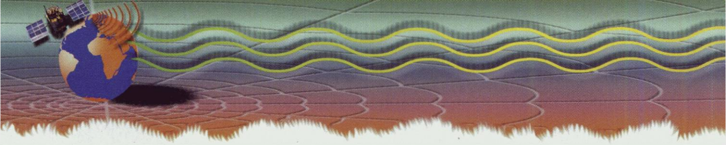

HARD ROCK CAFE

American cuisine. The Boston outpost of the famed restaurant-rock 'n' roll emporium and gift shop follows the same basic formula as all of the others – loud music and big plates of classic American food. Giant burgers, chicken wings, chili, onion rings and such compete with videos and memorabilia, including many with Boston flavor from the likes of Aerosmith, Extreme and Boston. Prices: inexpensive. 131 Clarendon Street (617) 424-7625.

JACOB WIRTH RESTAURANT

German cuisine. At Boston's oldest German restaurant, the bar still feels egalitarian and inviting while the dining room is Old World charming. The food is a return to the past, too: beer-steamed sausages, sauerbraten and Wiener schnitzel. Prices: moderate. 31 Stuart Street (617) 338-8586

JOE'S AMERICAN BAR & GRILL

American cuisine. A Back Bay staple on two levels: The busy bar and patio downstairs cater to the quick-bite burger crowd, while the mahogany paneling and hunt prints upstairs play off the Dartmouth Street address. 279 Dartmouth Street (617) 536-4200.

JULIEN RESTAURANT

In the luxurious Le Meridien Hotel, enjoy the wonderful flavors of French cuisine from a seasonal menu created by Executive Chef Mark Sapienza. Try mustard-rubbed roast rack of lamb with spatzele, niáoise olives and vegetable ragout. Enjoy cocktails and appetizers in the Julien Lounge. Prices: expensive. Open for lunch Tuesday through Friday, noon–2 PM; dinner Monday through Saturday, 6–10 PM. 250 Franklin Street (617) 451-1900.

LEGAL SEA FOODS

A mainstay of New England diners and a 40-year Boston tradition. More than 30 varieties of fish served daily (broiled, baked, fried, steamed or raw), as well as fish chowder and spicy steamed mussels. Still as good as its reputation. Prices: moderate. Several locations, including 100 Huntington Avenue (617) 266-7775 and 800 Boylston Street (in the Prudential Center) (617) 266-6800.

L'ESPALIER

French cuisine. Housed in a beautiful brownstone and featuring prix fixe nine-course meals (excellent lamb, rabbit and lobster), this French restaurant is synonymous with elegance and romance. Just about as expensive as it is special, L'Espalier is considered by many to be Boston's best French restaurant. Prices: expensive. 30 Gloucester Street (617) 262-3023.

LOCKE-OBER COMPANY

American cuisine. For 125 years this venerable restaurant has entertained a wide variety of personalities in its elegant Edwardian surroundings. The cuisine is traditional American and Continental and the service is exemplary. Locke-Ober is able to provide private dining rooms for 2–200. Prices: expensive. Lunch served Monday through Friday; dinner served Monday through Saturday; closed Sunday. 3 Winter Place (617) 542-1340.

MISTRAL RESTAURANT

Inspired by the wind that sweeps through the South of France, Mistral will captivate you with its air of refreshment. The design of acclaimed chef/owner Jamie Mammano's South End restaurant is both elegant and informal, resonating with the ambiance of Province. All of the traditional materials, such as stucco, iron, aged wood and stone, are visible throughout this grand space. Arched, floor-to-ceiling windows encircle the room, drenching

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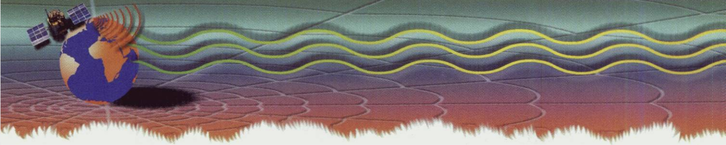

it with warmth and light. Mistral features a crisp linen dining room as well as a casual lounge and bar. Prices: expensive. 223 Columbus Avenue (617) 867-9300.

The Oak Room

American cuisine. Sumptuous, formal surroundings of tapestry-covered chairs, crystal chandeliers, mahogany-trimmed mirrors and heavy curtains. A leisurely place to enjoy modern interpretations of grilled favorites like tenderloin of beef, New York strip steak, fresh salmon and halibut. Try the martinis. Prices: expensive. 138 St. James Avenue (Fairmont Copley Plaza) (617) 267-5300.

Palm Restaurant

Specialty: steak. Everything is big: banquettes, ceilings, portions. Local celebrities can be found on the restaurant's walls of fame and often in person. Prices: expensive. 200 Dartmouth Street (617) 867-9292.

Papa Razzi

Italian cuisine. This small Northern Italian chain boasts flavorful pasta dishes, unusual appetizers and an atmosphere that makes for festive dining. Lunch or dinner, the place is usually full, but tables turn fast and the hosts deliver ETAs with precision. Prices: moderate. 271 Dartmouth Street (617) 536-9200.

Rattlesnake Bar and Grill

Southwestern cuisine. Boston's young and beautiful gravitate toward this Boylston Street establishment. The Rattlesnake offers reasonably priced Mexican/Southwestern food with genuine flair. Generous portions, the Urban Cowboy patio and an attractive bar keep the crowds coming. Prices: moderate. 384 Boylston Street (near Arlington/Berkley Streets) (617) 859-8555.

Samuel Adams Brew House

Located in the Lenox Hotel. Features 12 varieties of draught beers, a full-service bar and an all-American menu. Open daily, 11 AM to 2 AM. 710 Boylston Street (617) 536-2739.

Santarpio's Pizza

Italian cuisine. We had to include this one. A great stop on the way to or from Logan Airport for the best pizza in town. Order some barbeque (lamb or sausage) and a pizza. Lefty will take care of you. Prices: inexpensive. 111 Chelsea Street (617) 567-9871.

Skipjack's

These seafood specialists are known for consistency at all four of their locations. They offer a variety of fresh traditional seafood dishes as well as a few seasonal delicacies. Try any of the dishes cooked "Skipjack's style." The jambalaya and salmon au poivre are also excellent. Great bread to boot. Prices: moderate. 199 Clarendon Street (617) 536-3500.

Sonsie Restaurant

Eclectic. Called the place to "see and be seen" by *Boston* Magazine, Sonsie has a reading salon, 50-foot mahogany bar, brick oven and beautiful, colorful dining room. Award-winning Chef Bill Poirier's multinational menu includes skillet roast mussels and herb-grilled swordfish with lobster potato tortellini in brodetto. The café in front allows for excellent people watching on Newbury Street. Prices: expensive. 327 Newbury Street (near Hereford Street) (617) 351-2500.

Tapeo Restaurant & Tapas Bar

Spanish cuisine. The menu features tapas, paella and Iberian fish and lamb platters. The bar is laden with garlic braids and dried peppers. Prices: moderate. 268 Newbury Street (617) 267-4799.

Top of the Hub

American cuisine. Located atop the landmark Prudential Center, Boston's Top of the Hub Restaurant combines an unrivaled view of the city with superior New American cuisine, distinctive presentation and romantic ambiance. Top of the Hub's elegant lounge features a midnight gourmet menu and live jazz. This restaurant is popular with residents and visitors alike. Prices: expensive. 800 Boylston Street (617) 536-1775.

Turner Fisheries

An award-winning seafood restaurant located at the corner of Dartmouth and Stuart Streets, Turner's was recently named Boston's Best Raw Bar and also features Hall of Fame Clam Chowder. The cuisine is inspiring; the décor is rich and welcoming; the experience is

Helpful Web Sites

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www.bostonphoenix.com

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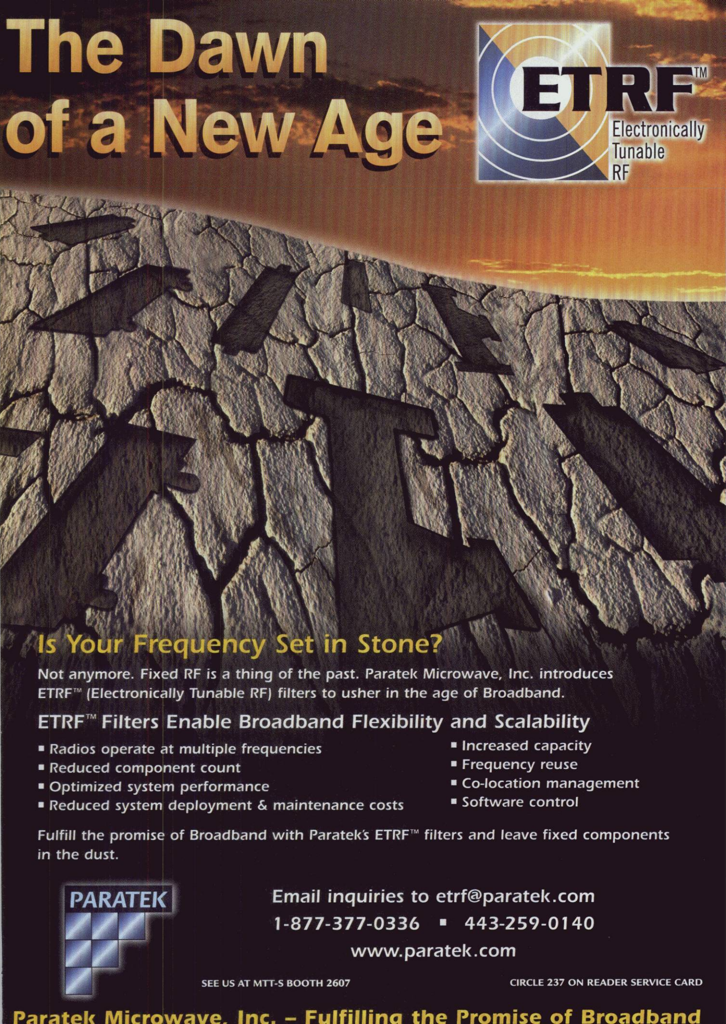

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unforgettable. The restaurant is open for lunch and dinner daily and features an extravagant Sunday brunch. Turner's lounge features live jazz Thursday through Sunday from 8:30 PM to 12:30 AM. There is no cover charge. 10 Huntington Avenue (617) 424-7425.

Union Oyster House

It's been around forever (since 1826), but its charm is genuine and a seat at the raw bar is a group experience. Prices: moderate. 41 Union Street (617) 227-2750.

Nightlife

Avalon

Located across from Fenway Park on the popular Lansdowne Street, Avalon brings the big city club experience to Boston. Bars and a lot of lights surround this stylish nightclub with a large dance floor and stage, making for one of the hottest club experiences in Boston. Avalon hosts International Night on Thursday, national-name DJs on Friday, progressive house music on Saturday and the area's largest gay club on Sunday. Avalon also offers many big-name rock and alternative concerts. Hours: Thursday through Sunday until 2 AM. 15 Lansdowne Street (617) 262-2424.

Back Bay Brewing Company

This brew pub offers award-winning, hand-crafted beers and an innovative menu by one of Boston's hottest chefs. Voted *Boston* Magazine's Best Brew Pub in 1997, 1998 and 1999, Back Bay Brewing Company has an upstairs bar, dinning room and lounge area and a downstairs bar and café. Hours: Monday through Saturday from 11:30 AM; serving dinner until 11 PM Monday through Wednesday and until 12 AM Thursday through Saturday. Sunday brunch from 11 AM–3 PM. 755 Boylston Street (617) 424-8300.

The Big Easy

Located in the Alley in Boston's Back Bay, this New Orleans-style club features two floors of fun. Downstairs has two bars and a large dance floor with a stage. Upstairs includes a wraparound balcony that overlooks the dance floor, a billiards room, two bars and lounges with couches and tables. This dance club features local bands and DJs who spin a mix of top-40 dance hits, house and hip-hop. Hours: Thursday through Saturday, 9 PM–2 AM. 1 Boylston Place (617) 351-7000.

Bill's Bar & Lounge

This tribute to deceased rock stars including Elvis Presley and Jimi Hendrix features an atmosphere of black-and-white portraits and newspaper obituaries mixed with good music. Wednesday features live bands and DJs, Thursday is Swing Night with a live band and dance instructions, Friday and Saturday offer local personalities from Boston's WBCN radio station, and Sunday is Reggae Night. Hours: Monday through Saturday, 9 PM–2 AM; Sunday, 10 PM–2 AM. Cover charge varies from $4 to $6. 5 Lansdowne Street (617) 421-9678.

Black Rose

Located next to Faneuil Hall, this Irish pub gets its name from an allegorical reference to Ireland. The Black Rose offers an Irish atmosphere with green walls, Gaelic murals and Ireland county flags hanging from the ceiling. Live Irish music and a mix of Irish and American food are what you will find at this pub with two floors. Hours: daily from 11:30 AM–2 AM. 160 State Street (617) 742-2286.

Boodle's Bar

Located in the Hilton Boston Back Bay Hotel, Boodle's Bar was named the Best Hotel Beer Bar in the US. Boodle's offers a wide selection of microbrews of the world with more than 45 selections, including weekly specials. A lite fare menu is available until midnight. 40 Dalton Street (617) 266-3537.

The Cactus Club

Located on Boylston Street, The Cactus Club has been voted the place to find the Best Margaritas in Boston. This Tex-Mex bar and restaurant offers a unique atmosphere with skulls mounted on the walls, paintings and a stuffed buffalo with smoke-puffing nostrils. A casual environment and some of the best fajitas and margaritas make for a good night out. Hours: daily until 2 AM. 939 Boylston Street (617) 236-0200.

Champions Sports Bar

This casual sports bar located in the Copley Place Marriott features 22 television screens and two 10-foot screens along with sports memorabilia from the New England Patriots and Boston Bruins. The fun atmosphere is enhanced on the weekends with a DJ. Hours: Sunday through Thursday, 11:30 AM–12 AM; Friday and Saturday, 11:30 AM–1 AM. 110 Huntington Avenue (617) 578-0658.

Cigar Masters

The first cigar cafe in Boston, Cigar Masters offers more than 500 types of cigars, a complete line of accessories, cigar tasting, a wide selection of wines and ports, and worldwide shipping. Hours: Monday through Saturday, 11 AM–12 AM; Sunday, 12 PM–11 PM. Proper dress is required after 7 PM. 176 Newbury Street (617) 266-4400.

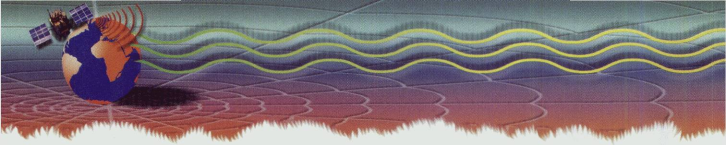
Comedy Connection

Located on the second floor of the Quincy Market building in Faneuil Hall, the Comedy Connection hosts many nationally known and local comedians as well as R-rated hypnotists. This large club has no bad seats and serves appetizers and drinks. Reserved seating is available. Hours: open daily, show times vary. 245 Quincy Market Building (617) 248-9700.

Daisy Buchanan's

This watering hole offers a break from the upscale atmosphere on Newbury Street and features pub-style food and dance music. Usually an after-work crowd populates this typical sports bar with tables in the back and a bar at the front. Hours: daily, 11:30 AM–2 AM. 240 Newbury Street (617) 247-8516.

[Continued on page 74]



House of Blues

The multiple-award-winning original House of Blues opened its doors in November 1992. This tribute to the Mississippi Delta region surrounds its guests with the sights and sounds of the Southern culture. Live music is presented nightly and a critically acclaimed menu features American cuisine. The House of Blues also can be considered a living museum with more than 200 pieces of original artwork by some of the South's most innovative artists. Hours: daily for lunch and dinner as well as three seatings for a Southern-style buffet and show known as "Gospel Brunch." 96 Winthrop Street, Cambridge (617) 491-2583.

Jake Ivory's

Offering a slightly different scene than that of the rest of the clubs on Lansdowne Street, this dueling piano bar engages its crowd in high energy sing-alongs to the sounds of such artists as Jimmy Buffet and Billy Joel. At the back of the club, two pianists face each other and play while the wild crowd calls out requests. Two matching pianists up on a stage and tropical murals on the walls give Jake Ivory's the unique atmosphere that goes along with the experience. Hours: Thursday through Saturday, 7:30 PM–2 AM. 1 Lansdowne Street (617) 247-1222.

Jillian's

Located behind Fenway Park, Jillian's is three floors of entertainment and fun. On the first floor walk into Atlas Bar & Grill, which pumps the latest in top-40 dance music mixed with some techno. With two large bars, tables and booths, televisions, five pool tables and a spacious dance floor amidst lights and a giant video wall, Atlas is a casual and hip dance club with staircase access to the second floor. On the second floor enter the world of video games, with 250 new and classic video games, from multiple-player racing games to 3-D fighting games. Jillian's also features virtual reality games amongst its art deco bar and lounge area. From there you can venture to the third floor where you will find 52 billiard tables, black jack tables, darts and foosball. The bar and lounge offer socializing and relaxing. Hours: daily until 2 AM. 145 Ipswich Street (617) 437-0300.

The Oak Bar

This upscale bar located inside the Fairmont Copley Plaza Hotel features a nostalgic late-1920s feel with cigar boxes, high ceiling, oak-paneled walls and live jazz music. More than 32 variations of a martini and a number of single malt scotches are offered. If you are looking for a wide selection of coffee drinks, this is also the place to go – an entire page of the menu is dedicated to these warm beverages. Proper dress is required. Hours: daily, 5 PM–1 AM. 138 St. James Street (617) 267-5300.

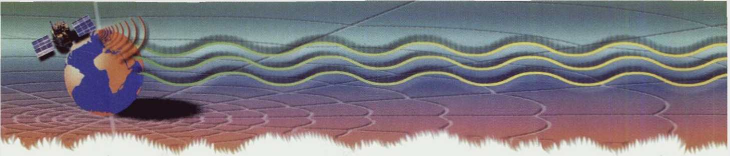
Punch Bar

Located on the second floor of the Sheraton Hotel & Tower, this British-influenced bar and lounge offers cigars, personal humidors, scotch and imported beers. You can enjoy your cigar or cocktail at the circular bar or while sitting on any of the comfortable leather chairs and couches clustered together. Surrounded by walls covered in vintage tobacco ads, the Punch Bar's atmosphere is dim and cozy. 39 Dalton Street (617) 236-2000.

The Rack

Located next to Faneuil Hall, this upscale bar and billiards club features 22 Brunswick Gold Crown tables, live music seven nights a week, an 80-foot black marble and onyx bar, and outdoor dining with a view of Faneuil Hall. Winner of the *Improper Bostonian*'s Boston's Best award as well as *Boston* Magazine's Best of Boston award, The Rack is one of the hottest bars for atmosphere, entertain-

[Continued on page 76]



ment and décor. Lunch, dinner and late-night fare are served from 11:30 AM–1 AM. 24 Clinton Street (617) 725-1051.

THE ROXY

Located in Boston's theatre district in the Tremont Hotel's old Grand Ballroom, The Roxy is one of the largest clubs in Boston. Offering champagne, this elegant multilevel club has marble walls, an upstairs VIP bar, a 1200-square-foot dance floor and an elevated stage. The music varies with the night – Thursday offers Latin music, Friday is international and house music, and Saturday is top-40 dance, house and club classics. Proper dress is required. Hours: Thursday, 10 PM–2 AM; Friday, 10:30 PM–2 AM; and Saturday, 10 PM–2 AM. Cover charge: Thursday, $10; Friday and Saturday, $15. 279 Tremont Street (617) 338-7699.

RYLES

Located in Inman Square, Ryles offers live jazz, blues and world-beat music in its two-level establishment. Booking well-known as well as local musicians, the street-level floor has a larger stage. Downstairs has just enough space for an intimate evening of food, drinks and music. If you get there early enough (before the dance floor begins to shake), swing and salsa dance lessons are provided prior to the bands' performances. Hours: Tuesday through Thursday and Sunday, 8:30 PM–1 AM; Friday and Saturday, 8:30 PM–2 AM. 212 Hampshire Street, Cambridge (617) 876-9330.

SCULLERS JAZZ CLUB

Located on the second floor of the Double Tree Guest Suites Hotel in Boston, Scullers is an upscale, classy club with live jazz most nights. Its small tables, wood-paneled walls and great acoustics make this jazz club one of the best in Boston according to *Boston* Magazine and the *Improper Bostonian*. Scullers offers some of the best jazz players from the young lions to the respected veterans as well as a beautiful view of the Charles River. Show times vary. 400 Soldiers Field Road (617) 562-4111.

SUNSET GRILLE & TAP

Located in Allston, the Sunset Grille & Tap was voted *Boston* Magazine's Bar with the Best Beer Selection in Boston. With more than 400 microbrews and 112 beers on tap, the Sunset Grille's motto is "Beer isn't just for breakfast anymore." This colorful bar has many neon beer signs and coasters as well as license plates from all over the country decorating the walls. Dinner and appetizers are served until 1 AM and there is a free midnight buffet Sunday through Tuesday. 130 Brighton Avenue, Allston (617) 254-1331.

ATTRACTIONS

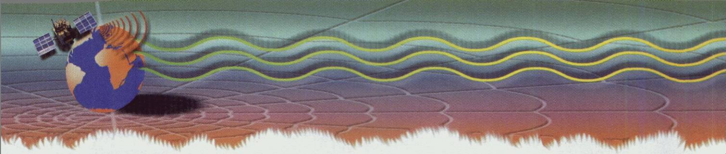
DUCK TOURS

Take a tour through Boston in a renovated World World II tank/boat. The tour begins at the Prudential Center on the Boylston Avenue side and then journeys through the Back Bay, Beacon Hill, downtown Boston and the North End. When your tour guide turns off the street and onto the Charles River, you will be treated to a unique view of the city. Tours begin every half hour daily until an hour before sunset and last approximately 80 minutes. Price: $19 (adults). 790 Boylston Street (617) 723-3825.

FANUEIL HALL MARKETPLACE

A shopping and restaurant complex built around three long market buildings where visitors can find bargains with the outdoor vendors or shop at more well-known establishments such as The Gap and Abercrombie & Fitch. Dine quietly in one of the many restaurants or browse through the long food court and then eat either indoors or outside where

[Continued on page 78]



street performers often can be seen entertaining the crowd. 3 Faneuil Hall Market Place (617) 523-1300.

FREEDOM TRAIL

This footpath measures two and a half miles and includes 16 historic sights. The self-guided tour begins at the Boston Common Visitor Center at State and Washington Streets, where you can pick up a map of the trail. Follow the painted red line through the city and take in some of the following sights: the State House and Archives, King's Chapel and Burying Ground, the Boston Tea Party Ship and Museum, the Bunker Hill Monument, Boston Common, the Boston Massacre Site, Faneuil Hall and the Paul Revere House. 15 State Street (617) 242-5642.

HARVARD SQUARE

This town center is a melting pot of American culture from body-pierced skateboarders to street musicians to college professors. Here you will find bookstores, coffee houses, restaurants and specialty shops. Cambridge Center, T-stop: Harvard Square.

NEW ENGLAND AQUARIUM

Home to jellyfish, sea turtles and the recently welcomed blue penguins. You can view these sea creatures as well as feed the stingrays. Also of interest is the show, *Georges Bank*, which raises awareness of life in Georges Bank and some of the damage brought upon it. Hours: Monday through Friday, 9 AM–5 PM; Saturday and Sunday, 9 AM–6 PM. Price: $12.50 (adults).

PRUDENTIAL CENTER

Connected to the Hynes Convention Center, this shopping mall is home to several well-known stores, including Ann Taylor, Saks Fifth Avenue, The Body Shop and the original Levi's Store. Grab a snack at the food court and venture up to the 50th floor for a breathtaking view of the city or dine elegantly on the 52nd floor at Top of the Hub. An information booth is located on the main floor for any of your tourist questions. 800 Boylston Street (617) 267-1002.

PUBLIC GARDENS

America's first botanical garden, this 24-acre area offers a peaceful setting amidst the surroundings of the fast-paced city. The garden features hundreds of beautiful flowers and several types of greenery as well as a charming stone and iron bridge covering a man-made pond where you can float along with the ducks during a ride on Boston's famous Swan Boats. Also located in this garden are several monuments such as the statue of George Washington seated on a horse and the eight ducks from the famous children's book *Make Way for Ducklings*. Across the street is Boston Common, the oldest public park in the United States. Both parks are closed from 10 PM until dawn. Charles Street (617) 635-7383.

RED SOX AT FENWAY PARK

See a game in the oldest and smallest ballpark in the major leagues. Fenway Park is home to the persevering Red Sox baseball team, which hasn't won the World Series since 1918 – maybe this will be their year. The weekend starting June 16 the Red Sox will host the Toronto Blue Jays in a three-game series. Purchase tickets on your way to the game at the box office in front of the park. Tickets start at $14. 4 Yawkey Way (617) 267-1700. ■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Serious Microwave Firepower.
Let's face it – technology waits for no one. Your alliance with strong microwave suppliers today will be critical to your success tomorrow. Through strategic acquisitions, and focused research and development, the Herley Microwave Products Group continues to meet the expanding requirements of large EW system integrators. But don't let our prominence in the defense/aerospace arena be misleading. We've proven ourselves in the global commercial marketplace too. Click on www.herleympg.com and learn more about our growing arsenal of components, MFAs, and subsystems.
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Technology with a Personal Touch

There's no doubt about it. We're living in an era of merger mania, "bigger-is-better" and global networks.

But while giant corporations seem to be taking over the earth, it's possible to find companies that believe in doing business the old-fashioned way.

Companies like Mesa Microwave.

Our Customers: The Reason For Our Success

We're family run and proud of it. And while some might find it unfashionable, we've spent the last 30 years putting our customers first. Whatever their service needs, we handle each order personally.

In addition to our work as custom fabricator of waveguide subsystems, Mesa Microwave can provide system testing as well as maintenance for almost any radar system.

Quality is a given. We know how to work within a budget and understand the need for timely delivery.

We also can build to print and deal in custom fabrication.

Simply put, we believe in giving our customers the kind of service we would want for ourselves. Each and every order is handled personally "one-to-one."

From Design Through Manufacturing, You Can Be Assured Of Quality Every Step Of The Way

Everyone at Mesa Microwave subscribes to a simple concept: excellence. We all work together to make sure that every order is produced, on time, with the desired quality at the budgeted cost.

Our philosophy has always been a simple one: everyone in the line organization, from the production manager to the first-level supervisor, needs to work with our employees, raw materials and machinery to produce the highest quality products on time and on budget.

This philosophy has paid off in products that offer our customers consistent quality and reliability.

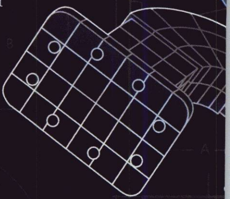
No Mesa Microwave product leaves our premises without meticulous mechanical electrical test conducted by our quality control experts.

Quality Work At Competitive Prices Equals Satisfied Customers

The equation is a simple one. You don't stay in business for well over 30 years unless you're doing the kind of work that people both want and respect. At Mesa Microwave, we've satisfied many customers, including the following:

- Hughes
- ITT
- Milcom Systems Corporation
- Raytheon
- Lockheed Martin
- U.S. Military

We can do the same for you and we would welcome assisting you with any present or future projects.

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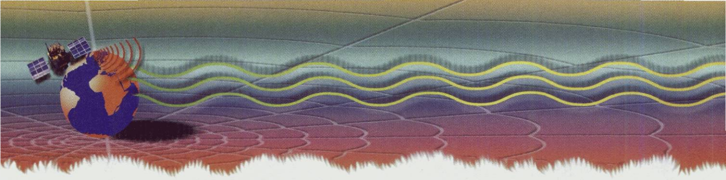


2000 IEEE MTT-S IMS EXHIBITION GUIDE

The following exhibitors are recognized for their sponsorship of the complimentary beverage services in the exhibition hall during the 2000 MTT-S International Microwave Symposium and Exhibition:

ANSOFT CORP. – BOOTH 2005
4 Station Square, Suite 200
Pittsburgh, PA 15219
Sponsor of the services on
Tuesday morning, June 13
Wednesday morning, June 14
Thursday morning, June 15

GILBERT ENGINEERING – BOOTH 1408
5310 W. Camelback Rd.
Glendale, AZ 85301
Sponsor of the service on
Tuesday afternoon, June 13

ANRITSU COMPANY – BOOTH 2125
490 Jarvis Dr.
Morgan Hill, CA 95037
Sponsor of the service on
Wednesday afternoon, June 14

Following are product and service descriptions received from exhibitors who responded to a call for information prior to the March 3 deadline. Each entry also contains a category listing of products offered by that company. For a complete list of exhibitors and booth numbers, see pages 168–174.

A-Alpha Waveguide Co. 3011
El Segundo, CA

J. Joseph, R. Coronati

Manufacturer of high quality rigid standard and thin wall precision waveguide tubing. Employing a cold drawing progress for defense aerospace and telecommunications. Immense warehouse stocks ensure very fast delivery.

Waveguide and Waveguide Components

Accumet Engineering Corporation 220
Hudson, MA

H. Muffoletto

Diced, lapped and polished ceramic, BeO, Silica, AlN and other dielectric substrates for the entire microelectronic industry.

Materials

ACE Technology 525
Chatsworth, CA

D. Sung, J. Berry, D. An, D. Chun

Amplifiers, Antennas/Radomes, Connectors/Cables/Adapters, Couplers, Filters, Isolators/Circulators, Power Dividers, Systems and Subsystems

Advanced Control Components Inc. 339
Eatontown, NJ

T. Couse

Amplifier detectors and switch matrices will be featured.

Amplifiers, Attenuators, Phase Shifters, Signal Processing Components, Switches

Advanced Noise Technologies 1125
New Cumberland, PA

P. Bates

Specialized noise measurement and noise calibration equipment and systems will be featured.

Systems and Subsystems, Test and Manufacturing

Advanced Switch Technology 133
Kingston, Ontario, Canada

G. Cappelli, M. Cappelli, P. Cappelli

Advanced Switch Technology is dedicated to the design and fabrication of microwave and coaxial switches operated by a device called the Quadrant Driver. The Quadrant Driver is a new and patented invention that, through the use of a high magnetic density magnet and two coils, operates the rotor of the switch.

Switches

Advanced Technology Group Inc. 1020
Rockaway, NJ

F. Hanus, E. Maier, L.Y. Tao, R. Jonassen

Featured products include glass to metal seal packages including but not limited to flatpacks, dual inline headers, TO style headers, machined housings, multimetal packages and custom packages.

Hybrids, Optoelectronic Components/Fiber Optics, Oscillators, SAW Devices

Advance Reproductions Corp. 316
N. Andover, MA

C. Losanno, S. Alaimo, M. Crowley

Photomasking services on glass with chrome, iron oxide or emulsion and mylar. Photomask sizes range from 2-1/2″ up to 24″ × 24″.

Services

Aeroflex Circuit Technology 1809
Plainview, NY

S. Cantor

Aeroflex Circuit Technology is a manufacturer of advanced microelectronic multichip modules (MCM) for airborne, space, shipboard, ground-based and commercial avionics.

Amplifiers, Hybrids, Power Supplies

Aeroflex Comstron 1809
Plainview, NY

T. Ursprung

Aeroflex Comstron is a world leader in the design, development and manufacture of wideband fast-switching measurement systems, including fast-switching frequency synthesizers, phase noise instrumentation and RCS measurement equipment.

Filters, Hybrids, Isolators/Circulators, Synthesizers

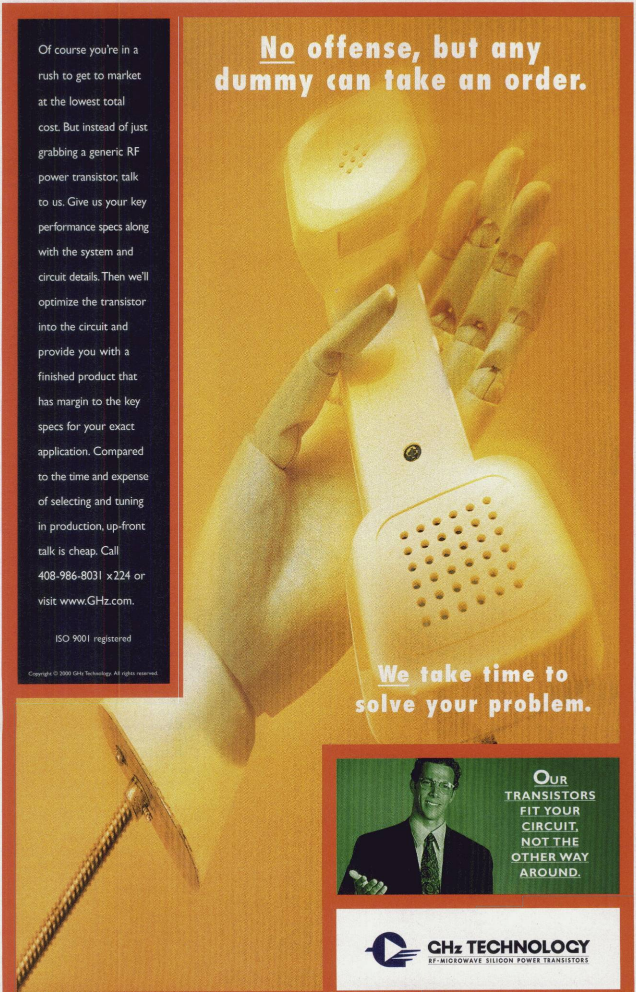
Aeroflex Lintek 1809
Powell, OH

J. Berlekamp

Aeroflex Lintek provides microwave virtual instruments for satellite payload, T/R module and radio test solutions. Benefits include unrivaled throughput speed and system flexibility.

Test and Manufacturing Equipment

[Continued on page 84]



No offense, but any dummy can take an order.
Of course you're in a rush to get to market at the lowest total cost. But instead of just grabbing a generic RF power transistor, talk to us. Give us your key performance specs along with the system and circuit details. Then we'll optimize the transistor into the circuit and provide you with a finished product that has margin to the key specs for your exact application. Compared to the time and expense of selecting and tuning in production, up-front talk is cheap. Call 408-986-8031 x224 or visit www.GHz.com.
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We take time to solve your problem.
OUR TRANSISTORS FIT YOUR CIRCUIT, NOT THE OTHER WAY AROUND.
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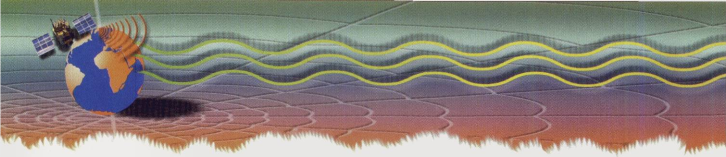


Aeroflex MIC Technology 1809
North Andover, MA

J. Buyko

Aeroflex MIC Technology produces state-of-the-art microelectronic module, interconnect and testing products used in satellite communications, telecommunications infrastructure and other applications.

Amplifiers, Filters, Hybrids, Isolators/Circulators, MMICs, Resistors/Capacitors/Inductors, Synthesizers

Aerowave Inc. 2307
Medford, MA

L. Kozul, T. Kozul

Antennas/Radomes, Attenuators, Couplers, Hybrids, Isolators/Circulators, Millimeter-wave Components, Mixers/Modulators/Detectors, Phase Shifters, Power Dividers, Switches, Terminations, Waveguide and Waveguide Components

Agilent Technologies 1421
Santa Clara, CA

D. Wilson

Agilent introduces six new products for the design and test of handsets, amplifiers, filters and mixers. Agilent Technologies – helping to make dreams real.

Amplifiers, Attenuators, Connectors/Cables/Adapters, Couplers, Filters, Optoelectronic Components/Fiber Optics, Power Dividers, Power Supplies, RFICs, Services, Software, Synthesizers, Switches, Terminations, Test and Measurement Equipment

Airpax Corporation 620
Cambridge, MD

L. Atkins, B. Kopp, J. Tito, T. Coughlin, J. Favinger

Airpax Corporation's Electronic Packaging Products Division produces hermetic glass-to-metal and ceramic-to-metal packaging for the protection of highly sensitive hybrid microcircuits.

Hybrids, Optoelectronic Components/Fiber Optics

Airtron 1817
Morris Plains, NJ

B. Hathaway, J. Michalski, J. Robinson, B. Ochrym, T. Anderson, D. Echo

Silicon carbide substrates and a millimeter flat plate antenna will be featured.

Antennas/Radomes, Attenuators, Connectors/Cables/Adapters, Couplers, Filters, Hybrids, Isolators/Circulators, Materials, Millimeter-wave Components, Mixers/Modulators/Detectors, Phase Shifters, Power Dividers, Services, Systems and Subsystems, Switches, Terminations, Waveguide and Waveguide Components

A.J. Tuck Company 605
Brookfield, CT

A. Tuck, B. Boudreau, L. Hunt, D. Tuck

Filters, Hybrids, Millimeter-wave Components, Waveguide and Waveguide Components

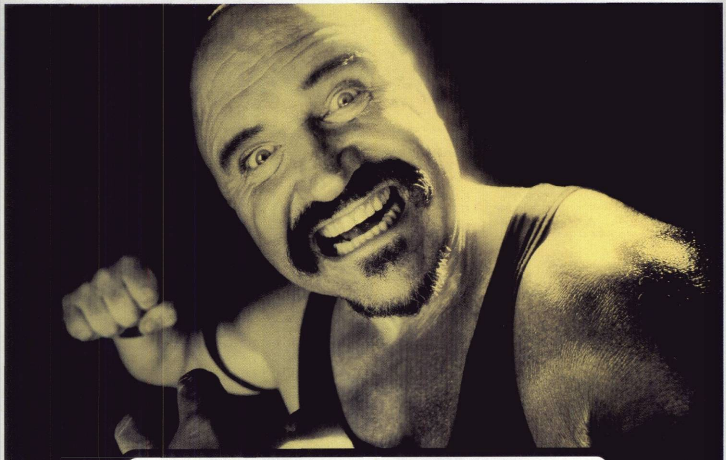
Akon Inc. 1136
San Jose, CA

S. Sareen, P. Sridkar, S. Hartman, M. Jindra

Featured products include DLVAs, ERDLVAs, SDLAs, microwave subassemblies, phase shifters, digitally controlled attenuators, switch filter banks, converter assemblies, detectors, limiters and power dividers. Frequency range is 0.2 to 20.0 GHz.

Amplifiers, Filters, Phase Shifters, Power Dividers, Systems and Subsystems, Switches

[Continued on page 86]



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Xpedion has created a new breed of EDA tools for use in designing wireless communication systems and circuits.

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Simulation support includes RF Linear, Harmonic-Balance and Envelope Transient analyses for detailed circuit design. Xpedion's revolutionary model compiler, incorporating patent-pending neural network technology, delivers high-performance, highly accurate models that enable precise design trade-offs during system simulation.

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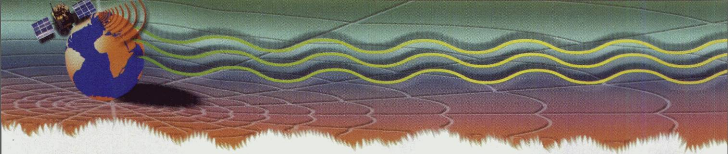


Alan Industries Inc. 920
Columbus, IN

B. Kennedy, D. King

Alan Industries specializes in the custom design and manufacture of attenuators and other passive components.

Attenuators, Couplers, Power Dividers, Switches, Terminations

Alberta Microelectronic Corp. 2917
Edmonton, Alberta, Canada

Alcatel USA Ferrocom Ferrite Products 414
San Jose, CA

R. Sanders, D. Diaz, T. Nguyen, M. Swift

Featured products include miniature drop-in and surface-mount isolators and circulators for cellular, EGSM, GSM, TETRA, Landmobile, PCS, DCS 3G and local loop bands. High power versions are also available.

Isolators/Circulators, Terminations, Waveguide and Waveguide Components

Alpha Industries 1904
Woburn, MA

C. Ducharme

Alpha Industries offers GaAs RFICs, discrete semiconductors and millimeter-wave products for wireless and telecommunication applications, including RF, microwave and mm-wave GaAs ICs: amplifiers, switches, attenuators and mixers; and discrete semiconductors; PIN, receiving and varactor diodes and FETs. Passive products include directional couplers, power dividers and vector modulators. The recent acquisition of Network Device Inc., Sunnyvale, CA, has added advanced GaAs Fab, HBT design capabilities and a West Coast design center.

Amplifiers, Attenuators, Couplers, Diodes/FETs/Transistors, Millimeter-wave Components, Mixers/Modulators/Detectors, MMICs, Power Dividers, RFICs, Switches

AMCOM Communications Inc. 1100
Clarksburg, MD

P. Yang

Custom design services (microwave components including low noise amplifiers, high power amplifiers, mixers, oscillators, switches, attenuators and phase shifters) and special microwave GaAs FETs will be featured.

Amplifiers, MMICs

American Technical Ceramics (ATC) 510
Huntington Station, NY

T. Heil, S. Arnow, S. Litt, S. Beyel, P. Tomasi, G. Pinto

Featured products include the ATC 600 series ultra-low ESR microwave capacitors. The company's new 600 series NPO 0603 capacitors for high performance RF and microwave applications offer the lowest ESR in their class (typically 80 mΩ at 1 GHz).

Resistors/Capacitors/Inductors

AMITRON Inc. 717
North Andover, MA

Y. Commenator

Low cost microwave circuitry — thin-film performance, thick-film pricing.

Attenuators, Printed Circuit Boards, Resistors/Capacitors/Inductors

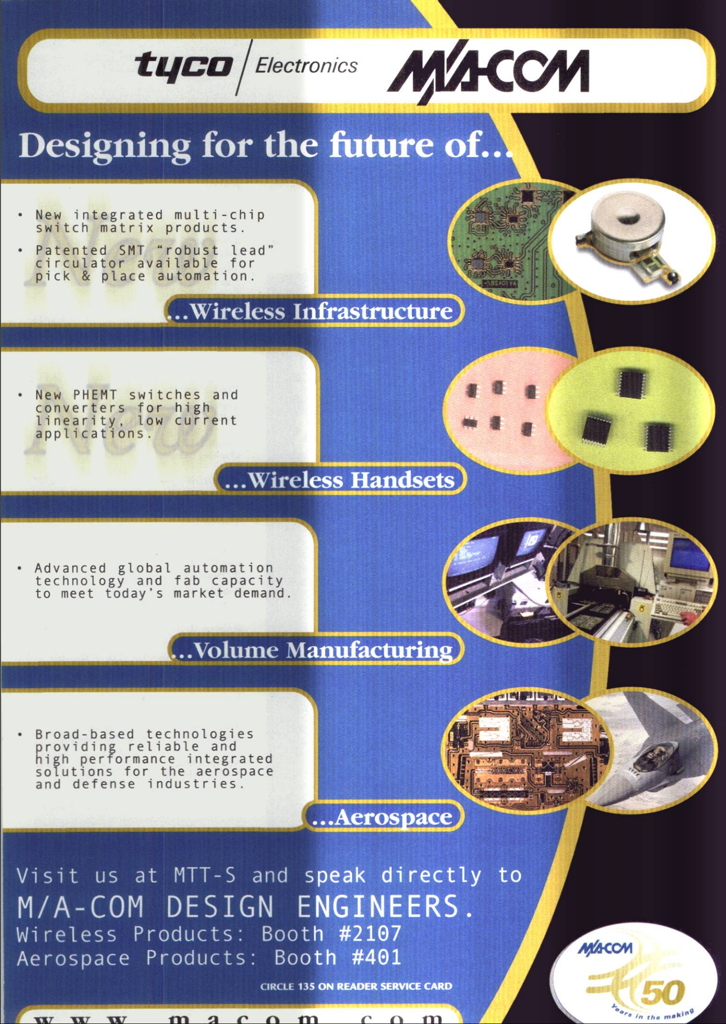
AML Communications Inc. 2900
Camarillo, CA

K. Waldron, T. Mazilu, D. Faigenblat, S. Le, B. Achiriloaie, F. McAvoy

AML introduces the Gain Block™ series low noise and 1 W microwave amplifiers covering the 500 MHz to 22 GHz spectrum. Additional show introductions include high IP3, low noise multicoupler products for two-way messaging and an upconverting cellular to PCS 60 W amplifier.

Amplifiers

[Continued on page 88]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...Wireless Infrastructure
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...Wireless Handsets
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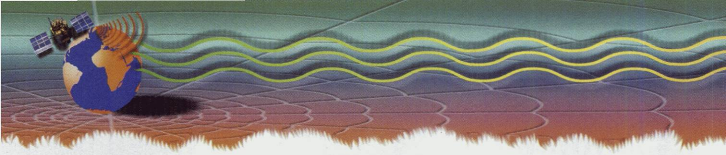
Wireless Products: Booth #2107
Aerospace Products: Booth #401
CIRCLE 135 ON READER SERVICE CARD
M/A-COM
50
Years in the making



Amphenol CNP 2216
Danbury, CT

J. Fairchild

The company's 1.0/2.3 subminiature push-pull connectors feature push-pull coupling that ensures positive locking; 500+ mating cycles; low insertion force; and DC to 4 GHz, broadband performance with low reflection. The PCB connectors are available with compliant pins that eliminate soldering.

Connectors/Cables/Adapters

Amplifier Research 1005
Souderton, PA

D.R. Shepherd, E. Shepherd, K. Shepherd, D.W. Shepherd, C. Schealer, R. Rogers

The S series broadband linear power amplifiers (0.8 to 4.2 GHz, 1 to 200 W) with low spurious emissions and noise figures are useful for testing driver amplifiers and related equipment for wireless communications applications.

Amplifiers, Antennas/Radomes, Couplers, Software, Systems and Subsystems, Test and Manufacturing Equipment

Amplifonix Inc. 1016
Philadelphia, PA

A. Riben, M. Roumeliotis, W. Witt, V. Walthour

Low cost VCOs and amplifiers in surface-mount packages (0.50 square to 0.81 square and 5 to 3000 MHz) will be featured.

Amplifiers, Attenuators, Hybrids, Detectors, Oscillators, Switches

AmpliX, Wireless and Satcom 604
Quebec, Canada

ANADIGICS Inc. 2237
Warren, NJ

T. Blanke, L. Gorman, T. Lagatta

ANADIGICS has a new family of pHEMT switches: the model AWS5505 transfer switch with a single-pole, double-throw (SPDT), the models AWS5507 and AWS5512 transfer switches and the model AWS5508 single-pole, four-throw.

Amplifiers, MMICs, Optoelectronic Components/Fiber Optics, RFICs, Switches

Anaren Microwave Inc. 711
East Syracuse, NY

D. Eastwood, M. Bowyer, B. Clark, E. Schnettler

Xinger crossover components enhance signal crossing methods by reducing the need for expensive multilayer boards. They mount by tape and reel for high volume manufacturing.

Antennas/Radomes, Couplers, Hybrids, Mixers/Modulators/Detectors, Power Dividers

Anatech Ltd. 132
Springfield, VA

G. Barr, D. Lavelli

Plasma cleaning systems; Casidium™ diamond-like carbon deposition services; high rate copper and nickel deposition services.

Shielding, Test and Manufacturing Equipment

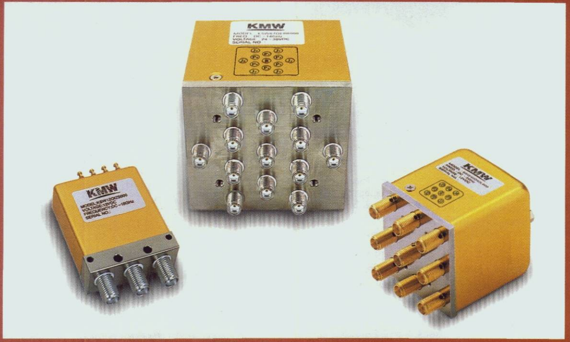
Anritsu Company 2125
Morgan Hill, CA

J. Imanaka

Anritsu Company will introduce the C series lightning vector network analyzers, the only coaxial VNAs that cover 40 MHz to 65 GHz in a single sweep. Also being introduced are the next generation of the MS2711 hand-held spectrum analyzer, software that enhances the performance of the company's PATS, an enhanced ver-

[Continued on page 90]

Designed for Ultimate Quality



Your Complete Switching Solution from KMW

■ 6P7T switch is designed for IMT2000 (6-sector Redundancy)

Product Code No.	KSW12O12S000	KSW67O4AB001	KSW45O48L000
Switch Type	SPDT	6P7T	4P5T
Frequency Range	DC ~ 18GHz	DC ~ 3GHz	DC ~ 3GHz
Insertion Loss (Max.)	0.2 ~ 0.5dB	0.2dB	0.2dB
VSWR (Max.)	1.15:1 ~ 1.5:1	1.15:1	1.15:1
Isolation (Min.)	80 ~ 60dB	80dB	80dB
Operating Mode	TTL Latching with IND.	Latching with IND.	Latching
Actuating Voltage /Current (Max.)	12Vdc ± 10% /240mA (@12Vdc, 25°C)	20 ~ 30Vdc /95mA (@24Vdc, 25°C)	24 ~ 30Vdc /85mA (@26Vdc, 25°C)
I/O Port Connector	SMA(F) / SMA(F)	SMA(F) / SMA(F)	SMA(F) / SMA(F)
RF Power Handling	100W CW (@1GHz)	200W CW (@1GHz)	250W CW (@1GHz)
Dimension (inch)	1.339*1.575*0.528	2.441*2.043*2.177	1.626*1.874*1.626

Higher Frequency available on Multi-Pole Multi-Throw, up to 18GHz
Power Handling capability of 4P5T Switch, up to 250W CW & 4Kw Peak @1GHz
Slim type 6P7T Switch, 2.409*1.417*2.216 (inch), also available.

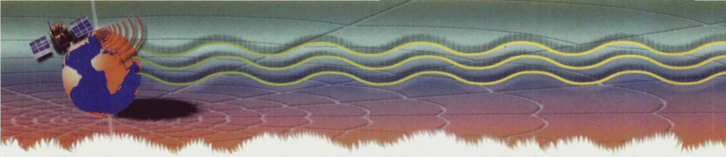
■ Available Options

Internal Termination, Indicator Circuitry, Suppression Diode, TTL Logic,
Self De-Energizing Circuitry, Various I/O Connector type, Other Operating Voltage

■ 5 million life cycle SPDT switch is available now.

CIRCLE 126 ON READER SERVICE CARD

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



sion of the El Toro family of synthesizers, and a high performance bias tee.

Attenuators, Connectors/Cables/Adapters, Isolators/Circulators, Millimeter-wave Components, Synthesizers, Terminations, Test and Manufacturing Equipment, Waveguide and Waveguide Components

Ansoft Corp. — 2005
Pittsburgh, PA

J. Arnold

Ansoft's Serenade Design Environment is a comprehensive software tool set that provides today's wireless and microwave engineer with circuit, electromagnetic and system simulation, layout, IC package modeling and links to third-party tools. Handshaking between tools allows engineers to solve tough design problems while maintaining the flexibility to focus on critical components at any stage of design.

Software

Antcom Corporation — 3005
Torrance, CA

G. Cheng, S. Huynh, M. Sanchez, S. Acharva, M. Jensen

A hybrid near-field antenna test system, satellite handset/terminal antennas, satellite MBA design and analysis software, and beamforming networks will be featured.

Amplifiers, Antennas/Radomes, Filters, Power Dividers, Software, Test and Manufacturing Equipment, Waveguide and Waveguide Components

API Delevan Inc. — 3017
East Aurora, NY

D. Minnick, R. Nugent

API Delevan introduces the 0603 and 0805 series ceramic core, wirewound inductors usable to gigahertz frequencies, plus ferrite shielding materials to reduce EMI/RFI emissions.

Resistors/Capacitors/Inductors

APLAC Solutions Inc. — 1212
Irving, TX

M. Lähepelto, H. Rekonen, M. Joronen

APLAC is a revolutionary RF and microwave circuit design suite featuring state-of-the-art linear and nonlinear simulation methods and a versatile interface to common design tool frameworks.

Software, Services

Applied Engineering Products — 2313
New Haven, CT

B. Trivelli, D. Flanders

The company is a manufacturer of subminiature and miniature coaxial connectors and cable assemblies.

Connectors/Cables/Adapters

Applied Microwave and Wireless — 1218
Tucker, GA

G. Breed, S. Spencer, T. Burkhard, N. Breed

A monthly publication serving RF/microwave engineers and engineering managers.

Publications

Applied Specialties Inc. — 1025
Beltsville, MD

J. Pariseault, K. Coleman Jr.

Make up to 60 different adapters and coaxial cable assemblies from adapter kits. Models for 1, 8 and 18 GHz are priced from $160.

Amplifiers, Antennas/Radomes, Attenuators, Connectors/Cables/Adapters, Couplers, Isolators/Circulators, Mixers/Modulators/Detectors, Power Dividers, Switches, Terminations

Applied Thin-film Products — 107
Fremont, CA

D. Adams, F. Pietroforte

The company offers custom manufacturing thin-film services for wireless and military applications. Capabilities include in-house pattern-generated masks and CO_2 laser drilling. Processing capabilities are vias (standard or poly-filled), bridges (polyimide or air), double-sided patterning and fine pattern definition (gaps < 0.0004"). A wide variety of materials and metals are available.

Hybrids, Materials, Printed Circuit Boards, Resistors/Capacitors/Inductors

Applied Wave Research Inc. — 2401
El Segundo, CA

T. Miracco

Preview Microwave Office 2000 Version 4.0! The award-winning RF & microwave design software now includes advanced system analyses capabilities for 3G-CDMA and a Microwave Compiler for synthesizing common components like filters, couplers, matching networks, amplifiers and mixers.

Software

Apta Group Inc. — 1106
San Diego, CA

P. Danner

Fine line gold etch, hermetic feedthroughs in ceramic substrates and thick film on silicon will be featured.

Hybrids

ARC Technologies Inc. — 1219
Amesbury, MA

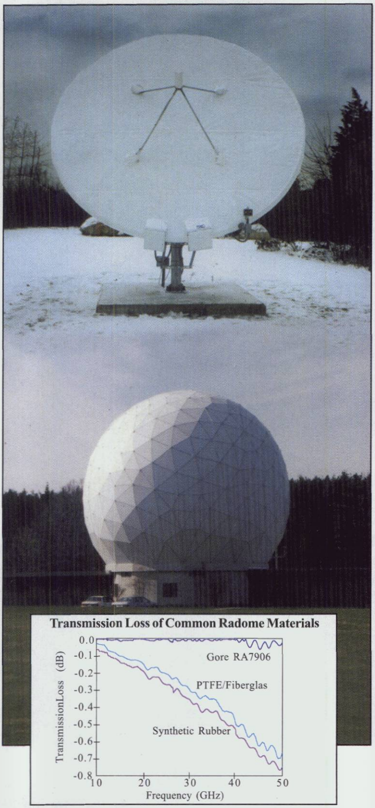
E. Macomber, T. Durant, J. Snow

ARC Technologies is a leading manufacturer of radar absorbing materials, dielectric materials,

[Continued on page 94]

Do you need the world's lowest loss radome material?

Visit Us At MTTS! Booth #1412



Gore Microwave Fabrics feature strength, flexibility, and environmental stability in the lowest loss radome material available.

Gore microwave fabrics keep the weather out while allowing mirowave and millimeterwave signals to get through.

We use unique woven fibers combined with fluorocarbon resins to create the lowest transmission loss and reflection coefficient of any exterior radome fabric.

Superior Product Performance

- **Environmentally stable:** Proven 10-year life in fielded military systems
- **Mechanically Stable:** Used to cover large areas
- **Lowest dielectric constant**

Gore microwave fabric is used in the following demanding applications: Antenna aperature covers, geodisic radomes, portable radome structures, and satellite dish covers.

1 (800) 445-GORE
in North America or

+49/9144-6010
in Europe

Visit our website at: www.gore.com

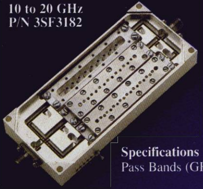
GORE
Creative Technologies Worldwide

CIRCLE 344 ON READER SERVICE CARD

If You Need to Switch

Don't Fight It !!

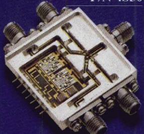
3 Channel Switch Filter Bank
10 to 20 GHz
P/N 3SF3182



Specifications

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

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



Specifications

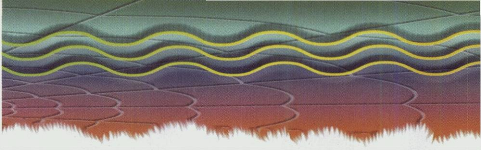
Frequency Range	2.0 - 18 GHz
Insertion Loss	2.9 dB max
Isolation	55 dB min
VSWR	2.0:1 max
Switching Speed	50 ns max

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

Specifications

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

MVS *Microwave & Video Systems, Inc.*
87B Sandpit Road
Danbury, CT 06810
TEL (203) 792-7474
FAX (203) 792-7475
mvsmicro@worldnet.att.net



AMI/RFI gaskets and specialty composites for aerospace, defense and telecommunications applications.

Materials

Arlon Materials for Electronics 225
Rancho Cucamonga, CA

S. Little

The company will feature its AD and AR series low cost, low loss copper-clad laminates for frequency-dependent PWB applications.

Materials

Artech House Publishers 814
Norwood, MA

M. Walsh, J. Stone, W.M. Bazzy

The company will be offering special show discounts on new and recently published books, including *Neural Networks for RF and Microwave Design* and *Understanding Microwave Heating Cavities*.

Publications

Assemblies Inc. 1504
Warner Robins, GA

J. Daniel Jr., J.C. Tinney

New low loss cables (2 to 50 GHz) will be featured.

Connectors/Cables/Adapters

Astrolab Inc. 1305
Warren, NJ

M. Ceres, S. Toma, S. Donovan, R. Fuks

Astrolab designs and manufactures passive microwave components including cables, connectors, cable assemblies, adapters, phase shifters and waveguide components for commercial, space and military requirements.

Attenuators, Connectors/Cables/Adapters, Terminations

Atlantic Microwave 406
Bolton, MA

F. Cavallaro, M. Sweet, P. Walker

Medium to high power microwave components including dual-mode feeds, monopulse comparators, circulators, water loads, filters, pressure windows, power dividers, hybrid couplers and diode switches.

Couplers, Filters, Hybrids, Isolators/Circulators, Power Dividers, Switches, Waveguide and Waveguide Components

ATN Microwave 919
North Billerica, MA

B. Cole, V. Adamian, V. Zohrabian, T. Devlin, A. Boudiaf

ATN provides turnkey solutions for RF and microwave device characterization measurement systems. The company will be debuting its latest system for measuring differential balanced circuits.

Systems and Subsystems, Test and Manufacturing Equipment

A.T. Wall Company 1012
Warwick, RI

B. Diggett, K. Dimicco, B. Look, B. Lafaille

Waveguide tube from WR650 to WR3, millimeter waveguides for LMDS, flat lids for SAW devices, and covers and eyelets for crystal and oscillator products will be featured.

BAE Systems Aerospace Electronics Inc. 1818
Lansdale, PA

G. Bolger, R. Shillady, J. Cordero, C. Lopacki

Custom MIC subassemblies covering 0.1 to 50 GHz including receiver front ends, up- and downconverters; monolithic SDLAs covering 0.1 to 4 GHz; and broadband spiral, horn, LP and array antennas will be featured.

Amplifiers, Antennas/Radomes, Systems and Subsystems

Barry Industries Inc. 238
Attleboro, MA

R. Barry, R. Schmidt, J. Wood, M. Frietas, L. Hathaway

BeO-free stripline termination operates at 10 W, DC to 2 GHz with a return loss of 25 dB and a 0.5-inch standard SMA flange with a BeO-free termination and a 0.040-mil-wide lead.

Attenuators, Hybrids, Resistors/Capacitors/Inductors, Terminations

Besser Associates 1110
Mountain View, CA

R. Frobenius, A. Reed, J. Lange, L. Besser, A. Podell

Six new courses! All About 3G (Third Generation Wireless), Advanced Wireless and Microwave Techniques, RF CMOS Design, RF Power Amplifier Linearization Techniques, Minimizing Degradation of Wireless System Performance, Mobile Computing and Wireless Data Networks, and Short-range Wireless Communications and Bluetooth.

Services

Bird Component Products 2033
Largo, FL

D. Distler, D. Whisler, J. Trulock

New 1000 W RF loads and attenuators will be featured. The model 1000-T series loads and attenuators feature 1000 W convection cooling and are ideal for benchtop and field application.

Attenuators, Power Dividers, Systems and Subsystems, Switches, Terminations, Test and Manufacturing Equipment

Bird Electronic Corp. 2033
Solon, OH

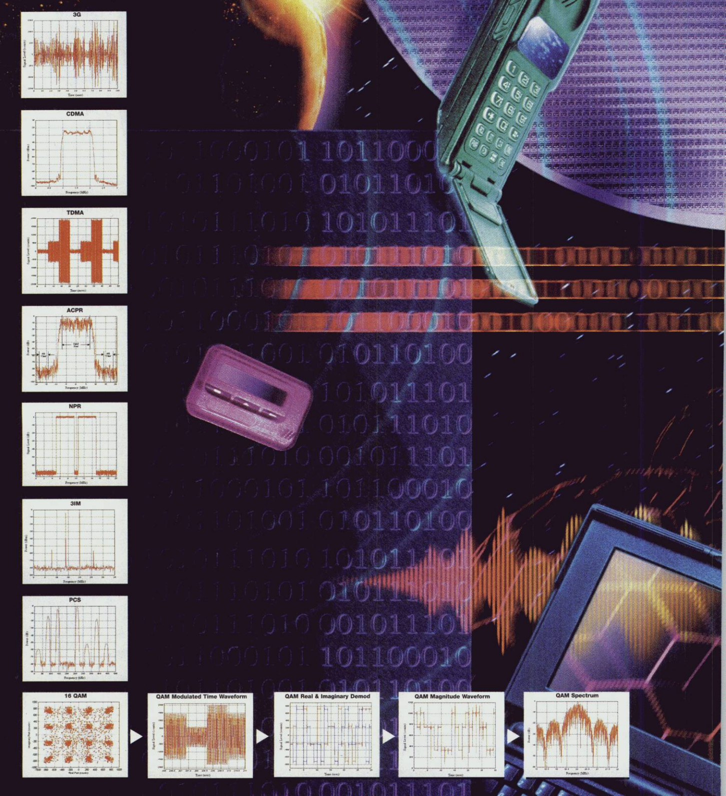
D. Distler

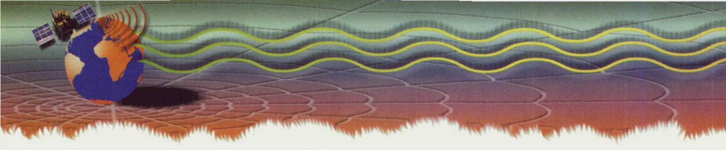
New 300, 500 and 1000 W attenuators and terminations will be featured.

Attenuators, Terminations

[Continued on page 98]

IMAGINE A TEST & MEASUREMENT SYSTEM THAT DOES ALL THIS





Bliley Electric Company 2409
Erie, PA

P. Wisniewski

Bliley will feature its NV45 SC-cut-based SMT OCXOs in 1" sq housings with heights as low as 0.530". Also featured is the company's 155.52 MHz TV 79, SONET and Stratum III reference in the 14-pin DIP.

Oscillators

Boonton Electronics Corporation 2310
Parsippany, NJ

G. Kohli, D. Dawson

Boonton Electronics, a manufacturer of RF and microwave test equipment, sets the standards in CW and peak power measurements. We manufacture RF peak power analyzers/meters, CW power meters, RF voltmeters, capacitance meters, audio analyzers and modulation analyzers/meters. Products are available in benchtop or VXI formats.

Test and Manufacturing Equipment

Boston Micro-Components 2812
Burlington, MA

A. Cobin

Boston Micro-Components is a New England manufacturer's representative. Products include die bonders and wire bonders, test handlers, microwave diodes, VCOs, transformers, inductors, microwave MMICs, filters, packages, thin film and resistors.

Amplifiers, Attenuators, Couplers, Diodes/FETs/Transistors, Filters, Hybrids, Materials, Millimeter-wave Components, Mixers/Modulators/Detectors, MMICs, Optoelectronic Components/Fiber Optics, Oscillators, Power Dividers, Resistors/Capacitors/Inductors, RFICs, SAW Devices, Services, Shielding, Terminations

Brush Wellman 219
Newburyport, MA

B. Simmons

Brush Wellman's RF 130 package was created for power circuit designers who wish to incorporate die and matching circuitry in a single package. As with all CuPack® products, applications include LDMOS, SiC, GaN and GaAs.

Amplifiers, Millimeter-wave Components, MMICs

Brush Wellman 219
Tucson, AZ

J. Sepulveda, E. Cooke

The company is a manufacturer of high performance copper/tungsten heatsinks for LDMOS packages with thermal conductivity of 200 W/mK. Beryllia ceramic substrates are also manufactured with thermal conductivity of 300 W/mK.

Materials, Optoelectronic Components/Fiber Optics, Tubes, Waveguide and Waveguide Components

California Eastern Laboratories (CEL) 1925
Santa Clara, CA

N. Matteson

CEL is NEC Corp.'s exclusive North American sales, marketing and engineering partner for RF and wireless semiconductors, fiber-optic components, optocouplers and solid-state relays.

Amplifiers, Diodes/FETs/Transistors, MMICs, Optoelectronic Components/Fiber Optics, RFICs, Switches

Carleton University 1101
Ottawa, Ontario, Canada

Q.J. Zhang, V. Devabhaktuni

New products include NeuroModeler, the world's first neural- and knowledge-based microwave modeling software. NeuroADS plugs neural models to the Agilent-ADS simulator for neural-based microwave design.

Software

Cascade Microtech Inc. 1315
Beaverton, OR

P. Andrews

Software, Test and Manufacturing Equipment

Celeritek 2012
Santa Clara, CA

F. Sasselli

Amplifiers, Millimeter-wave Components, MMICs, RFICs, Systems and Subsystems

Celerity Systems, L-3 Communications Corp. 2703
Cupertino, CA

J. Reeves, S. Altimari, J. Anderson, D. Griffin

Celerity Systems, an L-3 company, has introduced the CS29010 fully integrated distortion measurement test set, the newest innovation in test and measurement technology, with extensive applications for use in the telecommunications, space/satellite communications and broadband data communications industries.

Signal Processing Components, Test and Measurement Equipment

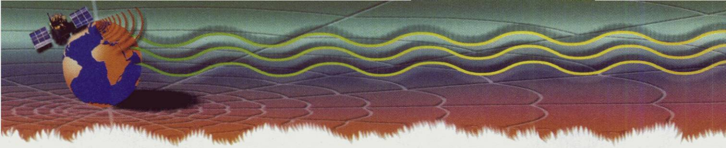
C.E. Precision Assemblies Inc. 211
Chandler, AZ

H. Richards

Coaxial cable assemblies from DC to 65 GHz (custom design, build-to-print and catalog), custom coaxial connectors, delay lines and wire harnesses will be featured.

Connectors/Cables/Adapters

[Continued on page 100]



Channel Microwave Corporation 125
Camarillo, CA

R. Roach, E. Vadnais, K. Boswell, M. Myerow, D. Gildea

Channel Microwave offers a comprehensive line of ferrite and passive components for the wireless world. New products include low IMD drop-ins, ISO filters, ISO couplers and combiners.

Attenuators, Couplers, Isolators/Circulators, Millimeter-wave Components, Power Dividers, Terminations, Waveguide and Waveguide Components

Circuits Processing Technology 219
Oceanside, CA

J. Occhipinti, J. Karker

Integrated thick-film circuitry with frequency to 44 GHz+ will be featured. Applications include transmit/receive modules, power amplifiers and complex multilayer modules. The company's facility is ISO 9002 registered.

Amplifiers, Millimeter-wave Components, MMICs, Optoelectronic Components/Fiber Optics, Resistors/Capacitors/Inductors, Waveguide and Waveguide Components

CirQon Technologies 2215
Gurnee, IL

C. Wolf, M. Zak

CirQon Technologies Corp. introduces standard and custom leadless packages for RFIC applications. Cirpak® packages feature plated and bonded copper (PBC) on alumina ceramic for superior electrical and thermal conductivity. Packages are easily customized with low tooling costs and short lead times.

Amplifiers, Couplers, Filters, Hybrids, Millimeter-wave Components, MMICs, Oscillators, Power Dividers, Power Supplies, Printed Circuit Boards, Resistors/Capacitors/Inductors, RFICs

Clear Comm Technologies Inc. 439
Salisbury, MD

J. Devlin, J. Evans

Delay filter assemblies for cellular and PCS applications will be featured as well as waveguide filters and diplexers covering frequencies from 6 to 40 GHz.

Filters, Waveguide and Waveguide Components

CMR Circuits 301
Pte. Claire, Quebec, Canada

R. Handyside, D. Guerrera

The company's supplied products and services vary from printed circuit boards in Teflon, duroid polyimide, MC5, FR4, etc. At CMR we also provide printed circuit layout and laser photoplotting.

Materials, Printed Circuit Boards, Services

Coilcraft 602
Cary, IL

Coilcraft will showcase its new 0402 wirewound RF inductors as well as low profile (1 mm) SMD power chokes.

Filters, Resistors/Capacitors/Inductors

Coleman Microwave Co. 1013
Edinburg, VA

K. Coleman, J. Coleman, D. Braithwaite

Featured products include a 40 GHz diplexer with low insertion loss, a 28 GHz diplexer and bandpass filter, a tunable coaxial diplexer (1.4 to 2.7 GHz) and a four-port differential phase shifter (9.2 to 9.8 GHz).

Filters, Isolators/Circulators, Terminations, Waveguide and Waveguide Components

Communications & Power Industries Inc. (CPI) 2207
Georgetown, Ontario, Canada

J. Meacham, A. Carrera, G. Traverse

CPI manufactures microwave and millimeter-wave amplifiers for communications, radar and instrumentation applications. High power, wide bandwidth amplifiers from 1 to 140 GHz are available.

Amplifiers

Communications & Power Industries (CPI-MPP) 3002
Palo Alto, CA

T. Webb, F. Ortiz, J. Ross

CPI-MPP, the acknowledged industry leader for manufacturing microwave devices, offers helix TWTs, klystrons, coupled-cavity TWTs, gyrotrons, microwave power modules (MPMs) and high power transmitters.

Tubes

Communication Systems Design 239
San Francisco, CA

L. Carrillo

Communication Systems Design (formerly a Miller Freeman publication) focuses on the technology information needs of electronic engineers who design communication hardware and software. The monthly magazine addresses technical, how-to-design issues common to all communication systems, from packet switches and routers to telco equipment, from digital cell phones to Internet terminals and from satellite modems to ADSL modems.

Publications

Communication Techniques (CTI) 1607
Whippany, NJ

The communication market's undisputed leader in low phase noise signal generation from 7 MHz to 30 GHz, CTI offers phase-locked and free-running DROs, CROs, VCOs and microwave frequency synthesizers for SATCOM, LMDS and digital radio applications. In addition, CTI designs and manufactures clock and data recovery products to 10 GHz for SONET SDH applications.

Millimeter-wave Components, Optoelectronic Components/Fiber Optics, Oscillators, Synthesizers, Systems and Subsystems

Compac Development Corp. 817
Holbrook, NY

C. Groves, P. Rao

SRF series shielded enclosures with off-the-shelf attenuation of 80 dB and 20 GHz will be featured. The products can be modified to your design.

Shielding

Compex Corp. 313
Medford, NJ

D. Gordon, G. Gordon

Single-layer ceramic microwave chip capacitors will be featured in addition to margins, row, split-electrode (surface-mount), arrays and custom configurations. Forty-eight-hour guaranteed delivery list is available as well as gold or tin terminations.

Resistors/Capacitors/Inductors

Component Distributors Inc. 725
Plano, TX

J. Williammee, T. Rees, D. Williammee, S. Montgomery

Amplifiers, Attenuators, Connectors/Cables/Adapters, Couplers, Diodes/FETs/Transistors, Filters, Hybrids, Isolators/Circulators, Millimeter-wave Components, Mixers/Modulators/Detectors, MMICs, Optoelectronic Components, Fiber Optics, Oscillators, Phase Shifters, Power Dividers, Power Supplies, Resistors/Capacitors/Inductors, RFICs, SAW Devices, Shielding, Signal Processing Components, Switches, Terminations

Comtech PST 1510
Melville, NY

B. Yoruckso, B. Liebman, D. Hill, M. DeLuca, N. Jawdat

State-of-the-art, high power, broadband, solid-state amplifiers from 1 to 4200 MHz, 2 W to kilowatts, will be featured.

Amplifiers

Conexant Systems Inc. 2901
Newport Beach, CA

Conexant, a world-leading communications semiconductor provider, offers integrated RF subsystems, PAs and infrastructure components for the world's major wireless standards as well as complete solutions for GSM, GPS and advanced spread spectrum applications, including Bluetooth.

Amplifiers, MMICs, Systems and Subsystems

Connecting Devices Inc. 318
Long Beach, CA

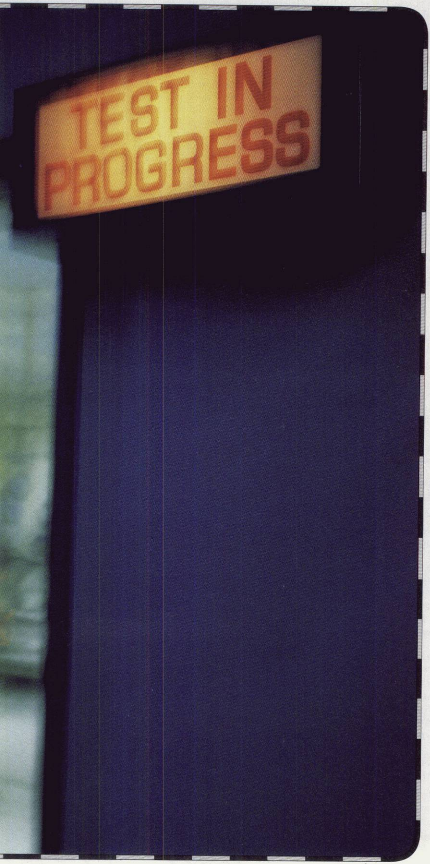
W. Carpenter, M. Peeran, J. Dunbabin, J. Costello

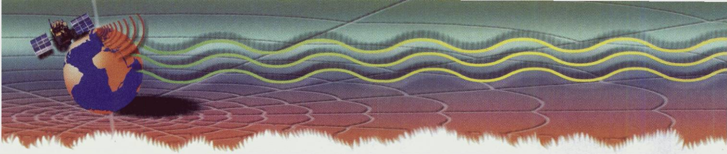
The company will feature 40 GHz SMP miniature blind-mate and the new reduced-size SSMP microminiature family of connectors plus SMA, SSMA, "K", TNC, N and a complete line of handformable, flexible and semirigid cable assemblies.

Connectors/Cables/Adapters

[Continued on page 104]


VIDEO
TELECOM
COMPUTING


TEST IN
PROGRESS



Continental Microwave & Tool Co. 406
Exeter, NH

J. Ripel, T. Brown, D. Cottis, R. Novello

The company offers passive flexible and rigid waveguide components and assemblies; waveguide filters, antennas and distribution networks; rectangular and double-ridged waveguide; and seamless flexible styles WR43 to WR19.

Couplers, Filters, Isolators/Circulators, Millimeter-wave Components, Power Dividers, Terminations, Waveguide and Waveguide Components

Coorstek (formerly Coors Ceramics Co.) 2211
Golden, CO

D. Pivic, S. Monyon

Coorstek now offers a dry-pressable steatite, mullite and talc for a wide variety of electronic applications. For further information contact your Coorstek sales representative.

Hybrids, Materials, Printed Circuit Boards, Resistors/Capacitors/Inductors

Cougar Components 404
Sunnyvale, CA

S. Cheadle

Analog and threshold detectors (10 MHz to 6 GHz) and subsystems and multifunction modules (including mixer amps, switching amps and selectable gain amps) will be featured.

Amplifiers, Attenuators, Hybrids, Mixers/Modulators/Detectors, Signal Processing Components, Systems and Subsystems

Cree Inc. 2712
Durham, NC

Cree Research Inc., the world leader in the development and manufacture of semiconductor materials and electronic devices made from silicon carbide (SiC), introduced the first SiC RF power transistor product designed for wireless and broadcast applications. This device, CRF-20010-101, is a 48 V, 10 W high linearity transistor with 12 dB of gain at 2 GHz.

Diodes/FETs/Transistors

CSIRO Australia 2040
Sydney, Australia

M.A. Sprey, S. Guigni

A Ka-band transponder; 94 GHz amplifier; 60 GHz array; X-band, dual-polarized patch array; 180 to 220 GHz test set; traffic management radar; packaged subassemblies up to 20 GHz; and wideband dielectric-lined horns will be featured.

Amplifiers, Antennas/Radomes, Couplers, Diodes/FETs/Transistors, Filters, Hybrids, Millimeter-wave Components, Mixers/Modulators/Detectors, MMICs, Power Dividers, Services, Software, Systems and Subsystems, Waveguide and Waveguide Components

CST of America 2417
Cambridge, MA

R. Field

A new version of Microwave Studio will be featured. The company is changing the standards for three-dimensional EM simulation. With a vast international customer base of design engineers involved in EM analysis and design, MAFIA-4 and CST Microwave Studio™ have firmly established CST's place at the forefront of CAE software houses.

Software

CTS Reeves Frequency Products Inc. 115
Carlisle, PA

K. Goldman, K. Finkenbinder, D. Smith

Low power, small OCXOs; high frequency VCXOs; 5 × 7 and 9 × 14 VCXOs and clocks; VTTN-compensated TCXOs; and thru-hold and SMT crystals will be featured.

Materials, Oscillators

CTT Inc. 709
Santa Clara, CA

D. Tai, S. Mussynski, R. Shubin, G. Graham

CTT designs and manufactures microwave GaAs FET amplifiers and amplifier-based subassemblies for use in a wide variety of military and commercial applications covering the 500 MHz to 40 GHz spectrum.

Amplifiers, Millimeter-wave Components, Systems and Subsystems

Cuming Microwave Corporation 1434
Avon, MA

D. Turi, M. Kocsik, J. DaSilva, M. Heafey, J. Bruun

Cuming Microwave Corporation will be exhibiting the company's capabilities to mold or cast RF absorbers onto customer lids for mode suppression. This capability is a lower cost alternative to machining channels into housings for isolation and adhering an RF absorber to the lid as a secondary operation.

Antennas/Radomes, Materials, Shielding, Waveguide and Waveguide Components

Cushcraft Corporation 2802
Manchester, NH

Antennas from 30 MHz to 40 GHz for a variety of wireless applications including cellular, GSM, PCS/DCS and WLAN as well as other commercial wireless applications will be featured.

Antennas/Radomes, Connectors/Cables/Attenuators

Custom Cable Assemblies Inc. 2603
Warner Robins, GA

J. DiDiego, T. DiDiego, W. Moore

Flexible and semirigid cable assemblies will be featured.

Connectors/Cables/Adapters

Datum 210
Beverly, MA

K. Reuning

Datum provides a complete line of sophisticated timing and frequency solutions that are in use in the most precise frequency references in the world clock, master references in radio astronomy ground stations, space-qualified frequency standards in GPS systems, master references for secure communications systems, stable frequency generators in satellite ground terminals, calibration reference sources in meteorology laboratories and the master reference in laboratory research facilities.

Oscillators, Systems and Subsystems, Test and Manufacturing Equipment, Tubes

DB Products Inc. 1334
Pasadena, CA

T. Prentice, J. Williams, S. Chen

Founded in 1958 as a manufacturer of custom magnetics devices, DB Products operates three divisions: Microwave (RF/MW electromechanical switches), Magnetics (space and aerospace) and CEHCO (high power rectification products).

Filters, Power Supplies, Resistors/Capacitors/Inductors, Switches

Delta Electronics Manufacturing Corp. 119
Beverly, MA

G. Moore, M. Reagan, C. Rose

Delta Electronics will feature its new quick-disconnect products, which replace typical thread-on connectors and are currently available in three different interfaces.

Connectors/Cables/Adapters

Diablo Industries 631
Minden, NV

S. Burt, R.J. Gibson

Full thin-film capability, metallized substrates, resistors, capacitors, circuits, photolithography, etching, dicing, heat treat, environmental testing, MIL-STD qualified.

Resistors/Capacitors/Inductors

Diamond Antenna & Microwave 1309
Lowell, MA

J. Gilling, P. Burton, P. Christia

The company's precision rotating components include a patented coaxial rotary joint module offering the long-life advantages of noncontacting but with better performance and smaller size.

Millimeter-wave Components, Switches, Waveguide and Waveguide Components

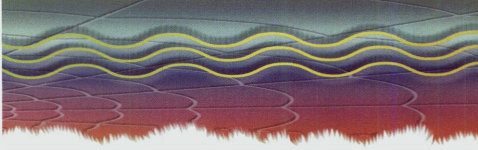
Dielectric Laboratories 1613
Cazenovia, NY

G. Vorlop, W. Hautaniemi, K. Orth, R. Nikodem

New Cap Cad V3 modeling software, Milli-Cap™ millimeter-wave SMD capacitors, broadband DC blocks, high Q SMD and single-layer capacitors will be featured as well as DiPak™ LTCC on metal packaging.

Materials, Millimeter-wave Components, Resistors/Capacitors/Inductors

[Continued on page 106]



Ditom Microwave Inc. 1025
San Jose, CA

D. Hassett, M. Weisz

Coax isolators from 150 MHz to 40 GHz, drop-in isolators from 700 MHz to 18 GHz and microstrip isolators from 3.7 to 40 GHz will be featured.

Isolators/Circulators, Millimeter-wave Components, Waveguide and Waveguide Components

DML Microwave Ltd. (DML) 2025
Essex, UK

K. Kearns, P. Dumbell

Founded in 1979, DML (formerly Densitron Microwave Ltd.) is an ISO 9000-certified supplier of high performance microwave and RF components including ferrite isolators, circulators, and solid-state low noise and power amplifiers used in wireless communication systems and test applications.

Amplifiers, Isolators/Circulators

Dorado International Corp. 2406
Seattle, WA

H. Rutstein, C. Puetz

Many new devices and antennas for LMDS systems (18 to 44 GHz) will be featured including sector horn antennas 30° to 120°, omnidirectional, planar array (1 to 100 GHz) and components such as isolators and circulators (microstrip and waveguide) as well as a broad array of passive waveguide parts for test systems and production equipment (8.2 to 110 GHz).

Antennas/Radomes, Attenuators, Connectors/Cables/Adapters, Couplers, Isolators/Circulators, Millimeter-wave Components, Terminations, Waveguide and Waveguide Components

Dow-Key Microwave 1612
Ventura, CA

J. Trujillo

The CANbus switches (SP6T and transfer) offer a unique design based on the ISO-defined serial communications bus and are targeted toward test applications where fast system integration and flexibility to modify or extend switch layout are requirements.

Signal Processing Components, Switches, Test and Manufacturing Equipment, Waveguide and Waveguide Components

Ducommun Technologies Inc. 907
Carson, CA

V. Harter, G. Clothey, C. Trotter

DC to 46 GHz electromechanical coaxial switches and custom high power filters for extreme environments will be featured as well as high performance SP10T and 4×4 matrix switches for automatic test equipment and a patented T-switch for satellite applications.

Filters, Switches

DuPont Microcircuit Materials 2116
Research Triangle Park, NC

S. Horowitz

DuPont Microcircuit Materials is the world's leading supplier of ceramic thick-film and Green Tape™ materials for high performance military and aerospace and high volume cost-sensitive automotive and telecommunications applications. Green Tape, Fodel® photo-definable thick-film and QG150 high density conductors provide excellent high frequency performance, high thermal conductivity, compatibility with bare chip assembly processes and patterning capability for high circuit density. For more information, see the wireless section at www.dupont.com/mcm.

Materials

DuPont Superconductivity 2117
Wilmington, DE

A. Lauder, C. Wilker, Z. Shen, D. Laubacher, D. Kountz

DuPont Superconductivity manufactures custom, prototype and commercial superconducting components, devices and subassemblies for communications. The company also provides world-leading HTS thin films, foundry services and design support for high performance microwave components.

Antennas/Radomes, Filters, Materials, Oscillators

Dynawave Inc. 2039
Haverhill, MA

C. Lewis, M. Lewis, B. Iwowicki, G. Lianelfo

A new FB connector series for use in the telecom market will be featured. (The connectors' primary usage is in antenna applications).

Connectors/Cables/Adapters, Couplers, Services

Eagleware 1919
Tucker, GA

R. Rhea, T. Cutler, R. Carter, P. Beavin, G. Parker

Stop by Eagleware's booth and see nonlinear simulation now made fast, easy and affordable. The new Genesys version 7.5 with harmonic balance nonlinear simulator, new synthesis products and empower improvements will be featured.

Software

East Coast Microwave 2709
Stoneham, MA

B. Ginz, B. Cooper, J. Mansfield

East Coast Microwave is an electronics distributor specializing in RF/microwave connectors, components and cable assemblies.

Attenuators, Connectors/Cables/Adapters, Couplers, Millimeter-wave Components, Mixers/Modulators/Demodulators, Power Dividers, Resistors/Capacitors/Inductors, Switches, Terminations, Waveguide and Waveguide Components

EDO Electro-Ceramic Products 2719
Salt Lake City, UT

J. Chabria, E. Belousof

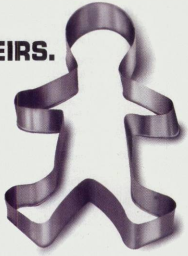
"Super Q" dielectric resonators, narrow line width garnets, low loss ferrites, and dielectric and magnetic substrates will be featured.

Materials

[Continued on page 108]

THERE ARE TWO KINDS OF MICROWAVE AND RF CONNECTORS OUT THERE.

THEIRS.



OURS.

The cookie-cutter approach to engineering just doesn't cut it. We never took it with our founding military defense clients, and we don't take it with our wireless and telecomm customers. In fact, every connector, every cable assembly, has to be designed and built as if the entire system depended on it. That's the Dynawave way.

A team approach.
Balancing reliability with performance and cost is what our design engineers do best. They work with you, at no charge, to deliver CAD, CAD-CAM, fast-turn prototypes and complete documentation packages for solutions to your design challenges. And they will personally work with you for the life of your product.

High quality manufacturing.
Dynawave has been a leader in the design and manufacture of cost-effective RF and microwave cable assemblies, delay lines, harnesses, and connectors for over 15 years. All of our products undergo 100% functional performance verification. Data collection and product traceability are available to support your needs.

Contact us.
Ask for our new brochure. Contact your representative or call us at (978) 469-0555, fax us at (978) 521-4589, or e-mail us at *connect @dynawave.com*. You won't get cookie-cutter answers, either.

Visit us at Booth #2039.

dynawave® INCORPORATED

1985 – 2000 15 YEARS OF EXCELLENCE Dynawave Incorporated

135 Ward Hill Avenue • P.O. Box 8224 • Haverhill, MA 01835 / TEL: 978-469-0555 / FAX: 978-521-4589
Dynawave is an ISO 9001 UL Registered Company • www.dynawave.com

EiC Corp. **1102**
Fremont, CA

B. Lin

The EiC gain block family currently consists of three parts: the EC-1019 and EC-1119 are packaged in plastic Micro-X SMD with an 85-mil diameter; the EC-1078 is housed in SOT-89 and has higher power output levels (P1dB = 21 dBm) than the Micro-X parts.

Amplifiers, Diodes/FETs/Transistors, MMICs, RFICs

Elanix Inc. **2503**
Westlake Village, CA

J. Kirshman

The new 3G Design Studio for SystemView fully supports the ETSI 3GPP standard, frequency division duplex (FDD). Optional hardware provides real-time signal generation and analysis of 3G waveforms.

Software

Electro-Films Inc. **232**
Warwick, RI

D. Brakenwagen, J. Devine

Electro-Films is the broadest dedicated supplier of thin-film components including multilayer - MCM, passive microwave components, complex pattern substrates, air or supported bridges, chip resistors, capacitors, inductors, precision networks, flip chip and BGA versions. Surface-mount and through-hole package resistor networks are also offered.

Millimeter-wave Components, Resistors/Capacitors/Inductors, Signal Processing Components

ElectroMagneticWorks Inc. **1210**
Montreal, Quebec, Canada

A. Khebir, A. Argoubi

ElectroMagneticWorks Inc. (EMW) is an electronic design automation (EDA) company. EMW focuses on the development, marketing and support of computer-aided engineering (CAE) and compute-aided design (CAD) tools based on electromagnetic principles and phenomena. The company's growing list of products includes ATLASS and HFWORKS.

Software

Elisra Electronic Systems Ltd. **922**
Bene Beraq, Israel

M. Shalit

High speed synthesizers will be featured.

Amplifiers, Filters, Hybrids, Millimeter-wave Components, Mixers/Modulators/Detectors, Optoelectronic Components/Fiber Optics, Oscillators, Phase Shifters, Synthesizers, Systems and Subsystems, Switches

EMAG Technologies **1231**
Ann Arbor, MI

K. Sabet, J. Cohen

The company's new CAD software product, PiCASSO, allows quick and easy design, analysis and optimization of any planar antenna. Novel high frequency software and hardware solutions also are offered.

Antennas/Radomes, Services, Software

EMC Technology Inc. **2617**
Cherry Hill, NJ

J. Mazzochette, D. Markman, K. Canelli, T. Adair, L. Catalina, R. Bussemer, M. Sonstein, J. Porreca, R. Pulchlopek

EMC Technology Inc. is the industry's leading provider of passive microwave components. The company offers a full line of surface-mount terminators, attenuators, resistors, hybrid baluns and flange loads, and is celebrating the 10-year anniversary of the Thermopad, it unique solution to temperature compensation.

Attenuators, Resistors/Capacitors/Inductors, Terminations

Emerson & Cuming Microwave Products **208**
Randolph, MA

J. Gear, J. Delprete, M. Carpenter

To meet the expanding requirements for microwave absorbers in wireless technology, the company has built a state-of-the-art automated processing facility for producing carbon impregnated microwave absorbers.

Antennas/Radomes, Materials, Shielding

EMF Systems **2309**
State College, PA

J. Chernega

EMF's new catalog covers phase-locked oscillators and synthesizers and special products.

Oscillators, Synthesizers

Emhiser Micro-Tech **2916**
Verdi, NV

EMS Technologies Inc. **2702**
Atlanta, GA

G. Maag, T. Vaughn

EMS supplies high performance ferrite products to the commercial and defense markets. EMS products and services include ferrite materials/substrates, components, phase shifters and switching/routing subsystems.

Amplifiers, Antennas/Radomes, Filters, Hybrids, Isolators/Circulators, Materials, Millimeter-wave Components, Mixers/Modulators/Detectors, Phase Shifters, Power Dividers, Power Supplies, Systems and Subsystems

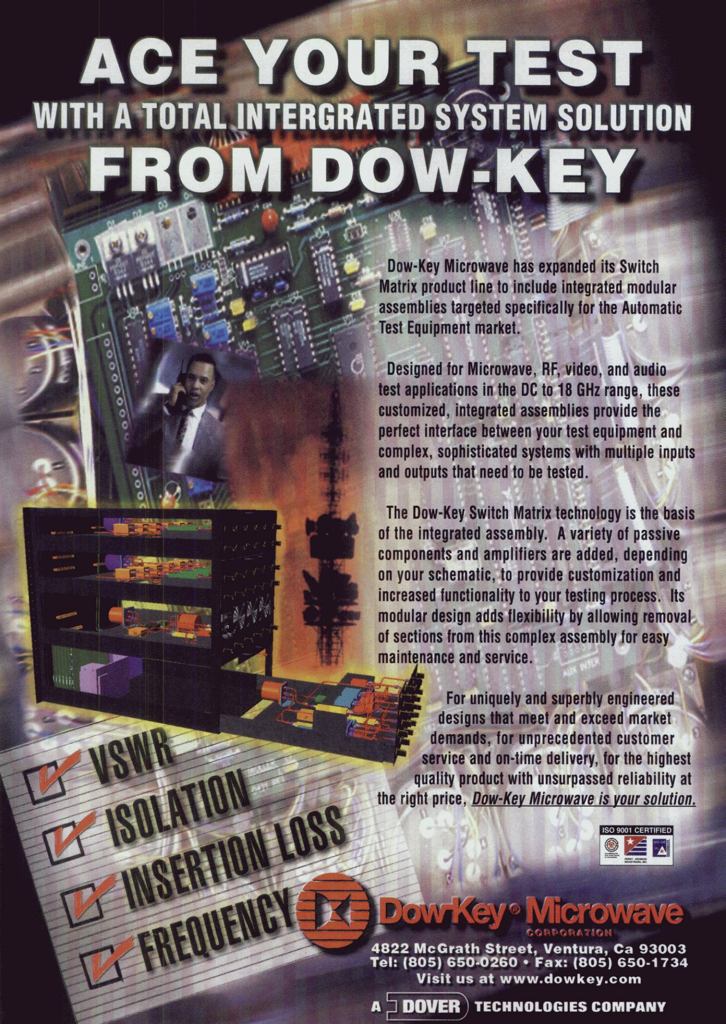
Epsilon Lambda Electronics **2120**
Geneva, IL

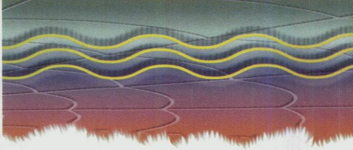
D. Sreniawski, R. Knox

Stop by our booth and learn about our new 76.5 GHz forward-looking radar subsystems for the automotive collision warning/intelligent cruise control market. Our Web site is www.epsilonlambda.com.

Antennas/Radomes, Millimeter-wave Components, Oscillators, Systems and Subsystems

[Continued on page 110]


ACE YOUR TEST
WITH A TOTAL INTERGRATED SYSTEM SOLUTION
FROM DOW-KEY
Dow-Key Microwave has expanded its Switch Matrix product line to include integrated modular assemblies targeted specifically for the Automatic Test Equipment market.
Designed for Microwave, RF, video, and audio test applications in the DC to 18 GHz range, these customized, integrated assemblies provide the perfect interface between your test equipment and complex, sophisticated systems with multiple inputs and outputs that need to be tested.
The Dow-Key Switch Matrix technology is the basis of the integrated assembly. A variety of passive components and amplifiers are added, depending on your schematic, to provide customization and increased functionality to your testing process. Its modular design adds flexibility by allowing removal of sections from this complex assembly for easy maintenance and service.
For uniquely and superbly engineered designs that meet and exceed market demands, for unprecedented customer service and on-time delivery, for the highest quality product with unsurpassed reliability at the right price, Dow-Key Microwave is your solution.
VSWR
ISOLATION
INSERTION LOSS
FREQUENCY
ISO 9001 CERTIFIED
Dow-Key® Microwave
CORPORATION
4822 McGrath Street, Ventura, Ca 93003
Tel: (805) 650-0260 • Fax: (805) 650-1734
Visit us at www.dowkey.com
A DOVER TECHNOLOGIES COMPANY



Ericsson Microelectronics 2133
Morgan Hill, CA

S. Stevenson

Visit our booth for demonstrations on Bluetooth and RF power transistors. Featured products include 150 W W-CDMA and 130 W PCS RF transistors.

Amplifiers, Diodes/FETs/Transistors

Evaluation Engineering 1227
Nokomis, FL

S. Berlin

Evaluation Engineering is the pioneering magazine serving engineers and managers responsible for test and product quality in the design development, manufacturing and service of electronic products and systems.

Publications

Excelics Semiconductor Inc. 1221
Santa Clara, CA

R.T. Chen

Featured products include 0.1 to 2 W MMICs over the 4 to 40 GHz frequency range, 1 to 8 W internally matched power FETs over the 9 to 20 GHz and DC to 6 GHz frequency ranges, and 0.5 to 4 W high IP3/low LN FETs in SOT89.

Amplifiers, Diodes/FETs/Transistors, Millimeter-wave Components, MMICs

EZ Form Cable Corporation 2519
Hamden, CT

F. Volpe, J. Buccitti

Low loss cables from 0.047″ to 0.250″ diameter will be featured.

Antennas/Radomes, Connectors/Cables/Adapters

Farran Technology Ltd. 1326
Ballincollig, Cork, Ireland

J. Joyce, D. Vizard, M. Issel, A. Gowen, P. Duffy, M. Feely

Catalog and custom, mm and sub-mm microwave components from 18 to 3000 GHz will be featured as well as new 77 GHz FMCW radar front ends and MMIC-based integrated subsystem design solutions, including BWA up-/downconverters and subscriber transceivers for PP, PMP wireless infrastructure and 40 to 58 GHz/MVDS connectivity.

Amplifiers, Antennas/Radomes, Attenuators, Couplers, Diodes/FETs/Transistors, Filters, Hybrids, Isolators/Circulators, Millimeter-wave Components, Mixers/Modulators/Detectors, MMICs, Oscillators, Phase Shifters, Services, Synthesizers, Systems and Subsystems, Switches, Terminations, Waveguide and Waveguide Components

Film Microelectronics Inc. 1320
North Andover, MA

D. Stevenson, P. Richards

AlN resistor terminations, filled vias, ferrite substrates and quartz with forty-eight-hour turnaround are offered. Custom substrates on various materials are available. Call for details.

Attenuators, Couplers, Filters, Optoelectronic Components/Fiber Optics, Resistors/Capacitors/Inductors, Terminations

Filtel Microwave Inc. 118
Vaudreuil-Dorion, Quebec, Canada

J. L'Ecuyer, J. Delgado

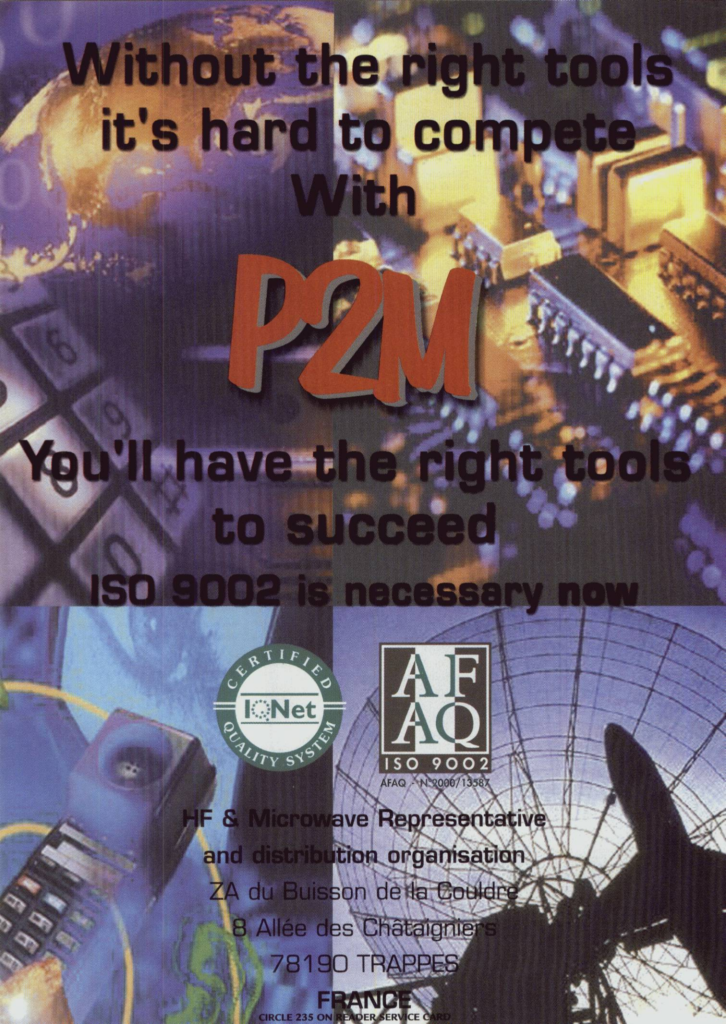
Diplexers for microwave radio systems will be featured.

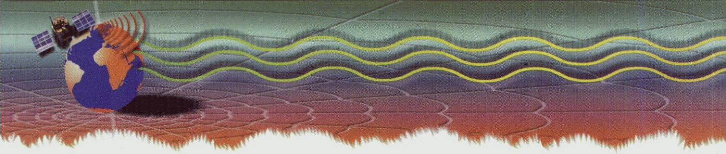
Couplers, Filters

Filtran Microcircuits Inc. 2000
Ottawa, Ontario, Canada

L. Parsons, C. Sutton

[Continued on page 112]


Without the right tools
it's hard to compete
With
P2M
You'll have the right tools
to succeed
ISO 9002 is necessary now
CERTIFIED
IQNet
QUALITY SYSTEM
AF
AQ
ISO 9002
AFAQ - N°2000/13587
HF & Microwave Representative
and distribution organisation
ZA du Buisson de la Couldre
8 Allée des Châtaigniers
78190 TRAPPES
FRANCE
CIRCLE 235 ON READER SERVICE CARD



Filtran will highlight its ability to produce precision microwave circuitry, microstrip, bonded stripline, thick metal backed PTFE and mixed-dielectric multilayer. Examples of fine line/narrow gap circuitry with various plating combinations and the proprietary sputtered Blind Hole approach will be displayed.

Printed Circuit Boards

Filtronic **1900**
Santa Clara, CA

B. Franke, I. Pimintelli, S. Knight, P. Sahjani

Filtronic Solid State designs and manufactures microwave and millimeter-wave products for wireless, telecommunications and high reliability applications.

Amplifiers, Diodes/FETs/Transistors, Filters, Millimeter-wave Components, MMICs, Oscillators

Filtronetics Inc. **2920**
Kansas City, MO

S. Barrett

Electronic filters, crystal oscillators, assembly, coil winding and EMI filters will be featured.

Filters, Oscillators

First Technology-Control Devices **2213**
Standish, ME

S. Sheidy, D. Audesse, T. Godan, T. Ebling, T. Freeman, P. St. John

ER80 and ER21 materials will be featured.

Flexco Microwave Inc. **1010**
Hackettstown, NJ

R. Walker

Featured products include armored flexible test cables – low loss, phase- and amplitude-stable cable assemblies (DC to 40 GHz), which maintain 100 percent shielding when flexed.

Connectors/Cables/Adapters

Florida RF Labs **2225**
Stuart, FL

E. DeVita, M. Trivison, D. Sampson

Low cost flange terminations are available in half-inch and one-inch-square flanges with power handling capacity of 1 to 20 W and SWR less than 1.065 from DC to 2 GHz.

Attenuators, Connectors/Cables/Adapters, Resistors/Capacitors/Inductors, Terminations

Focus Microwaves Inc. **804**
Montreal, Quebec, Canada

C. Tsironis, C. Ghali, S. Mikhael

New products include MLTF, a minimum loss transistor test fixture for sub-1 Ω load pull measurements; prematching tuners for high SWR load pull testing; and power amplifier design software, WinPADS.

Test and Manufacturing Equipment

Foranne Manufacturing **2810**
Ivyland, PA

V. Gentile, B. Hultmark

Foranne Manufacturing provides cost-effective precision machined packages and products for the microwave industry. Hermetic packages for couplers, waveguides, amplifiers, filters, cable modems and receivers are some of the products Foranne Manufacturing produces for the industry.

Materials, Optoelectronic Components/Fiber Optics, Services, Tubes, Waveguide and Waveguide Components

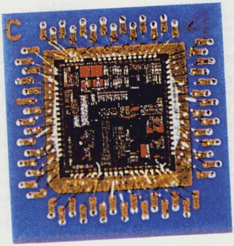
Fotofabrication Corp. **310**
Chicago, IL

B. Siegel, D. Brumlik

[Continued on page 114]

Application Profile

How to make Cell Phones Smaller and Lighter? BGA with Integrated Components using DuPont Green Tape™.



National Semiconductor is a leader in applying the LTCC advantages of high-density interconnect capability, ability to integrate passive components and functions, and low-loss performance. In a recent design, National chose to combine its advanced ICs for wireless communications with Green Tape™, DuPont's brand of LTCC tape dielectric material, to provide optimum performance in the smallest possible package.

Challenge: Decreased Size and Cost, Improved Performance for Wireless Devices

Portable wireless applications have quickly become the main driver for smaller, more cost-effective packaging and interconnects. For example, in the last few years, cell phones have evolved into lightweight, palm-size devices with a host of new functions. Their weight has decreased by a factor of 10, and the wholesale selling price by 75 percent.

OEM designers are now learning that integrating IC and package design to take advantage of the unique properties of Low Temperature Co-fired Ceramic (LTCC) technology can yield decreased size and improved performance in wireless devices.

Solution: Green Tape™ LTCC Allows for High I/O Counts in Chip Scale Package

National's newest chipsets use Green Tape™ packaging capabilities to provide a chip scale package that can accommodate the high I/O counts of a highly integrated RF analog front end using micro BGA (ball grid array) technology. The current package, only 9 x 9 mm, can provide 81 I/Os in a micro BGA array, plus topside pads for wire-bonding that interconnects to the BGA pads on the backside. The high number of I/Os allows for multiple grounds to improve RF performance, while the embedded multilayer structure contains 14 RF bypass capacitors constructed using a combination of high-K and low-K dielectrics.

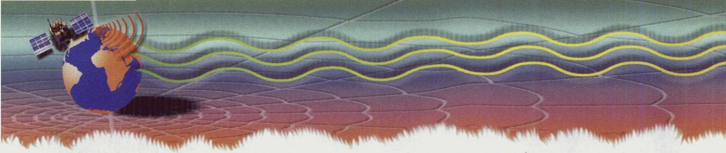
The performance of the frequency synthesizer function can be enhanced through the use of an embedded VCO resonator that provides a high Q, and therefore lower phase noise, than that available using a VCO resonator located on the silicon.

This approach, co-designing the silicon and LTCC elements to achieve optimized size and performance, demonstrates the use of co-integration for wireless applications requiring smaller package size and higher performance at the lowest possible cost.

For more information, call DuPont at 1-800-284-3382, press 3, or visit the DuPont Microcircuit Materials Web Site at http://www.dupont.com/mcm.

DUPONT®

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



See Fotofab's innovative custom and standard RF shields, antenna components, lead frames, contacts, connector components, screens, and other flat and formed thin metal parts. Lead times range from three days to three weeks.

Connectors/Cables/Adapters, Isolators/Circulators, Shielding

Fox Electronics **1213**
Ft. Myers, FL

R. Burns, M. Freyermuth

The Just-In-Time Oscillator, programmable from 340 kHz to 250 MHz, is intended to be a rapid response, low cost alternative for applications requiring a short lead time. Delivery is 10 days (ARO) for productions quantities.

Oscillators

Frequency Electronics Inc. (FEI) **1616**
Mitchel Field, NY

G. Kushner

OCXOs, rubidium clocks and associated distribution systems. Microwave MMIC devices are offered in chip or packaged form. FEI also provides a broad range of custom microwave assemblies.

Amplifiers, MMICs, Oscillators, Synthesizers

Frequency Management **111**
Huntington Beach, CA

J.J. Justus

Filters, Oscillators, Resistors/Capacitors/Inductors

Fujitsu Compound Semiconductor Inc. **1714**
San Jose, CA

C. Burnett, J. Zazkowski, T. Iida, B. Utter

Fujitsu manufactures a complete range of microwave field effect transistors and GaAs MMICs for use in communications and radar systems from 900 MHz to 76 GHz. These applications include cellular and wireless phone and LAN systems, terrestrial radio link, satellite telemetry and satellite system uplink/downlinks, phased-array radar and DBS receivers.

Amplifiers, Diodes/FETs/Transistors, Millimeter-wave Components, MMICs, Optoelectronic Components/Fiber Optics

Future Electronics **2922**
Bolton, MA

V. Artokun

Future Electronics, a highly recognized distributor with more than 30 years of experience servicing your needs, introduces its Wireless and RF Business Unit.

Amplifiers, Attenuators, Connectors/Cables/Adapters, Couplers, Diodes/FETs/Transistors, Filters, Hybrids, Isolators/Circulators, Millimeter-wave Components, Mixers/Modulators/Detectors, MMICs, Optoelectronic Components/Fiber Optics, Oscillators, Power Dividers, Power Supplies, Resistors/Capacitors/Inductors, RFICs, SAW Devices, Signal Processing Components, Synthesizers, Systems and Subsystems, Switches, Test and Manufacturing Equipment

GBC Materials **307**
Latrobe, PA

S. Johnson

GBC Materials is a full-service manufacturer capable of high volume production of both glass and ceramic components for the telecommunications, electronics, automotive and instrument industries.

Materials

GEL-PAK LLC **511**
Sunnyvale, CA

P. Kennedy, J. Beacham

GEL-PAK's innovative shipping and handling products based on a proprietary elastomer provide protection for critical semiconductor devices. The GEL-PAK product family has been expanded with the addition of Gel-Frames™ for sorting, shipping and storing KGD in a Film-Frame format.

Materials, Services, Test and Manufacturing Equipment

General Microwave, a Herley company **516**
Farmingdale, NY

T. Salina, A. Caggiano, R. Schachter, M. Tuckman, M. Schlam

The model 7328H high speed, high dynamic range I-Q vector modulator has a modulation range better than 50 MHz (6 to 18 GHz) with 12-bit TTL control.

Attenuators, Millimeter-wave Components, Oscillators, Phase Shifters, Systems and Subsystems, Switches

GGB Industries Inc. **2121**
Naples, FL

G. Boll, H. Boll, M. Birmingham

Manufacturer of precision test instruments – Picoprobe line of microwave and oscilloscope probes, probe cards, cables and calibration substrates.

Test and Manufacturing Equipment

GHz Technologies Inc. **1511**
St-Laurent, Quebec, Canada

D. Geller, M. Bernleithner

GHz Technologies Inc. specializes in high volume, custom-made diplexers/filters for use in LMDS, MMDS, point-to-point and point-to-multipoint radios.

Attenuators, Connectors/Cables/Adapters, Couplers, Filters, Isolators/Circulators, Millimeter-wave Components, Power Dividers, Terminations, Waveguide and Waveguide Components

GHz Technology Inc. **2602**
Santa Clara, CA

M. Mallinger

World's highest power pulsed products for avionics applications and introducing LDMOS product for avionics driver applications.

Diodes/FETs/Transistors

Gigatech Co. Ltd. **2605**
Yongin-Si, Korea

I.Han

Connectors, cable assemblies, adapters, attenuators, power dividers and terminations will be featured.

Attenuators, Connectors/Cables/Adapters, Power Dividers, Terminations

Giga-tronics **1621**
San Ramon, CA

B. Morrell

The Giga-tronics Instrument Division supplies RF and microwave frequency synthesizers and power measurement instruments for use in cellular, PCS, radar testing, satellite and telecommunications systems applications.

Synthesizers, Test and Manufacturing Equipment

Gilbert Engineering **1408**
Glendale, AZ

J. Roberts

Gilbert Engineering designs and manufactures subminiature, blindmate and microwave frequency interconnect systems. The GPO™ and GPPO™ interconnect systems are the quality, performance and cost answer for your high reliability connection needs.

Connectors/Cables/Adapters

GIL Technologies **2306**
Collierville, TN

C. Zimmerman

The GML 1000 copper-clad laminate product line for high frequency applications has been extended to include GML 1100 with thicknesses of 0.0035" and 0.0039".

Materials

Gowanda Electronics **638**
Gowanda, NY

D. Schack, D. Minnick

All new offerings of SMD power and configurations in molded and open packages are available.

Filters, Resistors/Capacitors/Inductors, Shielding

G.T. Microwave Inc. **213**
Randolph, NJ

G. Apsley, T. Baliotis

Ultrabroadband microwave integrated components with operating bandwidths from 2 to 18 GHz, including I and Q vector modulators, phase shifters, switches, attenuators and custom subassembly integration.

Attenuators, Couplers, Hybrids, Mixers/Modulators/Detectors, Phase Shifters, Power Dividers, Systems and Subsystems, Switches

[Continued on page 116]


From
Milliwatts to
Megawatts
SPECIALIZED
Microwave
Components
PRODUCT RANGE:
TRAVELING WAVE TUBES
MAGNETRONS
PASSIVE COMPONENTS
LOW NOISE AMPLIFIERS
INTEGRATED MICROWAVE ASSEMBLIES
COMPLETE FRONT ENDS
FOR:
AVIONICS
DEFENSE
COMMUNICATIONS
MEDICAL
INDUSTRIAL
CUSTOM DESIGN PRODUCT DEVELOPMENT
WORLD CLASS CUSTOMER & PRODUCT SUPPORT
Shopping for microwave products couldn't be easier. Marconi is world renowned as the company with a wide range of components across the entire microwave spectrum. Now with the integration of solid-state activities Marconi can offer even more innovative integrated solutions for your requirements.
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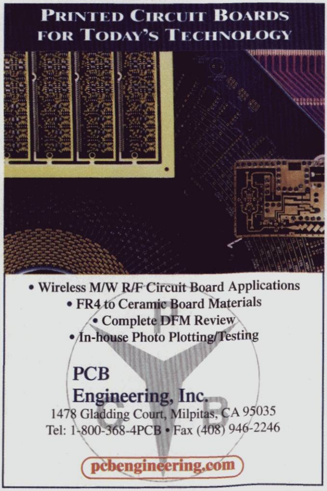
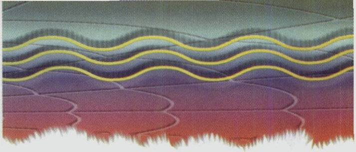
UK: Tel +44 (0)1245 453501 Fax +44 (0)1245 453703 email info@eev.com
Website: www.marconitech.com
Marconi
Marconi Applied Technologies





Habia Cable **236**
Princeton, NJ

K. Lundstrom, C. Sharp

Manufacturers of cable for telecommunications applications. New products include Multibend® the flexible alternative to semirigid coaxial cables, and Speedflex® halogen-free, high performance coaxial cables.

Connectors/Cables/Adapters

Harbour Industries **217**
Shelburne, VT

J. Palasciano, S. Dike

High performance foam dielectric coaxial cables and Sureform coaxial cables will be featured.

Connectors/Cables/Adapters

Haverhill Cable & Mfg. Corp. **819**
Haverhill, MA

D. Kneeland, S. Raucci, T. Kneeland

Cables of various sizes, types and finishes will be featured as well as cable assemblies, delay lines and components. (Semirigid and flexible versions are available.)

Connectors/Cables/Adapters

HEI Inc. **1215**
Victoria, MN

D. DeCosse, P. Chandler

The company is a full-service design and contract manufacturer providing custom solutions including high frequency MMIC chip packages, high linearity power amplifiers and complex front-end RF modules up to 50 GHz.

Amplifiers, Hybrids, Millimeter-wave Components, Optoelectronic Components/Fiber Optics

Heraeus Inc. **441**
W. Conshohocken, PA

P. Barnwell, J. Alexander, D. Malanga, C. Sabo, C. Fisher, A. London, M. O'Neill

Advanced materials for wireless and microwave applications will be featured with a focus on the company's KQ technology.

Materials

Herley-MDI **516**
Woburn, MA

R. Poirier, W. Sirois, J. Pare, M. Tucci, R. Provenzano

Solid-state receiver protectors, broadband multithrow switch matrices and an SP25T switch matrix will be featured.

Attenuators, Hybrids, Systems and Subsystems, Switches, Waveguide and Waveguide Components

Herotek **1104**
San Jose, CA

T. Wadholm Jr., E. Colety, C. Lai, B. Beniers

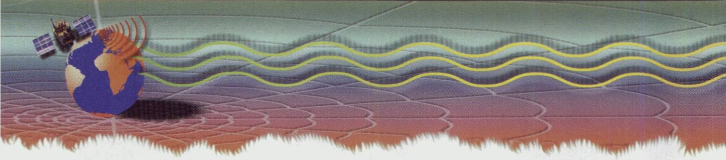
The company's wireless and millimeter-wave components include amplifiers, detectors and harmonic multipliers up to 50 GHz as well as super wideband amplifiers and components for optical modulation applications.

Amplifiers, Filters, Isolators/Circulators, Millimeter-wave Components, Mixers/Modulators/Detectors, Phase Shifters, Switches, Waveguide and Waveguide Components

Hexawave Inc. **2017**
Hsinchu, Taiwan, ROC

J. Bon

[Continued on page 118]



Hexawave Inc. designs, manufactures and markets GaAs-based microwave components. Products include MESFETs, MMICs, switches and power amplifiers. The company also provides high quality foundry service for MESFET and pHEMT with a well-furnished fab to handle 3" and 4" wafers.

Diodes/FETs/Transistors, MMICs, RFICs, Switches

Hi-Rel Alloys Ltd. **3009**
Fort Erie, Ontario, Canada

R. Stroehlein, T. Ganzenmuller

Metal piece parts for microelectronic packaging, eutectic solder preforms, hermetic lids, thermal spreaders for GaAs chips, moly tabs, a hydrogen/moisture getter, ring frames and precious metal for evaporation/sputtering will be featured.

Hybrids, Materials, Services

Hitachi Metals America **808**
Arlington Heights, IL

T. Dunne

Hitachi Metals manufactures a wide range of microwave components and is proud to introduce its new 4 mm isolator. Also available are antenna switch modules for cellular applications.

Couplers, Filters, Isolators/Circulators, Mixers/Modulators/Detectors, Switches

Hitachi Semiconductor America Inc. **812**
San Jose, CA

P. Patterson

Hitachi offers RF solutions for subscriber handset and base station applications. The company is a leading supplier of hybrid and discrete power amplifiers.

Amplifiers, Diodes/FETs/Transistors, Hybrids, Mixers/Modulators/Detectors, MMICs, Optoelectronic Components/Fiber Optics, RFICs, SAW Devices, Synthesizers

Hittite Microwave Corp. **431**
Chelmsford, MA

N. Hildreth, S. Daly

The company offers a broad range of MMIC components in die and packaged form from DC to 40 GHz. New millimeter-wave ICs, broadband low cost digital attenuators and multithrow switches will be introduced.

Amplifiers, Attenuators, Millimeter-wave Components, Mixers/Modulators/Detectors, MMICs, Optoelectronic Components/Fiber Optics, Oscillators, Phase Shifters, RFICs, Switches

Honeywell **101**
Plymouth, MN

B. Gingerich

Honeywell's custom 0.8 μm SOI CMOS microwave foundry platform features integration of active CMOS devices for RF, digital, analog and passives on a single IC.

Amplifiers, Attenuators, Mixers/Modulators/Detectors, RFICs, Switches

HTA Photomask, a division of HTA Enterprises Inc. **735**
San Jose, CA

K. Caple, P. Melen, K. Lycett

HTA Photomask is an established full-service mask-making company specializing in thin-film mask for microwave circuits.

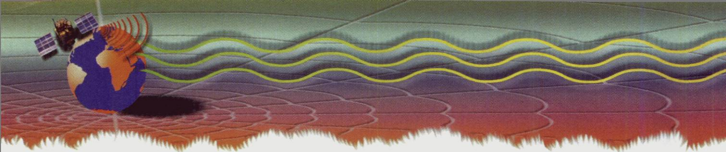
Services

Hypertronics Corporation **2610**
Hudson, MA

T. Kannally

High mating cycle, low insertion force coaxial contacts and connectors will be exhibited. Uses

[Continued on page 122]



include wireless devices, test equipment and portable computers for testing, battery charging and information transferral.

Connectors/Cables/Adapters

IMI Inc. **2407**
Haverhill, MA

P. Beaulieu, L. Shea, M. Gys, E. Macknes

Bonded stripline, microstrip, antennas, mixed dielectric processing and printed circuit boards supporting the wireless market will be featured. (Quick-turn prototype to production.)

Amplifiers, Printed Circuit Boards

IMS Connector Systems **611**
Lewisville, TX

B. Morrow, E.Greif, D. Rogers

Lightning protectors will be featured.

Connectors/Cables/Adapters, Couplers

IMST GmbH **1310**
Kamp-Lintfort, Germany

J. Borkes, A. Lauer, D. Köther

RFIC, MMIC and LTCC design services will be featured.

Amplifiers, Antennas/Radomes, MMICs, Printed Circuit Boards, RFICs, Services, Software, Systems and Subsystems, Test and Manufacturing Equipment

Infineon Technologies **531**
San Jose, CA

J. Cochrane, P. Thesing, C. Schmidek

Infineon offers a line of components and subsystems including discretes, MMICs, ICs, and chip sets and SAW filters for wireless RF front-end applications. Devices include Si RF transistors, GaAs transistors, PIN/varactor/Schottky diodes, Si MMICs, GaAs MMICs, RX/TX ICs and SAW filters. Building block MMICs such as switches, mixers, PAs and LNAs are available in GaAs. MMIC building blocks such as broadband gain blocks and self-biased transistors are available in silicon.

Amplifiers, Diodes/FETs/Transistors, Filters, Millimeter-wave Components, Mixers/Modulators/Detectors, MMICs, Optoelectronic Components/Fiber Optics, Oscillators, RFICs, SAW Devices, Synthesizers, Systems and Subsystems, Switches

Inmet Corporation **2025**
Ann Arbor, MI

T. Solomon, R. Garvey, C. Lindberg

Inmet is a designer and manufacturer of high quality, precision-made microwave components for commercial and military applications worldwide. Products include adapters, attenuators, DC blocks, equalizers, power dividers, terminations and resistors that operate over the DC to 50 GHz frequency range. The company is recognized for precision manufacturing, quality, competitive pricing and timely delivery.

Attenuators, Couplers, Resistors/Capacitors/Inductors, Terminations

In Phase Technologies **1025**
Clarksburg, NJ

E. MacMullen

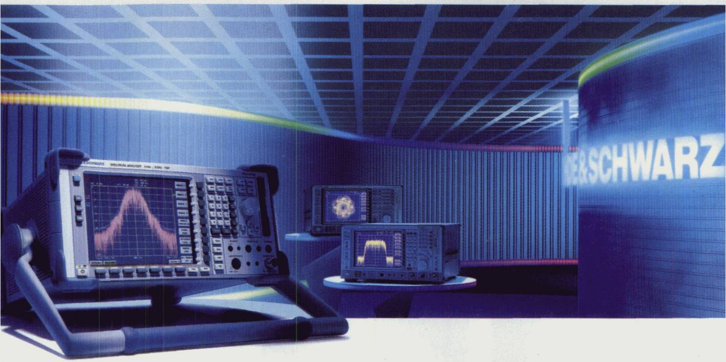
Automatic test equipment for optical wafers and satellite payloads will be featured as well as High Rel assemblies and direct sequence spread spectrum transceivers.

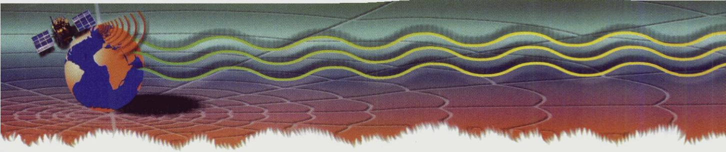
Millimeter-wave Components, Synthesizers, Test and Manufacturing Equipment

Insulated Wire Inc. **607**
Danbury, CT

S. Bruno, A. Nixon, M. Brewster

[Continued on page 124]





Microwave cable, cable assemblies and adapters up to 50 GHz will be featured.

Connectors/Cables/Adapters

Integra Technologies Inc. **440**
Torrance, CA

A. Barsegyan, J. Burger, J. Titizian

New products include a 3.1 to 3.4 GHz, 100 W transistor (300 μs/10%); a 1.2 to 1.4 GHz, 300 W device (250 μs/10%); and a MODE-S 800 W device (MODE-S pulse burst).

Diodes/FETs/Transistors

Integrated Microwave Corp. **1018**
San Diego, CA

C. Buck, D. Clark

Integrated Microwave designs and manufactures a full range of high performance ceramic, cavity and lumped filters and diplexers for commercial wireless and communications applications.

Filters

International Manufacturing Services Inc. **640**
Portsmouth, RI

B. Black, B. Hall, D. McHenry

Featured products include aluminum nitride chip terminators, ultra-low ohm Kelvin chip resistors, full and partial wraparound thick- and thin-film chip resistors, single-side chip resistors and surface-mount chip attenuators.

Resistors/Capacitors/Inductors

Ion Beam Milling **618**
Manchester, NH

R. Quagan, D. Marcotte

Custom think-film optoelectronic, microwave and millimeter circuits fabricated on a wide variety of dielectrics will be featured. Spiral inductors on quartz are the company's "fine line" specialty.

Attenuators, Couplers, Materials, Millimeter-wave Components, Optoelectronic Components/Fiber Optics, Printed Circuit Boards, Resistors/Capacitors/Inductors, Services

ITS Electronics Inc. **2918**
Concord, Ontario, Canada

ITT Industries, Microwave Systems **3000**
Lowell, MA

P. Macdonald, B. Lambalot, M. Chilton, S. Murray, T. Bompastore, B. Payne

Low cost Ku-band synthesizers will be featured.

Hybrids, Oscillators, Signal Processing Components, Synthesizers, Systems and Subsystems

Ixion Technologies **635**
Fall River, MA

S. Benisatto, M. Medeiros

New lightweight, high thermal, low expansion material for packages, heatsinks or any thermal applications will be featured.

Materials

Janco Electronics **300**
Dover, NH

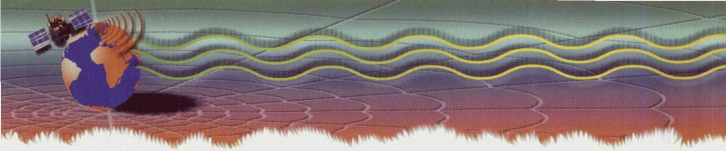
S. Sousa, J. Piwinski, B. Belanger, S. Driscoll

The company is a contract manufacturer for digital, microwave and RF assembly and test. Circuit board fabrication, microstrip, stripline, mixed-dielectric and prebonded metal back circuits will be featured.

Printed Circuit Boards

Jansen Microwave GmbH **1306**
Aachen, Germany

[Continued on page 126]



A. Meyer

The LINMIC+/N microwave & RFIC design suite MMIC CAD software (for Windows and UNIX/Linux) will be featured.

Services, Software

JCA Technology Inc. **308**
Camarillo, CA

G. Wasylewski

Amplifiers

JFW Industries **1006**
Indianapolis, IN

B. Walker, B. Zook, S. Watkins

Since 1979, JFW Industries has been a leader in engineering and manufacturing RF attenuators, switches, power dividers and test systems, delivering custom solutions at catalog prices.

Attenuators, Power Dividers, Switches, Terminations

Johanson Manufacturing Corporation **2004**
Boonton, NJ

R. Kauffman

Variable capacitors, air dielectric and ceramic types, will be featured as well as microwave tuning elements and fiber-optic connectors and components.

Resistors/Capacitors/Inductors

Johanson Technology Inc. **1313**
Camarillo, CA

S. Cole

Single-layer capacitors with border, gap and custom thin-film configurations will be featured as well as ISM bandpass filter chips, 0402 and 0603 high frequency MLCs with free S-parameter and SPICE modeling software.

Resistors/Capacitors/Inductors

Johnson Components **410**
Waseca, MN

J. Sybilrud

Johnson Components designs and manufactures RF coaxial connectors with SMA, SMB, SMC, MCX, MMCX, BNC, TNC, UHF, Mini-UHF and N interfaces as well as electronic hardware products.

Connectors/Cables/Adapters

John Wiley & Sons Inc. **2218**
New York, NY

D. Imus

John Wiley & Sons Inc. is an independent global publisher of print and electronic products specializing in scientific, technical and medical books and journals. New titles include Rohde: *RF/Microwave Circuit Design for Wireless Applications*; Chang: *RF and Microwave Wireless Systems*; and Chang/Sze: *ULSI Devices*. Journals include *Microwave and Optical Technology Letters* and the *International Journal of RF and Computer-aided Engineering*. Visit us online at www.wiley.com.

Publications

Jye Bao Co. Ltd. **105**
Taipei, Taiwan, ROC

C. Li, A. Chen, B. Wang

Connectors/Cables/Adapters

K&L Microwave Inc. **1606**
Salisbury, MD

L. Abbagnaro, D. Howett, G. Carmean

K&L Microwave offers RF/microwave and wireless filters, including ceramic, cavity, lumped element, waveguide and tunable, for military, commercial and telecommunications applications.

Filters, Waveguide and Waveguide Components

Kalmus **1322**
Bothell, WA

L. Smale, J. Olson

The company is a specialist in amplifiers, giving a genuine choice of performance, features and bandwidth for all RF power applications from 5 W to 10 kW, from 10 kHz to 100 MHz and beyond.

Amplifiers

Kaman Instrumentation **1913**
Colorado Springs, CO

R. Tyson, J. Foreman, J. Maddalena, T. Dillahunty, M. Winkler

The Microwave Products Group designs, manufactures and markets Stable Cable™ high performance coaxial cable assemblies and microwave components for demanding space, electronic warfare and airframe, and test applications.

Connectors/Cables/Adapters, Services

Karl Suss America **2923**
Waterbury Center, VT

KDI/Triangle Corporation **2025**
Whippany, NJ

M. Snyder, C. Schraufnagl, H. Shin

Designer and manufacturer of state-of-the-art technology for the RF and microwave industry for both commercial and military applications. Products include fixed attenuators (coaxial, chip and packaged stripline configurations), high power frequency resistors and terminations, amplifiers, digital diode switches, couplers, detectors, levelers, mixers, duplexers, upconverters, modulators, oscillators, phase shifters, discriminators, hybrid microelectronic circuits and custom components.

Amplifiers, Antennas/Radomes, Couplers, Mixers/Modulators/Detectors, Systems/Subsystems, Switches, Terminations

Kevlin Corporation **406**
Wilmington, MA

M. Federico, R. Lambrecht, J. Moran, A. Peuerin

Kevlin is a leader in RF rotary joints. Products include waveguide/coaxial single- to multichannel rotary joints with integrated slip rings/encoders. The company also repairs/refurbishes any manufacturer's rotary joints.

Couplers, Millimeter-wave Components, Waveguide and Waveguide Components

KMW Inc. **827**
Cerritos, CA

Y. Kim, A. Simmons, V. Chung

KMW is an RF and microwave component manufacturer and subsystem integrator. The company provides total solutions by incorporating its own components, including cable assemblies, electromechanical switches, TTLNAs, switchable combiners/dividers and phase shifters.

Amplifiers, Connectors/Cables/Adapters, Filters, Isolators/Circulators, Phase Shifters, Power Dividers, Systems and Subsystems, Switches, Waveguide and Waveguide Components

Korea Sangshin Electric Co. Ltd. **104**
Choongnam, South Korea

E.M. Choi

The company is a leading ISO 9002-certified contract manufacturer, supplying electronic components such as microwave filters, voltage-controlled oscillators and resonators since 1973.

Filters, Hybrids, Oscillators

Krytar Inc. **2511**
Sunnyvale, CA

D. Yoshii

Detectors and power meters will be featured.

Couplers, Hybrids, Power Dividers, Terminations

KW Microwave Corporation **315**
Carlsbad, CA

S. Tantod, D. Tantod, O. Rodriguez

The company manufactures RF/microwave components and subsystems, multiplexers, switch filters, PIN diode control switches, active/passive multipliers, ferrite circulators/isolators, ceramic filters, GPS filters, diplexers, low noise amplifiers and preamplifiers.

Amplifiers, Filters, Isolators/Circulators, Switches, Waveguide and Waveguide Components

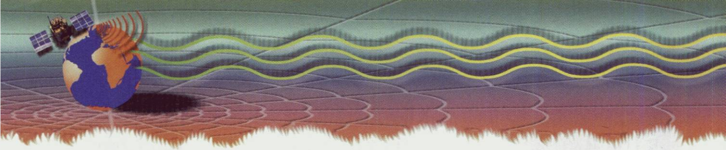
Kyocera America Inc. **2238**
San Diego, CA

B. Hamm, D. Berkel, E. Rose, B. Palumbo, M. Marder, F. McMahon, A. Piloto, J. Howell, T. Keegan, D. Hughes

Kyocera America designs, manufactures and assembles a broad range of electronic packaging solutions for the telecommunications and semiconductor markets based on advanced ceramic material technologies. The company's packages and services support broadband telecommunications, mobile and satellite communications, surveillance systems, sensors, automotive electronics, medical devices, computers and consumer electronics applications.

Antennas/Radomes, Materials, Millimeter-wave Components, MMICs, Optoelectronic Components/Fiber Optics, Services

[Continued on page 128]



Kyocera Industrial Ceramics Corp. **1224**
Vancouver, WA

C. Johnson, F. Roginski

Dielectric ceramic resonators, HDC substrates, sapphire, thick- and thin-film substrates, ferrites, AlN substrates, pressed and extruded insulators, and GPS patch antennas will be featured.

Antennas/Radomes, Hybrids, Resistors/Capacitors/Inductors

L-3 Communications – Narda West **1514**
Folsom, CA

L. Becker, M. Ferrand

Wireless filters and duplexers for AMPS, GSM, PCS and 3G will be featured as well as filters and multiplexers for military and space applications (UHF through Ku band), and isolators and circulators (500 MHz through 26 GHz).

Filters, Isolators/Circulators

Labtech Ltd. **2508**
Presteigne, Powys, UK

R. Lowther, B. Mazonas

MMIC interconnection products and conformal antennas will be featured. See www.labtechnical.com for a technical forum.

Antennas/Radomes, MMICs, Printed Circuit Boards, Services

Laserage Technology Corp. **3010**
Waukegan, IL

R. Capp, J. Coel

Laserage Technology Corp. is ISO 9002 certified and offers laser machining and scribing of ceramics, laser machining, cutting and drilling of metals, plastics, composites and laser welding of most metals. Custom cable and wire harness assembly services are also available. A companywide TQM/JIT program is in place.

Amplifiers, Connectors/Cables/Adapters, Hybrids, Materials, Oscillators, Power Supplies, Printed Circuit Boards, Services

Linearizer Technology Inc. (LTI) **126**
Hamilton, NJ

A. Katz, E. Klepner, R. Dorval, T. Ulrich, J. Dragone, A. Guida

LTI, a leader in distortion correction, announces new digital controlled adaptive linearizers for SSPAs and TWTAs in modular and rack-mount units.

Services, Signal Processing Components, Systems and Subsystems

Litton Electron Devices **1817**
San Carlos, CA

R. Elmore

Litton's new L-6096 helix TWT for satellite communications has a frequency range of 13.75 to 14.5 GHz with a minimum CW power output of 200 W.

Amplifiers, Millimeter-wave Components, Power Supplies, Systems and Subsystems, Tubes

Litton Winchester/Retconn **1817**
Watertown, CT

C. Ashworth, T. Wrenn

A full line of wireless antennas, RF coaxial connectors and cable assemblies is available.

Antennas/Radomes, Connectors/Cables/Adapters

Lorch Microwave **1808**
Salisbury, MD

K. Bernstein, P. Bernstein, M. Oluvic

Lorch Microwave, an ISO 9001-certified company, designs and manufactures custom ceramic, waveguide, cavity and discrete filters, diplexers and subassemblies to 40 GHz for commercial wireless and military applications.

Filters, Phase Shifters, Waveguide and Waveguide Components

LPKF Laser & Electronics **609**
Wilsonville, OR

S. Schmidt, J. Johnson, A. Haber

Prototype boards are available in record time with 4 mil trace and space width using Teflon® FR4 and Duroid® materials. Watch us create boards with the LPKF ProtoMat C60®

Materials, Printed Circuit Boards, Software

M2 GLOBAL Technology Ltd. **800**
San Antonio, TX

C. Salsberry, J. McCollum, J. Goebel

M2 Global, an ISO 9001-registered company, applies advanced ferrite technology to provide a variety of isolators and circulators in coax, waveguide, drop-in and surface-mount configurations covering frequencies of 300 MHz to 40 GHz. These devices are backed by a 10-year warranty, the best in the business, and are ideal for use in cellular, PCS, GSM, CDMA, satellite and commercial communications applications.

Filters, Isolators/Circulators, Services, Terminations, Waveguide and Waveguide Components

M/A-COM Aerospace & Defense Products **401**
Lowell, MA

B. Perrier

GaAs MMICs for active phased array and other defense applications, including high power amplifiers, low noise amplifiers and multifunction ICs, will be featured. (Formerly ITT GaAsTEK.)

Amplifiers, Antennas/Radomes, Attenuators, Connectors/Cables/Adapters, Couplers, Diodes/FETs/Transistors, Hybrids, Isolators/Circulators, Millimeter-wave Components, Mixers/Modulators/Detectors, MMICs, Phase Shifters, Power Dividers, RFICs, Signal Processing Components, Systems and Subsystems, Switches, Terminations, Waveguide and Waveguide Components

M/A-COM Inc. **2107**
Lowell, MA

D. Hutcheson

Amplifiers, Antennas/Radomes, Attenuators, Diodes/FETs/Transistors, Isolators/Circulators, Millimeter-wave Components, Oscillators, RFICs, Switches

Marconi Caswell Ltd. **537**
Towcester, Northants, UK

S. Cornelius, M. Seen

Millimeter-wave MMICs for broadband radio access LNAs, driver amplifiers and power amplifiers covering the 20 to 40 GHz frequency range will be featured.

Amplifiers, Attenuators, Millimeter-wave Components, MMICs, Switches

Marki Microwave Inc. **1223**
Morgan Hill, CA

F. Marki, C. Marki

Mixers and converters from DC to 40 GHz, mixer-based subassemblies, low noise receivers and medium power transmitters for point to multipoint and LMDS applications will be featured.

Mixers/Modulators/Detectors, Services, Systems and Subsystems

Maryatt Technologies Inc. **540**
Sunnyvale, CA

C. Maryatt, A. Maryatt, D. Schwertfeger

The company offers custom turnkey hermetic packaging utilizing aluminum, Kovar, stainless steel and titanium. Certified to your specifications from commercial to Hi-Rel.

Diodes/FETs/Transistors, Filters, Hybrids, Isolators/Circulators, Millimeter-wave Components, Mixers/Modulators/Detectors, Oscillators, Power Dividers, Waveguide and Waveguide Components

Maury Microwave Corporation **1411**
Ontario, CA

M. Maury, J. Adamson, S. Bali, G. Simpson, J. King, D. Smith, B. Szendrenyi, D. Anderson

Items featured in the device characterization Automated Tuner System (ATS) line include the 8 to 50 GHz high matching range coaxial tuner, dynamic prematching for subohmic devices, signal synthesis software, the Maury ATS to HP/Agilent ADS software data module, and harmonic and on-wafer systems. Also available are 250 MHz to 110 GHz systems.

Connectors/Cables/Adapters, Millimeter-wave Components, Signal Processing Components, Software, Systems and Subsystems, Terminations, Test and Manufacturing Equipment, Waveguide and Waveguide Components

MCE Companies Inc. **2025**
Ann Arbor, MI

J. Smucker, G. Smith, M. Burton, C. Schraufnagl

A leader in the design and manufacture of RF, microwave and wireless components and subsystems, MCE Companies comprises four innovative companies: Inmet Corporation, KDI/Triangle Corporation, Metelics Corporation and

[Continued on page 130]

Weinschel Corporation. These companies design and manufacture a wide variety of RF/microwave components and subsystems that can be found in applications worldwide.

Mega Industries **2801**
Gorham, ME

D. Paul Sr., R. Backman, J. Matzen

Mega Industries is a manufacturer of high power, low frequency fabricated waveguide components. The company's expanded product line now includes an inventory of copper, bronze, aluminum and Invar tubing in sizes from WR10 to WR2300.

Attenuators, Couplers, Hybrids, Phase Shifters, Power Dividers, Terminations, Waveguide and Waveguide Components

MegaPhase **2411**
Stroudsburg, PA

B. Pote, M. Sage Pote, J. Bright, D. Lutkins, C. Bourne

Featured products include the SM series site measurement cable test assemblies for field measurement, phase matched vector network analyzer test cable with the new NK connector, fiber-optic patch cables, waveguide-to-coax adapters and 50 GHz VNA cable.

Connectors/Cables/Adapters, Millimeter-wave Components, Optoelectronic Components/Fiber Optics, Test and Manufacturing Equipment, Waveguide and Waveguide Components

Meggitt Safety Systems Inc. **109**
Simi Valley, CA

B. Miller, C. Wright

Silicon dioxide insulated cable and delay lines in diameters as small as 0.047" as well as electrically stable assemblies for aircraft, satellite, missile and LRU applications will be featured. ISO 9001 certified.

Connectors/Cables/Adapters

MEMSCAP **3013**
Saint Ismier, France

P. Albert

RF-MEMS design tools and RF-MEMS components (including capacitors, switches and filters) will be featured.

Filters, Resistors/Capacitors/Inductors, Software, Switches

Merrimac Industries **1705**
West Caldwell, NJ

R. Dec, J. Dimech

Multi-Mix™ is a patent-pending, three-dimensional, multilayer process for designing integrated circuits and micromultifunction modules (MMFM™). Multi-Mix enables quads, couplers, filters, multiplexers, MMICs and other active and passive circuits to be packaged individually or cascaded into supercomponents for mixer/preamplifiers, vector modulators, feedforward networks, complex antenna feed distribution networks and other wireless applications.

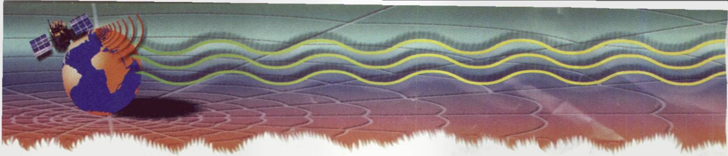
Couplers, Filters, Hybrids, Millimeter-wave Components, Mixers/Modulators/Detectors, Power Dividers, Signal Processing Components

Metelics Corporation **2025**
Sunnyvale, CA

F. Kwan, J. Godbout, R. Curby, C. McAllister, M. Dudero, J. Gagni

Metelics designs and manufactures a wide variety of microwave diodes and components. Since 1979, the company has supplied the microwave industry with high quality products that are used in commercial, industrial and high reliability applications. Products include PIN diodes, chip capacitors, RF/microwave components and subassemblies, detectors, step recovery diod

[Continued o



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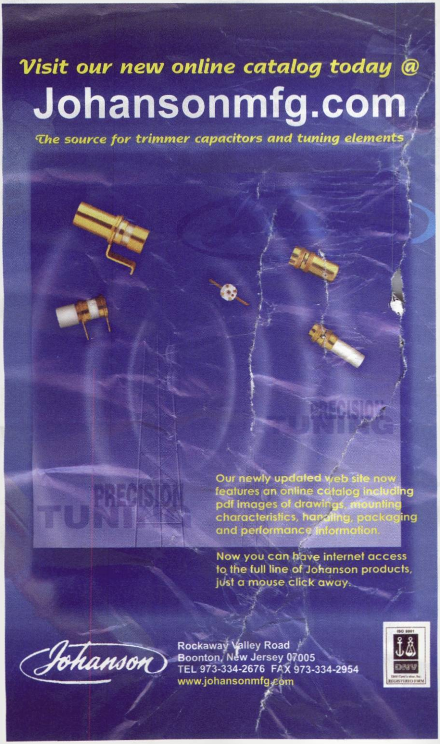
Attenuators, Couplers, Hybrids, Phase Shifters, Power Dividers, Terminations, Waveguide and Waveguide Components



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Connectors/Cables/Adapters, Millimeter-wave Components, Optoelectronic Components/Fiber Optics, Test and Manufacturing Equipment, Waveguide and Waveguide Components

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Simi Valley, CA

B. Miller, C. Wright

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Connectors/Cables/Adapters

MEMSCAP **3013**
Saint Ismier, France

P. Albert

RF-MEMS design tools and RF-MEMS components (including capacitors, switches and filters) will be featured.

Filters, Resistors/Capacitors/Inductors, Software, Switches

Merrimac Industries **1705**
West Caldwell, NJ

R. Dec, J. Dimech

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Couplers, Filters, Hybrids, Millimeter-wave Components, Mixers/Modulators/Detectors, Power Dividers, Signal Processing Components

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Sunnyvale, CA

F. Kwan, J. Godbout, R. Curby, C. McAllister, M. Dudero, J. Gagni

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[Continued on page 132]

At Trilithic, we understand that everyone's needs are a little different. And we're a little different in the way our engineers see the world. That's how we're able to create some of the most innovative products in the industry, including our line of custom filters. We offer a complete selection of filters (bandpass, lowpass, highpass, bandreject, helical resonators and dielectric resonators) in a variety of formats (surface mount, PC mount, cavity, combline, tubular, tunable, miniature, connectorized, hermetically sealed). Our filters can be designed for commercial, space, military and industrial applications. With a frequency range of 30 KHz to 18 GHz, and power up to 4 kW CW, we can customize a filter to cover the depth and breadth of any project. Put simply, no application is alien to us.

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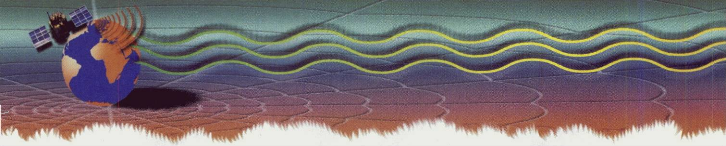


tuning varactors, PIN diode chips and beam leads.

Diodes/FETs/Transistors, Resistors/Capacitors/Inductors

Metropole Products Inc. **1025**
Stafford, VA

G. DePaola, A. Leaman

UHF SATCOM diplexer/LNA subassemblies will be featured.

Amplifiers, Couplers, Filters, Systems and Subsystems

MICA Microwave **610**
San Jose, CA

F. Mills, J. Rapadas

Mica Microwave products include a ferrite junction isolator and circulator, mixers, frequency doublers, detectors, limiters and multifunctional modules for military, space and commercial systems.

Isolators/Circulators, Mixers/Modulators/Detectors

Micro-Chem Inc. **715**
Santa Clara, CA

T. Selski

The company is a manufacturer of stripline, microwave and rigid ground plane PTFE circuit boards, specializing in single-sided, double-sided and multilayer Teflon and mixed dielectric substrates.

Printed Circuit Boards

Micro-Coax **418**
Pottstown, PA

B. Ash, J. Lewis, S. White, M. Andrioff

Building upon our industry leadership in microwave semirigid and flexible cables, Micro-Coax introduces tin-dipped formable cable in 0.047", 0.085", 0.141" and 0.250" diameters.

Connectors/Cables/Adapters

MicroFab **1025**
Manchester, NH

J. Kelley

Featured products and services include custom thin-film circuits, laser diode submounts and micromachining using an ion etching process to provide superior fine features with repeatable high yields.

Attenuators, Couplers, Filters, Hybrids, Isolators/Circulators, Millimeter-wave Components, Mixers/Modulators/Detectors, MMICs, Optoelectronic Components/Fiber Optics, Power Dividers, Resistors/Capacitors/Inductors, SAW Devices, Terminations

Micro Lambda Inc. **1328**
Fremont, CA

R. Leier, J. Nguyen, S. Wetenkamp, D. Soddarth

"Active Display" for the latest YIG-based synthesizer covering the 2 to 10 GHz frequency range. Specifications include greater than +10 dBm output power with frequency step size down to 1 Hz.

Filters, Millimeter-wave Components, Oscillators, Synthesizers

Micro Metalsmiths Ltd. **100**
Pickering, North Yorkshire, UK

P. Horsley, D. Sharp, C. Shaw

A new innovative range of low cost cavity filters being produced in high volumes for commercial applications (LMDS) has been developed by Micro Metalsmiths, building on more than 35 years of supplying quality components to the microwave industry.

Antennas/Radomes, Connectors/Cables/Adapters, Couplers, Filters, Millimeter-wave Components, Power Dividers, Waveguide and Waveguide Components

MicroMetrics Inc. **2100**
Londonderry, NH

J. Morgan, D. Langan, F. Gilligan, C. Lien

MicroMetrics is a leading manufacturer of point contact diodes. The company also manufactures hyperabrupt, abrupt and microwave tuning diodes, step recovery diodes, PIN/limiter and beam lead PIN diodes, capacitors, thin-film resistors, spiral inductor and Schottky diodes.

Diodes/FETs/Transistors, Resistors/Capacitors/Inductors

Micro-Mode Products Inc. **621**
El Cajon, CA

J. Lokken, P. Czikora, R. Benitez, M. Perry, D. Robinson, M. Cuban

MSSS ultraminiature blindmate coaxial connectors, which feature center to center spacing down to 0.100", will be featured. Hermetic packages and coaxial connectors for commercial, high reliability and space level applications are available.

Connectors/Cables/Adapters

Micronetics Wireless **821**
Hudson, NH

R. Marrone, D. Robbins, S. Bernstein, J. Puna, C. Iodice, F. Parin

The company will feature the new AWGN generator and multipath fading simulator for CDMA applications; wideband 0.50" VCOs designed for satellite communications, wireless local loop and broadband modems; and high power switches used in transmitter paths of communications and radar systems.

Attenuators, Diodes/FETs/Transistors, Mixers/Modulators/Detectors, Oscillators, Phase Shifters, Power Dividers, Switches, Test and Manufacturing Equipment, Waveguide and Waveguide Components

Micro Networks/ Andersen Laboratories **1037**
Worcester, MA

D. Emma, B. Nyulassy, B. King, J. Postlethwait, D. Lowcarage

Micro Networks offers a range of superior performance clock and data recovery modules and voltage-controlled oscillators for +10 Gbit high speed SONET applications. See www.micronetworks.com.

Amplifiers, Filters, Hybrids, Oscillators, SAW Devices, Synthesizers

Microsemi Corporation **1114**
Garden Grove, CA

I. Heinrichs, C. Silver

MTT-S 2000 is the first exhibition for Microsemi Corporation's expanded broadband capabilities, including MMSM™ microwave, RF and HBT GaAs semiconductors for advanced cellular, PCS and 3G, Blue Tooth and 5.7 GHz LAN applications.

Amplifiers, Diodes/FETs/Transistors, Oscillators

Microsemi Microwave Products **1114**
Lowell, MA

P. Gale

RF and microwave diodes including PIN, NIP Schottkies, limiters MNS capacitors, step recovery and noise diodes and, of course, the company's industry-leading tuning varactors, MMSM, will be featured.

Diodes/FETs/Transistors, Resistors/Capacitors/Inductors, Switches

Microsemi RF Products **1114**
Montgomeryville, PA

M. Nagle, B. Caccavale, J. Roth

The company is a manufacturer of bipolar and MOSFET RF transistors designed for applications covering HF through S-band frequencies.

Diodes/FETs/Transistors

Microsource Inc. **1617**
Santa Rosa, CA

J. Dunseth, B. Artz

The company will feature synthesizers for the LMDS market as well as fast-switching, low phase noise building blocks for high performance synthesizer applications.

Filters, Oscillators, Synthesizers, Systems and Subsystems

Micross Components Corp. **209**
Fairfield, NJ

G. Shiffman

High frequency, high Q capacitors will be featured

Diodes/FETs/Transistors, Resistors/Capacitors/Inductors

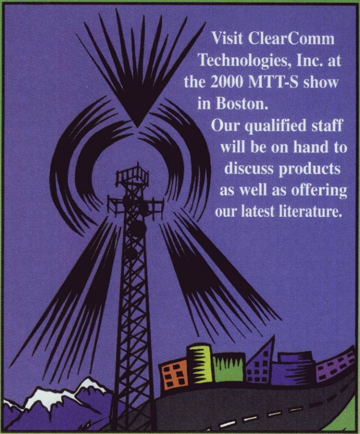
Micro Substrates Corporation **614**
Tempe, AZ

R. Panicker, B. Griffin, R. Greenman

Three new state-of-the-art VIA/BGA DC to 31.5 GHz ceramic packages will be featured. The standard VIA/BGA package dissipates 2 W. Also new for higher power applications: VIA/BGA pack-

[Continued on page 134]

Base Station Repeater Radio OEM's



Improve your system performance with ClearComm Technologies' line of "off the shelf" and custom designed, application specific Filter and Duplexer products. With ClearComm's state of the art design technology and technical support, OEM's are realizing the highest performance possible with the most cost effective solutions available.

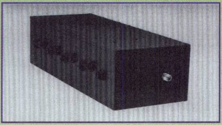
ClearComm Technologies offers a variety of filter products targeted at the wireless/telecommunications market.

Applications include:

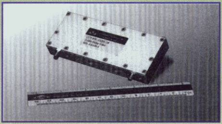
- Standard base station filters/duplexers
- Custom performance enhancing base station assemblies
- Delay filters for feed-forward amplifiers
- Cosite interference solutions
- Diplexers for 2.4-5.8GHz radios
- Custom products up to 40GHz

PCS/Cellular Duplexers

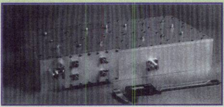
Transmit Receive Filters



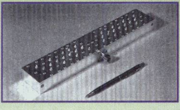
Delay Filter



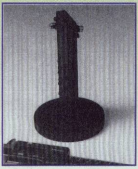
Integrated Assemblies



2.4/5.8 Duplexers



Waveguide/Duplexers



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ClearComm

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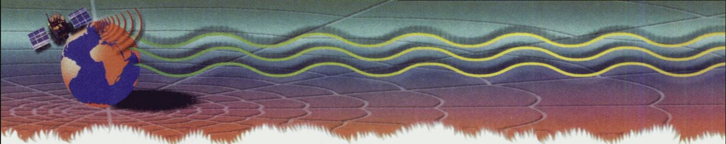
Salisbury, Maryland 21801



ages can be supplied with heat sinks.

Materials, Millimeter-wave Components

Microtech Inc. **600**
Cheshire, CT

J. McGregor, J. Marino, B. Hallock

Flexible and rigid waveguide (rectangular and double-ridged) assemblies and passive microwave components from 1.12 to 110 GHz including filters, diplexers, antennas and antenna feeds will be featured.

Antennas/Radomes, Attenuators, Filters, Materials, Millimeter-wave Components, Phase Shifters, Power Dividers, Signal Processing Components, Systems and Subsystems, Switches, Terminations, Test and Manufacturing Equipment, Waveguide and Waveguide Components

Microwave Circuits Inc. **601**
Washington, DC

J. D'Ostilio, L. Tran

The company will feature custom ceramic filters and diplexers, surface-mount L/C filters and diplexers, and cavity and combline filters and diplexers. Capabilities include quick-turn prototypes and high volume manufacturing.

Filters

Microwave Communications Laboratories Inc. (MCLI) **2710**
St. Petersburg, FL

K. Kulyk, T. Nguyen

MCLI is a manufacturer of RF/microwave components specializing in power dividers, directional couplers and switches. We are pleased to announce the release of our latest eight-way power divider (PS8-118) operating from 18 to 26.5 GHz with type SMA connectors, low insertion loss and high isolation.

Attenuators, Couplers, Hybrids, Isolators and Circulators, Power Dividers, Switches, Terminations, Waveguide and Waveguide Components

Microwave dB **1021**
Newbury Park, CA

J. Hoffman, S. Horton, G. Keithley, P. Nolan, C. Mueth

New internally and externally referenced PureSource phase-locked oscillators with a range of 9 to 13 GHz, excellent frequency stability, low current consumption and ultra-low noise performance will be featured.

Amplifiers, Hybrids, Millimeter-wave Components, Oscillators, Services, Systems and Subsystems

Microwave Development Company Inc. **1000**
Salem, NH

J. Cook, C. Tomes, M. Crittenden, P. Hocknell, J. Boucher, J. MacMillan, B. Williams, J. Walker

Custom waveguide components and subassemblies including broadband, high power microwave assemblies; integrated millimeter-wave assemblies; Gunn oscillators; custom waveguide isolators/circulators; custom feeds and comparators; waveguide; and coaxial filters.

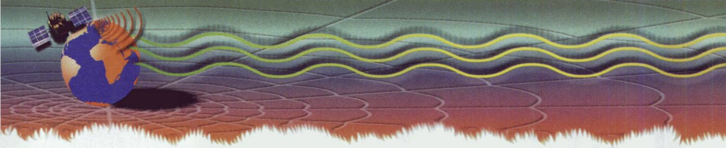
Attenuators, Couplers, Filters, Isolators/Circulators, Millimeter-wave Components, Oscillators, Power Dividers, Terminations, Waveguide and Waveguide Components

Microwave Development Laboratories (MDL) **1816**
Needham Heights, MA

E. Scollins, G. Riblet, B. Johnson, M. Hale

MDL offers a complete line of cast components from WR650 through WR10 waveguide. With the latest software we are able to model, simulate and manufacture sophisticated waveguide assemblies.

[Continued on page 136]



Antennas/Radomes, Connectors/Cables/Adapters, Couplers, Filters, Hybrids, Isolators/Circulators, Millimeter-wave Components, Mixers/Modulators/Detectors, Phase Shifters, Power Dividers, Services, Systems and Subsystems, Switches, Terminations, Test and Manufacturing Equipment, Waveguide and Waveguide Components

Microwave Devices Inc. (MDI) 2139
Franklin, IN

D. Mann, D. Mann, M. Utecht

MDI will feature its new line of drop-in circulators with an attenuator integrated for reverse power monitoring. Surface-mount filters and cable assemblies also will be offered.

Attenuators, Connectors/Cables/Adapters, Couplers, Filters, Hybrids, Isolators/Circulators, Millimeter-wave Components, Mixers/Modulators/Detectors, Power Dividers, Services, Systems and Subsystems, Terminations, Waveguide and Waveguide Components

Microwave Device Technology Corporation 802
Westford, MA

J. Dawson, M. Ayyagari, T.B. Ramachandran

Products include GaAs Gunn, abrupt and hyperabrupt varactor, PIN, IMPATT, Schottky, multiplier and ISIS diodes; millimeter-wave active components (oscillators, multipliers, switches, variable attenuators and mixers); millimeter-wave passive components (isolators, circulators, Faraday rotation devices, couplers, filters and waveguide products); and millimeter-wave subsystems, microwave sensors and wireless products.

Attenuators, Couplers, Isolators/Circulators, Millimeter-wave Components, Mixers/Modulators/Detectors, Oscillators, Power Dividers, Systems and Subsystems, Switches, Waveguide and Waveguide Components

Microwave Dynamics 1025
Irvine, CA

S. Adel, R. Earl

In addition to standard DROs, the company will be introducing CROs and new low cost DROs for the LMDS and wireless markets.

Amplifiers, Millimeter-wave Components, Oscillators, Systems and Subsystems

Microwave Engineering Corporation (MEC) 2316
North Andover, MA

J. Herrmann, R. Cheung, M. Aghion, C. Holman

MEC specializes in high power, broadband combiners; antennas; filters in stripline; and coaxial, waveguide and ridgeguide media from 0.1 to 110 GHz.

Antennas/Radomes, Attenuators, Connectors/Cables/Adapters, Couplers, Filters, Hybrids, Isolators/Circulators, Millimeter-wave Components, Phase Shifters, Power Dividers, Switches, Terminations, Test and Manufacturing Equipment, Waveguide and Waveguide Components

Microwave Innovation Group (MIG) 136
Bremen, Germany

J. Arndt

MIG provides extremely fast and rigorous WASP-NET electromagnetic CAD software. Within minutes on a PC, WASP-NET achieves the synthesis and optimization of waveguide components and networks in compliance with given specs. New developments include the CAD of dual-mode filters, antennas and wireless components.

Services, Software

Microwave Journal *818*
Norwood, MA

[Continued on page 138]

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!

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

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.

Mini-Circuits®

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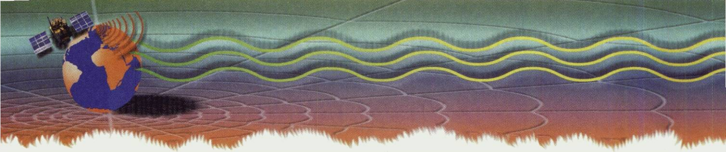
For detailed specs on all Mini-Circuits products refer to • 760 -pg. HANDBOOK • INTERNET • THOMAS REGISTER • MICROWAVE PRODUCT DATA DIRECTORY • EEM

ISO 9001 CERTIFIED



In its 43rd year, *Microwave Journal* is a premier technical journal covering RF, microwave and millimeter-wave technologies that mold the emerging wireless and commercial markets. Each issue contains valuable information on theory, practical uses and industry news.

Publications

Microwave Solutions Limited **2501**
Boreham, Herts, UK

Microwave Solutions designs and manufactures motion detector units. These microwave transceivers work at X-band and utilize the Doppler phenomenon to sense motion.

Microwave Test Solutions **1025**
Clarksburg, NJ

R. Twiggs

Direct sequence spread spectrum transceivers and communications simulators will be featured. Rapid prototyping and unit under test fixturing for most items are available.

Millimeter-wave Components, Synthesizers, Test and Manufacturing Equipment

Millitech LLC **1627**
Northampton, MA

W. Hanley, J. Lowe, D. Dixon, P. Newton, R. Chedester

An active multiplier chain (18 to 225 GHz), monopulse comparator, LNA and planar multipliers will be featured.

Amplifiers, Antennas/Radomes, Attenuators, Couplers, Filters, Isolators/Circulators, Millimeter-wave Components, Mixers/Modulators/Detectors, Oscillators, Phase Shifters, Power Dividers, Systems and Subsystems, Switches, Terminations, Test and Manufacturing Equipment, Waveguide and Waveguide Components

Millitron Inc. **2925**
Santa Clara, CA

Milmega **1322**
Ryde, Isle of Wight, UK

T. Mullineaux

Solid-state microwave amplifiers from 1 to 1000 W, 500 MHz to 10 GHz for communications (PIM), physics, EMC and defense applications. Standard products or design and build.

Amplifiers

Mini-Circuits **927**
Brooklyn, NY

B. Marks

Mini-Circuits' patented family of Blue Cell™ mixers delivers a unique combination of low conversion loss, superb temperature stability, thin profile and low cost to higher frequency designs. This level 7 (LO) MBA-671 model spans 2400 MHz to 6700 MHz with 36 dB L-R, 26 dB L-I isolation and low 6.5 dB midband conversion loss (all typical). Operating temperature is –40° to +85°C (max) and applications include satellite, ISM and PCMCIA.

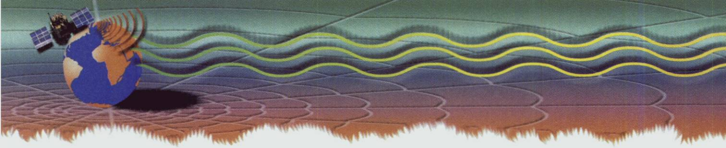
Amplifiers, Attenuators, Couplers, Filters, Hybrids, Mixers/Modulators/Detectors, MMICs, Oscillators, Phase Shifters, Power Dividers, Resistors/Capacitors/Inductors, RFICs, Signal Processing Components, Synthesizers, Switches, Terminations, Test and Manufacturing Equipment

Mini-Systems Inc. **205**
N. Attleboro, MA

W. Cashman

The company is a manufacturer of electronic components (thick-film chip resistors, thin-film chip resistors, capacitors, electronic flat packs

[Continued on page 140]



and custom hybrid circuits).

Attenuators, Hybrids, Resistors/ Capacitors/Inductors

MITEQ Inc. 419
Hauppauge, NY

D. Krautheimer, M. Haft, M. Kiiss, H. Kiiss

New products include a new-generation microwave optical link and power amplifiers for the communication markets.

Amplifiers, Couplers, Hybrids, Millimeter-wave Components, Mixers/Modulators/Detectors, Optoelectronic Components/Fiber Optics, Oscillators, Power Dividers, Signal Processing Components, Synthesizers, Systems and Subsystems, Switches, Waveguide and Waveguide Components

Mitsubishi Electronics America Inc., Electronic Device Group 411
Sunnyvale, CA

Mitsubishi Electronics America will introduce a new high power transistor family for microwave communication infrastructure applications.

Amplifiers, Diodes/FETs/Transistors, Optoelectronic Components/Fiber Optics, SAW Devices

MMCOMM Inc. 340
Torrance, CA

Y. Shih, L. Bui, D. Neilson, C. Shishido, M. Neilson

A complete product line of microwave/millimeter-wave components that are the foundation of MMCOMM's LMDS base station ODV and CPE transmit/receiver subsystems for broadband wireless applications will be featured.

Amplifiers, Antennas/Radomes, Attenuators, Filters, Isolators/Circulators, Millimeter-wave Components, Mixers/Modulators/Detectors, MMICs, Oscillators, Systems and Subsystems, Switches

Modco Inc. 1138
Sparks, NV

B. Wehe, R. Melcher

Voltage-controlled oscillators with frequency coverage from 5 MHz to 7 GHz, including the world's smallest commercial VCO measuring only 0.175" × 0.175" × 0.060", will be featured.

Oscillators

Modular Components National (MCN)/Maryland MPC 1717
Forest Hill, MD

P. Koosmann, S. Watson

MCN/MMPC will showcase microwave PCBs produced in a new 5000-square-foot plating facility. Examples will include aluminum-backed PTFE with PTH, mixed dielectric multilayers with buried vias and laser rooted products including TMM material.

Printed Circuit Boards

Molex RF/Microwave Connector Division 130
Mooresville, IN

D. Robison, D. Gould

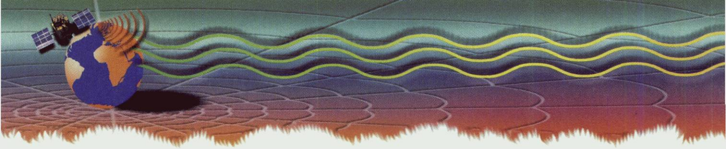
Molex RF/Microwave Connector Division designs and manufactures custom and standard RF microwave connectors for instrumentation, mil/aero and telecommunications applications. This includes all series and styles of MMCX, MCX, SMA, SMB, BNC, TNC and N. We provide our customers with quick-reaction sample and prototype services as well as an extensive offering of special custom/derivative connectors.

Connectors/Cables/Adapters

Morgan Electro Ceramics 305
Wrexham, UK

P. Slater, R. Ragonese

[Continued on page 142]



Compact size patch antenna substrates, ceramic assemblies for high power filters and metallized substrates for PCB applications will be featured.

Antennas/Radomes, Filters, Materials

Morrow Technologies Corp. (MTC) 1014
Largo, FL

T. Murphy

MTC will offer active demonstration of its model P9116 SATCOM remote monitoring equipment that allows satellite engineers to monitor their downlink signals at various ground station locations. A cellular base station analyzer also will be on display.

Test and Manufacturing Equipment

Motorola 1804
Tempe, AZ

S. Baniszewski, N. Castro

Motorola SPS is the world leader in RF products and technologies including RF LDMOS. Motorola provides complete system solutions for wireless infrastructure and wireless subscriber applications.

Amplifiers, Diodes/FETs/Transistors, MMICs, Resistors/Capacitors/Inductors, RFICs

MRSI (Micro Robotics Systems Inc.) 2704
Chelmsford, MA

D. Crowley, R. Farley

MRSI production lines support multiple interconnect technologies, including epoxy die bonding, eutectic attach and flip chip. MRSI delivers field-proven, turnkey production lines for the manufacture of microwave, optical, multichip and RF modules plus hybrid circuits.

Services, Test and Manufacturing Equipment

MTI-Milliren Technologies Inc. 3016
Newburyport, MA

J. Lekander

MTI's newly released 270 series, a double controlled crystal oscillator, offers high stability and reliability in a standard compact CO-8 footprint. Thermal stability over 100°C is 2E-10.

Oscillators

Murata Electronics North America Inc. 2008
Smyrna, GA

C. Seiz

Murata Electronics is a global leader in manufacturing and sales of ceramic-based electronic components, which include core products, application-specific components and functional modules. We are aggressively exploring new frontiers in the development of advanced electronic materials and new, multifunctional, high-density modules. Murata continues to utilize GaAs and multilayer LTCC technology as it moves forward with a new generation of products.

Connectors/Cables/Adapters, Filters, Isolators/Circulators, Oscillators, Power Supplies, Resistors/Capacitors/Inductors, SAW Devices

MWTG Telecom 113
Montreal, Quebec, Canada

M. Znojkiewicz, Z. Huszar

Mini repeaters, diplexers and duplexers will be featured.

Amplifiers, Couplers, Filters, Hybrids, Isolators/Circulators, Millimeter-wave Components, Mixers/Modulators/Detectors, Oscillators, Power Dividers, Synthesizers, Systems and Subsystems, Waveguide and Waveguide Components

Nagano Japan Radio Co. Ltd. 127
Nagano, Japan

K. Shinohara, Y. Tezuka, T. Minamizawa

A leader in the design and manufacture of RF/microwave high power amplifiers in Japan with offices in North America for better services. Exhibits this time include a series of power amplifier subsystems, amplifier modules, amplifier pallets, amplifier peripheral modules, a software radio and DC/DC converters for a power supply.

Amplifiers, Filters, Power Supplies, Signal Processing Components, Software, Synthesizers, Systems and Subsystems

Narda DBS, an L-3 company 1514
El Dorado Hills, CA

T. Rankin, T. Herot, N. Gri

The company will introduce a new variety of catalog and custom capabilities for narrowband low noise amplifiers as well as millimeter-wave up- and downconverters for military or commercial markets.

Amplifiers, Millimeter-wave Components, MMICs, Oscillators

Narda East, an L-3 company 1514
Hauppauge, NY

V. Chitkava, R. Palker, J. Mega

Narda will introduce a new series of low cost "Dept 26" couplers, power dividers, attenuators and RF switches. In addition, an expanded line of RF safety products will be premiered.

Attenuators, Couplers, Filters, Hybrids, Isolators/Circulators, Oscillators, Phase Shifters, Power Dividers, Switches, Terminations, Waveguide and Waveguide Components

Narda West 1514
Folsom, CA

M. Ferrand, D. Deck, L. Becker

New space-qualified up- and downconverters; S-, C-, X-, Ku- and Ka-band channel amplifiers; CDMA combiners; and SMR notch filters will be featured.

Amplifiers, Filters, Isolators/Circulators, Millimeter-wave Components, Signal Processing Components

National Instruments 612
Austin, TX

K. McCoy

National Instruments designs and manufactures computer-based instrumentation software and hardware products for a wide variety of measurement and automation applications. The company offers testing solutions for telecommunications that span wireless, telephony, datacom and broadcast.

Software, Test and Manufacturing Equipment

Netcom Inc. 108
Wheeling, IL

S. Diulus

The company is a manufacturer and custom designer of LC and crystal filters, PLL synthesizers and power supply products. Specialties include integrated networks and introducing oscillators.

Couplers, Filters, Oscillators, Power Supplies, Synthesizers

NexTek Inc. 2926
Westford, MA

P. Gallagher

NexTek is now building coaxial lightning protectors from DC to 6 GHz.

NJR Corporation 1941
Mtn. View, CA

D. Hammed, K. Westfall

New GaAs components include LNAs, driver amplifiers, mixers and multifunction MMICs in space efficient packages; SAW filters from 300 MHz to 2 GHz; and microwave Doppler modules at 10.5 GHz.

Amplifiers, Filters, Mixers/Modulators/Detectors, MMICs, SAW Devices

Noble Publishing 1216
Tucker, GA

G. Breed

New books cover small-signal amplifier design, power amplifier design, electromagnetic measurements and other engineering topics.

Publications

Noise Com 2314
Paramus, NJ

J. Kenneally

Noise Com is a manufacturer of innovative RF and microwave test equipment. We offer customers several unique noise test solutions as well as several noise generators and diodes.

Test and Manufacturing Equipment

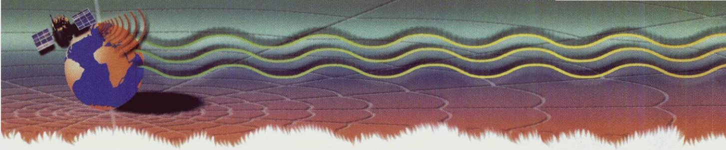
Northrop Grumman 3006
Linthicum, MD

M. LeBrun, J. Miller

Northrop Grumman's state-of-the-art devices for wireless applications include microwave and millimeter-wave MMICs as well as RF and microwave power devices.

Millimeter-wave Components, MMICs, Power Dividers

[Continued on page 144]



NTT Electronics Corporation 135
New York, NY

M. Hirano

Featured products and services include semi-auto-routing CAD for three-dimensional MMIC designing, a mixer family for LMDS applications and a custom-made MMIC designing service.

Amplifiers, Diodes/FETs/Transistors, Millimeter-wave Components, Mixers/Modulators/Detectors, MMICs, Oscillators

Nurad Technologies Inc. 406
Baltimore, MD

D. MacDonald, J. Shea

Nurad designs, develops and manufactures custom antennas, RF composite structures and antenna systems for the defense and commercial markets. The company is also a leading supplier of customer premises equipment antennas and infrastructure antennas for LMDS broadband.

Antennas/Radomes

Octagon Communications 128
Englewood Cliffs, NJ

R. Markhouse, R. Ranahan

Octagon Communications publishes *MPD/Microwave Product Digest*, a new product tabloid devoted to information on components, equipment and subsystems for RF and microwave engineers, and *Base Station/Earth Station*, a tabloid focusing on the technical infrastructure for the wireless communications OEM and USER markets.

Publications

Olin Aegis 207
New Bedford, MA

B. Boyes, S. Struck, P. Charpentier

Fiber-optic packages, microwave packages, surface-mount devices and hybrid metal packages will be featured.

Connectors/Cables/Adapters, Hybrids, Materials, Optoelectronic Components/Fiber Optics

Optotek Ltd. 2019
Kanata, Ontario, Canada

D. Kennedy

CAE/CAT software for RF and microwave applications will be featured. The MMICAD™ suite of software solutions comprises linear simulation, nonlinear simulation, schematic capture, layout, filter synthesis, small- and large-signal transistor modeling, yield prediction and sensitivity analysis, data acquisition and control of vector network analyzers.

Software

Osprey Metals Ltd. 2915
Neath, W. Glamorgan, UK

Pacific Aerospace & Electronics, Display Division 224
Vancouver, WA

D. Johnson

The company produces a variety of bonded glass displays that become inherently ruggedized after processing and have high contrast enhancement attributes and/or have been filtered for electromagnetic interference (EMI) and electromagnetic pulses (EMP).

Systems and Subsystems

Pacific Aerospace & Electronics, Filter Division 224
Wenatchee, WA

I. Sarda

The company manufactures EMI/RFI filtered feedthrus and assemblies. Home of the world's smallest filtered feedthru utilizing a 0.050" OD discoidal capacitor.

Filters

Pacific Aerospace & Electronics, Interconnect Division 224
Wenatchee, WA

D. Harper

Hermetic connectors, feedthrus and assemblies will be featured as well as new titanium composite hermetic packaging with excellent thermal dissipation characteristics and the new Jr.-D connector and mate with 0.030" pin-to-pin pitch.

Connectors/Cables/Adapters, Hybrids, Waveguide and Waveguide Components

Package Technologies Inc. (PTI) 1111
Taunton, MA

R. Duff, D. Taber

Thermal amplifiers for telecommunications, PEP packages, glass-to-metal hybrid packages, and standard hybrid and custom metal packages will be featured.

Palomar Technologies 2620
Vista, CA

K. Brandt

Featured products and services include fully automated high accuracy die and wire bonders featuring eutectic reflow, relative-to referencing, flip chip, ribbon bonding, constant wire length, Lange couplers and high frequency ultrasonics capability.

Test and Manufacturing Equipment

Panasonic Industrial Co. 514
Secaucus, NJ

N. Sadakane

A wireless RF module (Blue Tooth), ceramic dielectric bandpass filters and antenna duplexers will be featured.

Filters, Hybrids, Systems and Subsystems

Paratek Microwave Inc. 2607
Columbia, MD

S. Sengupta, M. Slavin, M. Hallman

Paratek is a leader in electronically tunable RF (ETRF) components and electronically scanning antennas fabricated using Parascan tunable dielectric materials. Featured products include ETRF filters for LMDS frequencies. These metallized-plastic waveguide filters provide a cost-effective and flexible solution for millimeter-wave radio applications.

Antennas/Radomes, Filters, Millimeter-wave Components, Phase Shifters, Waveguide and Waveguide Components

Pascall Electronics Limited 1118
Ryde, Isle of Wight, UK

A. Maclachlan, M. Fretter

Miniature log amplifiers and discriminators as well as high dynamic range, low noise amplifiers will be featured.

Amplifiers, Couplers, Mixers/Modulators/Detectors, Power Dividers, Power Supplies, Signal Processing Components, Software, Systems and Subsystems, Switches

PCB Engineering Inc. 215
Milpitas, CA

D. Moody

PCB Engineering provides quick-turn solutions for many of your RF/MW printed circuit board requirements.

Printed Circuit Boards

PC Dynamics/Performance Interconnect 830
Frisco, TX

E. Stefanko, D. Lippincott, S. Hallmark

Metal-backed PTFE with plated through holes; multilayer including mixed dielectric boards; and multiwire technology will be featured.

Printed Circuit Boards

Penn Engineering Components Inc. 216
No. Hollywood, CA

B. Washburn, C. Bareijsza, J. Washburn, M. Washburn

Penn Engineering was established in 1971 and produces standard custom microwave components, waveguide tubing and cast bends. Sizes carried include from WR 6 to WR 650.

Attenuators, Couplers, Hybrids, Millimeter-wave Components, Terminations, Waveguide and Waveguide Components

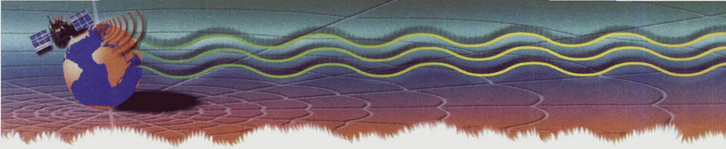
Peregrine Semiconductor Corp. 2706
San Diego, CA

D. Burman

Ultra-high linearity 2.5 GHz UTSI® FET Quad Mixer PE4120 and the industry's lowest power RF prescaler PE 3501 (4 GHz, divide by 2) will be featured.

Amplifiers, Attenuators, Mixers/Modulators/Detectors, MMICs, Oscillators, RFICs, Synthesizers, Switches

[Continued on page 146]



Photofabrication Eng. Inc. (PEI) **2816**
Milford, MA

C. Lehrer, L. O'Rourke, D. Dow

PEI is a manufacturer of chemically etched metal parts. The company produces parts such as circuits, striplines, isolators, waveguides, antenna arrays, RF shields, conductors, ground planes and many more. PEI's new product is an RF shield with a new easy-access removable cover.

Shielding, Waveguide and Waveguide Components

Piconics Inc. **702**
Tyngsboro, MA

D. London

Broadband conical inductors, HI-REL transformers and chokes will be featured as well as thin- and thick-film chip resistors and thin-film spiral inductors.

Attenuators, Millimeter-wave Components, Resistors/Capacitors/Inductors

Picosecond Pulse Labs **1132**
Boulder, CO

H. Botarelli, R. O'Rourke

New low cost 16 GHz oscilloscope trigger countdown! (< 1.0 ps jitter, divide-by-8 prescaler)

Amplifiers, Filters, Optoelectronic Components/Fiber Optics, Power Dividers, Test and Manufacturing Equipment

Pletronics Inc. **2510**
Lynnwood, WA

M. Monson

Now supplying all fiber channel and 1 GHz Ethernet oscillators (no PLL, all third overtone and low jitter).

Oscillators

Polese Company **1506**
San Diego, CA

M. Singer, J. Ehly

The company is a leading supplier of copper tungsten, copper moly, Silvar and aluminum silicon carbide for thermal management solutions for microelectronic and semiconductor applications. A fully vertically integrated powder to plating capability is offered.

Materials, Services

Poly Circuits **2036**
Bensenville, IL

J. Turek

Two-layer and multilayer microwave printed circuits using Teflon substrates are available. Special conductive adhesives are used to bond PCBs to metal heat sinks for power amplifier applications.

Printed Circuit Boards

Polyfet RF Devices **1119**
Camarillo, CA

E. Greenbaum, J. Citrolo

50 V, 175 MHz and 400 MHz FET modules (selectable over 2 to 30 W, 1 MHz to 1000 MHz, operating at 12 or 28 V), and MOSFET transistor replacements MRF and BLF will be featured.

Amplifiers, Diodes/FETs/Transistors

Polyflon Company **616**
Norwalk, CT

W. LaRusso, F. Monger, R. Williamson

High frequency copper-clad substrates – low loss, low cost POLYGUIDE,™ NorClad,™ a PPO base material, and copper-clad Ultem.

Materials, Printed Circuit Boards

Poseidon Scientific Instruments **2517**
Fremantle, Australia

D. Minchin, J. Searls, C. McNeilage

The Shoebox Oscillator is the lowest phase noise microwave oscillator commercially available. Packaged in an 8" × 8" × 2.5" machined aluminum enclosure and phase-lockable to 10 MHz crystal, the Shoebox is designed for premium applications.

Optoelectronic Components/Fiber Optics, Oscillators, Test and Manufacturing Equipment

Praxsym Inc. **737**
Fisher, IL

D. Heiser, W. Gordon, C. Hanson

The Low Frequency Power Detector Module (PFPDM) measures RF power to provide an indication of amplifier performance. Power levels are represented by a linear (mV/dB) signal. The PFPDM features a wide dynamic range in a 28-pin through-hole package.

Signal Processing Components, Synthesizers, Test and Manufacturing Equipment

Precision Ferrites & Ceramic Inc. **701**
Huntington Beach, CA

J. Lee, H. Macias

The company offers machining of all ceramic materials as well as metallization and brazing of ceramics. Ceramic to metal seals for electrical, mechanical optical and vacuum applications are available. Prototype and full production.

Materials, Optoelectronic Components/Fiber Optics, Tubes, Waveguide and Waveguide Components

Precision Tube **916**
Salisbury, MD

D. Kaplan, G. Nutter, C. Bogese

Coaxi-Form cable assemblies utilize a composite outer conductor of tin-filled copper braid. Cable assemblies are hand-formable and available in a variety of lengths with SMA connectors on both ends. Other connectors are available.

Connectors/Cables/Adapters

Presidio Components Inc. **1225**
San Diego, CA

D. Devoe

The company's new buried Single Layer™ capacitor offers higher capacitance values and greater Q factors. Available exclusively from Presidio (patent pending).

Resistors/Capacitors/Inductors

Princeton Electronic Systems Inc. **3015**
Princeton Junction, NJ

C. Ghosh, J. Holmquest, R. Raykar

Featured products include 0.5" × 0.5" footprint synthesizers, 10 Gbps fiber-optic transmitters, 10 Gbps fiber-optic receivers, WDM transceivers for CATV and WDM transmitter-receiver pairs.

Optoelectronic Components/Fiber Optics, Oscillators, Synthesizers

Proto Circuit Inc. **1134**
Cuyahoga Falls, OH

Pulsar Microwave Corporation **438**
Clifton, NJ

P. Claudio, M. Chilimintris

A new line of high frequency switches, attenuators and digital phase-shifters will be featured.

Attenuators, Couplers, Hybrids, Mixers/Modulators, Detectors, Phase Shifters, Power Dividers, Signal Processing Components, Switches

Q-Tech Corporation **2820**
Culver City, CA

G. Slacum, K. Sariri

Our product line includes hybrid crystal oscillators, VCXOs and other frequency sources in both through-hole and surface-mount packages with output frequencies from 0.01 Hz to 700 MHz. Our products are designed with a special focus on critical applications such as aerospace, military and commercial aircraft, satellites and deep-sea communication. Q-Tech is a qualified supplier per MIL-PRF-55310 and MIL-790, and is ISO 9001 registered/certified.

Hybrids, Oscillators, Signal Processing Components, Synthesizers

Quasar Microwave Technology **2601**
Newton Abbot, Devon, UK

M. Jewell, P. Peddie

Flexible and rigid waveguides, filters, diplexers and couplers without tuning screws, rotary vane attenuators and a full supply of microwave waveguide components will be featured.

Attenuators, Couplers, Filters, Hybrids, Terminations, Waveguide and Waveguide Components

Questech Services Corporation **435**
Garland, TX

R. House, D. Hickman

Laser-machined epoxy preforms, thin- and thick-film alumina, BeO substrate materials, expanded resistor trimming capacity.

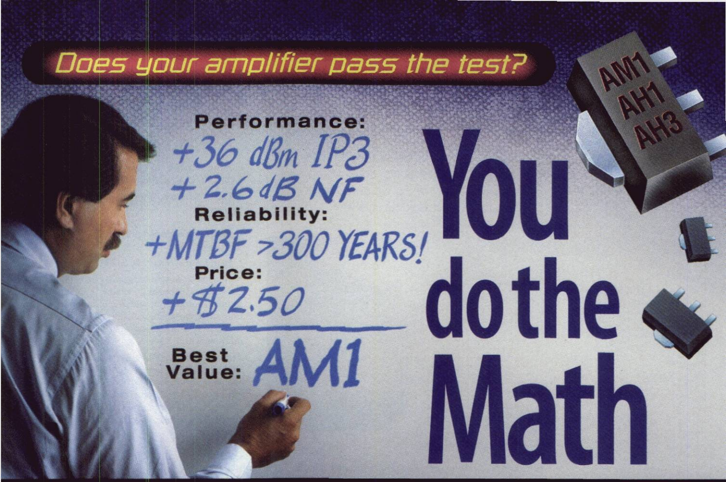
Materials, Services

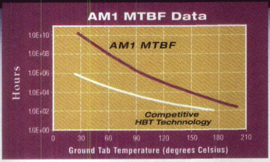
QUEST Microwave Inc. **2501**
Morgan Hill, CA

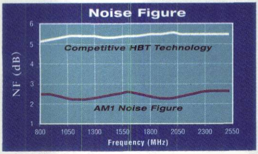
N. Khayat, A. Campbell, B. Campbell

QUEST Microwave manufactures ferrite products (isolators/circulators) for cellular/PCN/PCS

[Continued on page 148]







WJ's AM1 adds up to superior performance and reliability.

The combination of high IP3 and low noise figure at a low DC bias makes the AM1 the amplifier of choice for today's designer of multisignal wireless systems. Drawing only 75 mAmps, the AM1 boasts IP3 of +36dBm across the entire 250-3000 MHz band. Add the low 2.6 dB NF with the high IP3 and great price, and you have an extremely versatile amplifier to use in multiple locations, reducing your overall part count.

Some like it hot.

The AM1's superior electrical and thermal design ensures long term reliability at high temperatures. At 80°C, MTBF performance of the AM1 is 7 million hours.

Do the math, then make the call

Get more details today. Call our toll free number, fax us at 650-813-2447 or e-mail us at *wireless.info@wj.com* to request data sheets and a complete catalog.

WJ High Dynamic Range Amplifiers

Product	Frequency (MHz)	IP3 (dBm, typ.)	P1dB (dBm, typ.)	NF (dB, typ.)	Bias current (mA, typ.)
AM1	250-3000	36	18	2.6	75
AH1	250-3000	41	21	2.9	150
AH3	50-450	40	21	2.8	150

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communications, point-to-point radios and SATCOM/VSAT transceivers and converters.

Isolators/Circulators, Waveguide and Waveguide Components

QuinStar Technology Inc. **536**
Torrance, CA

L. Fong, J. Kuno, N. Deo, M. Smith

Millimeter-wave solutions: amplifiers, multipliers, sources, converters, antennas and control components; and innovative application-specific integrated assemblies and subsystems including transceivers, receivers, transmitters and test and measurement.

Amplifiers, Antennas/Radomes, Attenuators, Couplers, Diodes/FETs/Transistors, Filters, Isolators/Circulators, Millimeter-wave Components, Mixers/Modulators/Detectors, Oscillators, Phase Shifters, Power Dividers, Systems and Subsystems, Switches, Terminations, Waveguide and Waveguide Components

QWED **2333**
Warsaw, Poland

W. Gwarek, M. Celuch

Featured products include the QuickWave Series conformal FDTD-based software for electromagnetic analysis and optimization of a variety of closed and radiating structures from RF to submillimeter range.

Services, Software

R&K Company Limited **230**
Fuji, Shizuoka, Japan

K. Hirano

The company's product capability and technology are applicable to the market requirements for frequencies from 10 kHz to 11 GHz and power levels from 1 mW to 10 kW, including both surface-mountable packages and connectorized configurations.

Amplifiers, Attenuators, Couplers, Hybrids, Mixers/Modulators/Detectors, MMICs, Phase Shifters, Power Dividers, Switches

Radiall Inc. **201**
Stratford, CT

B. Matusz

Easy-Fit 7/16 connectors require no soldering or crimping, and the UMP series (Ultra Miniature Pressure Contact) offers low SWR with 2 mm SMT mated height.

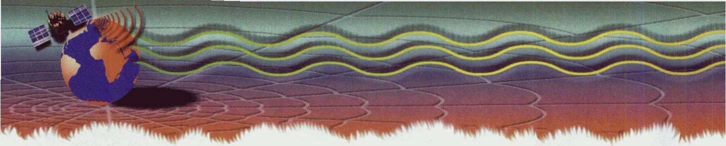
Attenuators, Connectors/Cables/Adapters, Couplers, Millimeter-wave Components, Optoelectronic Components/Fiber Optics, Switches, Terminations

Raltron Electronics Corp. **603**
Miami, FL

J. Mundschau, H. Rainone, R. Cerda, H. Longin

The new model VS9000 is a voltage-controlled SMT oscillator in a smaller 5 × 7 × 2 mm package. The OX2000 series outperforms common

[Continued on page 150]



TCXOs at a lower price. The new RTVY-174 TCXO uses a custom IC chip to slash size and cost, replacing larger, costlier units.

Oscillators, SAW Devices, Signal Processing Components

Raytheon RF Components **325**
Andover, MA

D. Laks, B. Reardon, J. Oakes

Raytheon will showcase its new GaAs power amplifier MMICs for cellular, PCS and millimeter-wave applications. Please visit booth 325 or our Web site at www.raytheon.com/micro.

Amplifiers, Millimeter-wave Components, MMICs

RDL Inc. **2327**
Conshohocken, PA

S. Elkins, M. Smith, F. Lupinetti, B. Graham

RDL will introduce a new low noise downconverter that provides unprecedented performance as part of the RDL Phase Noise Analyzer System. The noise floor of the system has been lowered by 10 to 15 dB over the range of 1 to 25 GHz. In addition, the RDL model MTG-2000 will be shown. Features 16 CW sources combine to achieve 4 dBm/tone with intermods below -85 dBc with phase control in 1° steps.

Test and Manufacturing Equipment

Reactel Incorporated **2615**
Gaithersburg, MD

E. Assurian, J. Assurian, S. Assurian

Reactal manufactures high performance RF/microwave filters and diplexers. We cover DC to 40 GHz for both military and commercial applications and specialize in combiners/diplexers for the cellular/wireless market.

Filters, Mixers/Modulators/Detectors, Switches, Waveguide and Waveguide Components

RelComm Technologies Inc. **437**
Salisbury, MD

J. Tinkler, M. Magda, T. Veal

RelComm will show the subminiature family of SMT coaxial 1P1T, 1P2T, transfer and circuit insertion relays, both fail-safe and pulse latching. Finally, 1P2T and transfer function waveguide relays operating from 26 to 40 GHz will be offered.

Signal Processing Components, Switches, Waveguide and Waveguide Components

REMEC Inc. **425**
San Diego, CA

A. Rosenzweig, B. Coleman, T. Mauk, J. Dziki, M. Rogers, J. Huang, P. Gardner, H. Perkins, B. Cole

REMEC is a leader in the design and manufacture of microwave multifunction modules (MFM) for microwave transmission systems used in defense applications and the commercial wireless telecommunications industry.

Amplifiers, Antennas/Radomes, Couplers, Filters, Millimeter-wave Components, Mixers/Modulators/Detectors, Optoelectronic Components/Fiber Optics, Oscillators, Phase Shifters, Services, Synthesizers, Systems and Subsystems, Switches

Remtec Inc. **541**
Norwood, MA

N. Rapoport, D. Suconick, B. Bogie

Custom-made metallized ceramic substrates and chip carriers with copper-plated, plugged vias are ideal for packaging Si, GaAs ICs, MMICs, RF power amplifiers and fiber-optic interconnects.

Amplifiers, Hybrids, Printed Circuit Boards, Resistors/Capacitors/Inductors, Services

Renaissance Electronics Corp. **237**
Boxborough, MA

C. McCauley

Renaissance is exhibiting its hottest isolator/circulator products: dual junction drop-in isolators for wireless applications, waveguides for LMDS and power dividers/combiners for wireless applications.

Couplers, Isolators/Circulators, Millimeter-wave Components, Power Dividers, Systems and Subsystems, Terminations, Waveguide and Waveguide Components

Resin Systems **2217**
Amherst, NH

W. Ohearn

In addition to in-stock waveguide loads, both low and high power, Resin Systems now offers flexible, narrowband, resonant absorber material tuned from 1 to 18 GHz. Available in both urethane and silicone sheets (12" × 12") or cut to custom sizes.

Attenuators, Materials, Terminations, Waveguide and Waveguide Components

RF Connectors **1112**
San Diego, CA

R. LaFay, W. Halbert

A new series of miniature high voltage MHV connectors provide shielded disconnects where high voltages are present and the BNC type interface is required.

Connectors/Cables/Adapters

RF Depot.com Inc. **1025**
Beltsville, MD

R. Pouliot, G. Pouliot

A single power divider covers 0.8 to 2.5 GHz wireless bands. Many other frequency bands available with quick delivery. Free catalog with prices.

Amplifiers, Attenuators, Connectors/Cables/Adapters, Couplers, Hybrids, Isolators/Circulators, Phase Shifters, Power dividers, Switches, Terminations, Waveguide and Waveguide Components

RF Design **122**
Englewood, CO

K. Clark, P. Kowalczewski

Published for more than 22 years, *RF Design* gives design engineers the practical, hands-on, applications-oriented material they need to efficiently and effectively design the radio frequency products that make wireless work.

Publications

RF Micro Devices **807**
Greensboro, NC

K. Ingram

RF integrated circuits, including modulators, demodulators, front ends and transceivers will be featured.

Amplifiers, Attenuators, Mixers/Modulators/Detectors, MMICs, Oscillators, RFICs, Switches

RF Solutions **2903**
Atlanta, GA

C. Cass, D. Cresci, S. Moghe, S. Richeson

MMICs, RFICs, systems and subsystems will be featured.

RF Vision **2924**
Santa Clara, CA

Richardson Electronics **530**
LaFox, IL

Richardson Electronics is a specialized international distributor of electronic components, equipment and assemblies, primarily for communications and industrial applications. Richardson's products include RF and microwave components, RF power semiconductors, RF connectors and cable assemblies, electronic security products and systems, electron tubes and data display monitors. The company specializes in selected niche markets that demand technical service and offers a wide range of specialty products and logistics services.

Amplifiers, Antennas/Radomes, Attenuators, Connectors/Cables/Adapters, Diodes/FETs/Transistors, Filters, Mixers/Modulators/Detectors, MMICs, Oscillators, Power Supplies, Resistors/Capacitors/Inductors, Switches, Test and Manufacturing Equipment, Tubes, Waveguide and Waveguide Components

RJR Polymers Inc. **1131**
Oakland, CA

R. Bregante, D. Pasfield, S. Mellen, M. Corey

RJR Polymers is a leader in electronic component packaging technology, delivering pre-applied B-staged adhesives, air-cavity packages and automatic sealing solutions for packages using glass, ceramic, plastic or metal lids.

Amplifiers, Antennas/Radomes, Attenuators, Hybrids, MMICs, SAW Devices, Test and Manufacturing Equipment

RLC Electronics Inc. **312**
Mount Kisco, NY

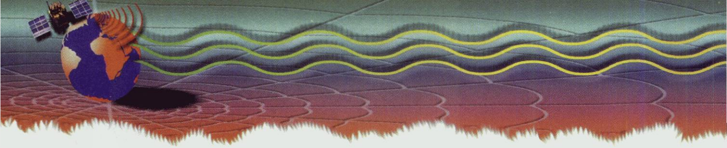
J. Seminoro

Featured products include specialized filters, surface-mount filters and filters for jitter measurements as well as miniature mechanical switches up to 18 GHz, low intermod switches, power dividers to 38 GHz and cellular duplexers to 10 kW (peak).

Attenuators, Couplers, Filters, Hybrids, Power Dividers, Switches, Terminations

Robinson Laboratories Inc., a Herley company **516**
Nashua, NH

[Continued on page 152]



S. Robinson, T. Cole, J. McClay

Featured products include microwave control components, receiver products, multifunction integrated assemblies, switch matrices, PIN diode switches, high power switches, phase shifters, PIN diode attenuators, limiters, detectors and broadband mixers.

Attenuators, Millimeter-wave Components, Mixers/Modulators/Detectors, Phase Shifters, Switches

Robinson Satellite Communications, a Herley company **516**
Nashua, NH

S. Robinson, T. Cole, J. McClay

Featured products include Ka-band LNBs for the satellite telecommunications market. Low noise figure PLL DRO-based technology is used for frequency-stable applications.

Amplifiers, Millimeter-wave Components, Systems and Subsystems, Waveguide and Waveguide Components

Rogers Corporation **1931**
Boston, MA

K. Walker

Rogers Microwave Materials Division highlights RO4000® thermoset high frequency materials with improved electrical and thermal properties targeted at wireless communication base station applications.

Materials, Printed Circuit Boards

Roos Instruments **1405**
Santa Clara, CA

J. Rossi

Roos Instruments, the benchmark of RF and microwave ATE systems, is a test supplier to industry leaders such as IBM, Motorola, Northern Telecom and Philips Semiconductors.

RFICs, Test and Manufacturing Equipment

Rosenberger of North America LLC **1706**
Lancaster, PA

B. Rosenberger, J. Muhammed

Rosenberger's updated line of surface-mount connectors includes SMP, MCX, BMA and SMA for frequencies up to 26.5 GHz. (Many are available in tape and reel.) Also being introduced are the latest developments in SMP calibration kits and test accessories.

Connectors/Cables/Adapters

Sage Laboratories Inc. **1902**
Natick, MA

P. Alfano, A. Collins, T. Cieri, B. St. Pierre

The company designs and manufactures detector log video amplifiers, digital frequency discriminators, switched multiplexers, frequency memory loops and custom subsystems.

Couplers, Filters, Hybrids, Mixers/Modulators/Detectors, Phase Shifters, Power Dividers, Signal Processing Components, Systems and Subsystems

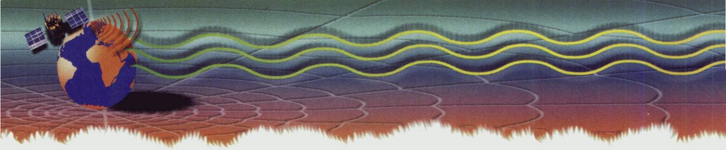
Salisbury Engineering Inc. **737**
Delmar, DE

R. Newberry, W. Barbley, W. Gordon

Salisbury Engineering has introduced a standard line of GPS pre-amps with various gains available as well as power supply options.

Amplifiers, Filters, Systems and Subsystems

[Continued on page 154]



Sanders, a Lockheed Martin company **2132**
Nashua, NH

J. Korcuba

Millimeter-wave GaAs and InP MMICs/modules, space-based processors, ASICs, ECBs and recorders will be featured.

MMICs

Saronix **302**
Menlo Park, CA

B. Kocher, E. Feldman

The model ST1307/1507 (1 to 31.999 MHz fundamental) HCMOS/TTL, tri-state, 5 × 7 mm SMD VCXOs for telecom and wireless applications features exceptionally low phase noise. The model ST1517/1317 (32 to 125 MHz) also will be on display.

Oscillators, SAW Devices

Sawtek Inc. **2715**
Orlando, FL

S. Orr, M. Andrews, B. Balut, J. Ladd, S. Russ, K. Schoenrock, B. Thomas

Sawtek offers many new RF SAW filters for all mobile standards plus its full line of IF SAW devices for base stations, data communications and handsets.

Filters, Oscillators, SAW Devices, Signal Processing Components, Systems and Subsystems

Scientific Microwave Corp. **1033**
Montreal, Quebec, Canada

A. Saad, M. Saad, G. Saad

The company offers design and manufacturing of 1 to 40 GHz passive microwave components with low and high power: narrow and wideband filters, diplexers, circulators, hybrids, couplers (ridge-shaped, crossguide, high directivity), transitions and coax adapters, terminations, OMTS, RFI filters, flanges and waveguide accessories, high power arms and filter combining networks. Interfaces can be coax, standard waveguide or ridge waveguide.

Attenuators, Couplers, Filters, Hybrids, Isolators/Circulators, Millimeter-wave Components, Phase Shifters, Power Dividers, Terminations, Waveguide and Waveguide Components

SDP Components Inc. **1311**
Pointe Claire, Quebec, Canada

D. Strunga

SDP Components Inc. provides quality RF and microwave connectors manufactured at its own facilities in China. The company specializes in standard as well as custom specials.

Connectors/Cables/Adapters

Semflex Inc. **1937**
Mesa, AZ

D. Hartje, V. Lutheran, B. Becker, B. Nothum, D. Thomas

The RHT series replaceable head test cable assembly, RTI series application-specific cable assembly and KW bulk cable for high power applications will be featured

Connectors/Cables/Adapters

Semi Dice Inc. **3003**
So. Easton, MA

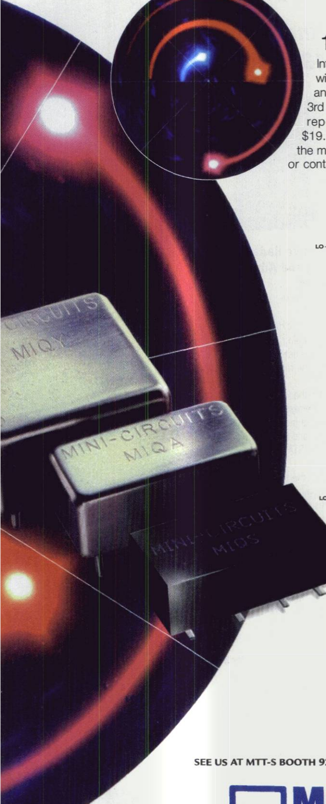
B. Marvel, W. Becker, D. Cormack, M. Myers

We are the solution to all your bare die requirements. The company is a bare die distributor with added value services, including wafer processing, lot qualifications and special parameter probing.

Amplifiers, Diodes/FETs/Transistors, Resistors/Capacitors/Inductors, Services, Signal Processing Components

[Continued on page 157]

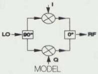
I&Q MODULATORS DEMODULATORS



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

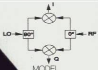
Infuse your cellular, spread spectrum, and communication system projects with the performance and reliability of Mini-Circuits I&Q modulators and demodulators. Surface mount and plug-in units feature excellent 3rd and 5th order harmonic suppression, low loss, and "skinny" 4.5 sigma repeatability unit-to-unit.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

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



I/Q MODULATORS

	MODEL	FREQ. (MHz) f_L	f_U	CONV. LOSS (dB) $\bar{x}$	σ	CARRIER REJ. (-dBc) Typ.	SIDEBAND REJ. (-dBc) Typ.	HARM. SUPPRESS (-dBc) Typ. 3xI/Q	5xI/Q	PRICE $ Qty. (1-9)
	MIQA-10M	9	11	5.8	0.20	41	40	58	68	49.95
	MIQA-21M	20	23	6.2	0.14	50	40	48	65	39.95
	MIQA-70M	66	73	6.2	0.10	38	38	48	58	39.95
	MIQA-70ML	66	73	5.7	0.10	38	38	48	58	49.95
	MIQA-91M	86	95	5.5	0.10	38	38	48	58	49.95
	MIQA-100M	95	105	5.5	0.10	38	38	48	58	49.95
	MIQA-108M	103	113	5.5	0.10	38	38	48	58	49.95
	MIQA-195M	185	205	5.6	0.10	38	38	48	58	49.95
	MIQC-38M	34	38	5.6	0.10	48	37	54	65	49.95
	MIQC-88M	52	88	5.7	0.10	41	34	52	66	49.95
	MIQC-176M	104	176	5.5	0.10	38	36	47	70	54.95
	MIQC-895M	868	895	8.0	0.10	40	40	52	58	99.95
	MIQC-1785M	1710	1785	9.0	0.30	35	35	40	65	99.95
	MIQC-1880M	1805	1880	9.0	0.30	35	35	40	65	99.95
☐	MIQY-70M	67	73	5.8	0.20	40	36	47	60	19.95
☐	MIQY-140M	137	143	5.8	0.20	34	36	45	60	19.95
	Surface Mount Models									
☐	JCIQ-88M	52	88	5.6	0.1	40	35	45	65	49.95
☐	JCIQ-176M	104	176	5.6	0.1	35	35	45	65	54.95



I/Q DEMODULATORS

	MODEL	FREQ. (MHz) f_L	f_U	CONV. LOSS (dB) $\bar{x}$	σ	AMP. UNBAL. (dB) Typ.	PHASE UNBAL. (Deg.) Typ.	HARM. SUPPRESS (-dBc) Typ. 3xI/Q	5xI/Q	PRICE $ Qty. (1-9)
	MIQA-10D	9	11	6.0	0.10	0.15	1.0	50	65	49.95
	MIQA-21D	20	23	6.1	0.15	0.15	0.7	64	67	49.95
	MIQA-70D	66	73	6.2	0.10	0.15	0.7	56	58	49.95
	MIQC-38D	34	38	5.5	0.10	0.10	0.5	60	65	49.95
	MIQC-60WD	20	60	5.3	0.10	0.15	1.0	55	67	79.95
	MIQC-895D	868	895	8.0	0.20	0.15	1.5	40	55	99.95
☐	MIQY-1.25D	1.15	1.35	5.0	0.10	0.15	1.0	59	67	29.95
☐	MIQY-70D	67	73	5.5	0.25	0.10	0.5	52	66	19.95
☐	MIQY-140D	137	143	5.5	0.25	0.10	0.5	47	70	19.95
	Surface Mount Models									
☐	JCIQ-176D	104	176	5.5	0.1	0.15	2	52	65	54.95
☐	JCIQ-895D	868	895	8.6	0.1	0.2	1	45	65	99.95
☐	JCIQ-1785D	1710	1785	8	0.2	0.2	2	50	65	99.95
☐	JCIQ-1880D	1805	1880	8	0.2	0.2	2	50	65	99.95

☐ NON-HERMETICALLY SEALED

MIQA case .4 x .8 x .4 in.
MIQY case .8 x .8 x .4 in.
MIQC case .8 x .8 x .4 in.
JCIQ case .9 x .8 x .25 in.

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

J-LEAD

SEE US AT MTT-S BOOTH 927

Mini-Circuits®

US 180 INT'L 181
CIRCLE READER SERVICE CARD

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

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

SierraCom 2412
Hopkinton, MA

C. Staszak

SierraCom will show its low cost 38 and 23 GHz Connection™ series radios, which provide links for short-range access applications, microcell connections or as a replacement for leased lines.

Antennas/Radomes, Couplers, Filters, Millimeter-wave Components, Power Dividers, Systems and Subsystems, Waveguide and Waveguide Components

Sigma Systems Corporation 1400
San Diego, CA

S. Hoover

The new model C4 controller for temperature chambers runs temp tests in half the time and doubles production throughput.

Test and Manufacturing Equipment

Signal Technology Corp. 317
Danvers, MA

T. Zinkowsky, A. Butts

Signal Technology's Wireless Group (SWG) provides customer-focused solutions for base station infrastructure, wireless local loop, point to point, digital radio and commercial space-based applications.

Amplifiers, Couplers, Filters, Hybrids, Isolators/Circulators, Millimeter-wave Components, Mixers/Modulators/Detectors, Oscillators, Phase Shifters, Power Dividers, Power Supplies, Signal Processing Components, Synthesizers, Systems and Subsystems, Switches

Sinclair Manufacturing Company 538
Chartley, MA

M. O'Keefe

Featured products include RF and microwave hermetic packages using glass, ceramic, multilayer ceramics; custom and standard power packages; hybrid flatpacks, platforms and plug-ins; and hermetic windows.

Hybrids, Optoelectronic Components/Fiber Optics, SAW Devices

SIWARD International Inc. 1217
Parsippany, NJ

H. Tseng, R. Sung, Y. Chen, E. Mu

SIWARD manufactures a full line of frequency control products, including crystal, MCF, oscillator, TCXO, VCXO and VC-TCXO. New products include ceramic resonator/filter and SAW resonator/filter.

Oscillators, SAW Devices

Sonnet Software Inc. 1710
Liverpool, NY

J. Rautio, S. Carpenter, D. Leiss, J. Willhite

Sonnet Software develops and supports EDA software for high frequency electromagnetic analysis, providing solutions for both planar and full 3D EM software applications. At this year's MTT-S exhibition, Sonnet will be demonstrating powerful new optimization and circuit parameterization capabilities added to the Sonnet EM Suite of tools for 3D planar EM analysis. Sonnet also offers free CDs of its award-winning Sonnet Lite for free planar EM analysis.

Software

Southwest Microwave 1302
Tempe, AZ

M. Midwin, J. Kubota, D. Leavitt, B. Lane

High performance microwave connectors to 50 GHz and SMA, 2.92 and 2.40 mm within-series and between-series adapters will be featured. Specials. Launches to microstrip, stripline, coax and waveguide. JIT and COTS.

Connectors/Cables/Adapters

Special Hermetic Products 1025
Wilton, NH

J. Pollack, A. DeSantis

Glass-to-metal seals, hermetic feedthrus, dielectric bushings, aluminum-compatible micro-miniature hermetic connectors, custom hermetic module housings and hermetic headers will be featured.

Connectors/Cables/Adapters, Resistors/Capacitors/Inductors, Shielding

Spinner North America 2138
Norcross, GA

D. McNeil, T. Beynon, P. Ottensmeyer, K. Queen

Spinner now offers high performance braided RG jumper cables. SWR-optimized connectors are soldered, both inner and outer conductors, and reinforced by injection-molded plastic roots.

Attenuators, Connectors/Cables/Adapters, Terminations, Waveguide and Waveguide Components

SPM 1506
Armonk, NY

J. Jankowski

The company is a worldwide supplier of aluminum, silicon aluminum and gold bonding wire and ribbon, and a manufacturer of solder and braze preforms, bond pads, heatsinks, moly pedestals and special clad connectors. Many parts packaged in tape on reel and waffle pack. Contract taping of components is available. ISO9002 and WS900 certified.

Materials

Sprague-Goodman Electronics Inc. 1109
Westbury, NY

M. Markson, S. Orman, B. Feller

Sprague-Goodman's small, low cost, lumped-element SMT directional couplers operate from 10 to 1000 MHz with four coupling values from 6 to 16 dB.

Diodes/FETs/Transistors, Resistors/Capacitors/Inductors

[Continued on page 159]


...RADIALL:
..BASE STATION EXPERTISE!
CORRUGATED CABLE ASSEMBLIES
• ULTRA LOW INTERMODULATION (-125dBm)
• AVAILABLE WITH 7/16 & N CONNECTORS
EASY-FIT 7/16 CONNECTORS
• 2-PIECE CONSTRUCTION
• INSTALLER FRIENDLY- NO SOLDERING OR CRIMPING
FULL LIGHTNING PROTECTOR RANGE
MULTI-BAND 1/4 WAVE
• 824 TO 960 MHz
• 1700 TO 2000 MHz
GAS DISCHARGE TUBE
• DC - 2.5 GHz
AMERICAS - Brasil: Radiall Componentes do Brasil El. Lta 55 21 282 13 25 ASIA - China: Shanghai Radiall Electronics Co., Ltd 86 21 66 52 37 88; Hong-Kong: Radiall Electronics Ltd 852 2 959 38 33; India: Radiall Protectron 91 80 839 46 73; Japan: Nihon Radiall KK 81 3 38 66 23 90 EUROPE - France: Radiall Worldwide Headquarters: 33 1 49 35 35 35; Finland: Radiall S.F.: 358 0 934 89 356; Germany: Radiall G.m.b.H.: 49 6 074 910 70; Italy: Radiall Elettronica S.R.L.: 39 2 48 85 12 1; Netherlands: Radiall B.V.: 31 33 253 40 09; Sweden: Radiall A.B.: 46 8 444 34 10; U.K.: Radiall Limited: 44 1 819 978 880
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RADIALL, INC. 260 Hathaway Dr., Stratford, CT 06615 T: 203.380.9800 FAX: 888.387.0001 www.radiallusa.com

SRC Cables 338
Santa Rosa, CA

D. Hirschnitz

Coax cable assembly experts. From flexible low loss to semirigid bent on CNC benders. The company's new SRC-316 offers 20 percent lower loss and two times the shielding of RG-316.

Connectors/Cables/Adapters, Shielding

SRI Connector Gage Company 2512
Melbourne, FL

S. McGeary

SRI will introduce a new line of precision low loss cable connectors (2.4, 2.9, 3.5 mm, SMA, N, TNC and 7 mm). Also new are 1.85 to 2.4 mm and 1.85 to 2.9 mm between-series adapters.

Connectors/Cables/Adapters

SSI Cable Corporation 2408
Shelton, WA

K. Gilchrist, R. Williams, B. Smith, R. Nava

SSI offers a line of welded stainless-steel cable assemblies (MIL-C-17 compatible) for high vibration and severe environment applications. Call for additional information: (360) 426-5719.

Connectors/Cables/Adapters

SSPA Microwave Corp. 918
Mississauga, Ontario, Canada

A. Leung, T.C. Cheng

A solid-state high power amplifier and high performance C- and Ku-band transceivers will be featured.

Amplifiers

Stamping Technologies Inc. 120
Laconia, NH

M. St. Gelais, F. DiChiara

Microwave packages (stamped, CNC machined, wire EDM). All materials: Kovar 42 alloy, CRS, Glidcop, molybdenum and clad metals. Tooling and prototypes.

Services

Standard Microdevices 231
Sunnyvale, CA

T. Kellar, D. Jensen, J. Quinnell, G. Simmons

SiGe-based discrete power transistors with power levels to 2 W; wideband, high linearity, InGaP MMIC amplifies; GaAs HBT high gain power amplifiers to 2 W; and 12 V InGaP power amplifiers with > 50 dBm IP3 will be featured.

Amplifiers, Diodes/FETs/Transistors, Mixers/Modulators/Detectors, MMICs, RFICs, SAW Devices

State of the Art Inc. 218
State College, PA

B. Hoy

State of the Art Inc. introduces new high frequency resistors with superior SWR developed for use in satellite communications, low noise amplifiers, wireless/cellular and SSPAs.

Attenuators, Resistors/Capacitors/Inductors, Terminations

Stealth Microwave 633
Trenton, NJ

S. Barthelmes Jr.

The SM1720-50L covers bands from 1.7 to 2.0 GHz, has 56 dB of linear gain and can typically produce 44 dBm output power for CDMA. Size: 7.5" × 4.0" × 0.8".

Amplifiers

Stellex Electronics Inc. 333
San Jose, CA

B. Quinn, D. Newton, M. Williams, A. Byun, L. Crowley, T. Galla, D. Woo, J. Diesso, B. Haluszczak, R. Piercey, K. Evans, K. Veeth, D. Merkley, F. Moore

Visit Stellex/Phoenix at booth 333 to see our new line of commercial surface-mount mixers, ultra-linear high power amplifiers, YIG-based synthesizers and ODUs.

Amplifiers, Attenuators, Millimeter-wave Components, Mixers/Demodulators/Detectors, Oscillators, Optoelectronic Components/Fiber Optics, Synthesizers, Systems and Subsystems, Signal Processing Components

Stetco Inc. 703
Franklin Park, IL

G. Murray

Stetco will show its new high current (over 2 A) 0805 chip coil series along with its standard 0603 and 1008 coils and 1812 transformers.

Resistors/Capacitors/Inductors

STI 117
Allentown, PA

D. Shaw

SAW filters; delay lines; resonators; RF connectors/adapters; amplifiers; circulators; passive filters for C-band, digital CATV applications; digital MMDS; and antennas for wireless data transfer will be featured.

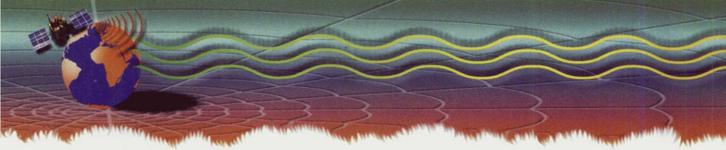
Amplifiers, Antennas/Radomes, Connectors/Cables/Adapters, Filters, Isolators/Circulators, Oscillators, Publications, SAW Devices, Signal Processing Components, Terminations, Waveguide and Waveguide Components

Storm Products – RF/Microwave Group 309
Hinsdale, IL

L. Backer, B. Barrath, G. Horton, M. Kotilinek, K. Weber

Storm Products – RF/Microwave Group is a leading manufacturer of high performance interconnect products for the makers of telecom, wireless, aerospace and military systems and test equipment. The company provides engineered solutions for applications through 50 GHz. Capabilities include in-house custom design and

[Continued on page 160]



development of cable, connectors and assemblies. New test system products include a Cal Kit and a line of push-on adapters that significantly reduce test times. New GPPO™ cable assemblies meet the demand for miniature products where increased packaging density is the norm.

Connectors/Cables/Adapters

StratEdge Corporation 314
San Diego, CA

C. Trondle, T. Going, A. Black, J. Grady, L. Montalto

The company is a worldwide supplier of GaAs MMIC packaging and ceramic filters: design through volume production, DC to 50 GHz, OC-192, configurations include leadless, leaded and surface mount.

Filters, Millimeter-wave Components

Sumitomo Electric Industries Ltd. 1113
Yokohama, Kanagawa, Japan

N. Shiga

Featured products include a GaAs power amplifier, 1.8 to 3.5 GHz for PCS and CDMA applications with P1dB of 32 to 40 dBm and excellent IP3 of 43 to 50 dBm.

Amplifiers, Diodes/FETs/Transistors

Sunrisetek 700
Kansas City, KS

D. Goldstein, R. Peckman

New, improved surface-mount temperature-compensated crystal oscillators and voltage-controlled crystal oscillators with frequencies to 200 MHz will be featured.

Oscillators

SV Microwave 2718
West Palm Beach, FL

SV Microwave is a full-service supplier to the microwave industry. The West Palm Beach facility is a leading producer of high quality RF connectors, cable assemblies and resistive products. The Commercial Products Group, located in Largo, FL, specializes in passive microwave components.

Attenuators, Connectors/cables/Adapters, Couplers, Hybrids, Mixers/Modulators/Detectors, Phase Shifters, Power Dividers, Resistors/Capacitors/Inductors, Terminations

C.W. Swift & Associates Inc. 2514
Van Nuys, CA

C. Swift, A. Swift, S. Swift

The company is a distributor of RF and microwave electronic components. High frequency coaxial connectors (3.5, 2.9, and 2.4 mm) and adapters are in stock. (Attenuators, couplers and power dividers, too.)

Attenuators, Connectors/Cables/Adapters, Couplers, Power Dividers, Resistors/Capacitors/Inductors, Terminations

Synergy Microwave Corporation 506
Paterson, NJ

A. Almeida

High power couplers, power dividers, fractional-N and conventional synthesizers, high IP_3 mixers and miniature voltage-controlled oscillators will be featured as well as a new line of surface-mount microstrip/stripline components.

Attenuators, Couplers, Filters, Hybrids, Mixers/Modulators/Detectors, Oscillators, Phase Shifters, Power Dividers, Synthesizers, Systems and Subsystems

Taconic 911
Petersburgh, NY

R. Nurmi, J. Bushie, B. Kline, R. Ross

Taconic has expanded its RF product line to include 6.15 and 3.0 dielectric constant materials. Ceramic property benefits are combined with organic resins.

Amplifiers, Antennas/Radomes, Couplers, Filters, Materials, Printed Circuit Boards

TDK/MH&W International Corp. 721
Mahwah, NJ

D. Timmerman, B. Kiernan, T. Noguchi

Stripline and ferrite substrate-type microwave devices, circulators and connector-type isolators; isolators and circulators; terminations, mixers and combiners; and keratherm thermal interface materials by Kernfol will be featured.

Isolators/Circulators

Tecdia Inc. 1019
Sunnyvale, CA

Y. Kubota

The company manufactures single-layer ceramic chip capacitors; GaAs FET protection DC power boards; wideband, high current bias Ts; and alumina, high K substrates.

Power Supplies, Resistors/Capacitors/Inductors

Tech-Ceram 1208
Amesbury, MA

C. Hailand

RF and microwave packages and aluminum nitride packages will be featured.

Materials, Millimeter-wave Components

Technical Distributors Inc. 1233
San Ramon, CA

B. DeJean

Nitrogen storage cabinets, pass-throughs, work stations and precision tools including tweezers and cutters will be featured as well as application-specific cabinets for storage of bonding wire, waffle paks and reels.

Services

Technical Research & Mfg. Inc. 415
Bedford, NH

T. Tirollo, W. Tirollo, P. Green, D. Fitzgibbons

Couplers, Hybrids, Mixers/Modulators/Detectors, Phase Shifters, Power Dividers, Signal Processing Components

Technical Sales and Solutions 1025
Nashua, NH

K. Coleman, C. Tramack

Attenuators, MMICs, connectors and cables, filters, mixers, software, isolators and circulators, waveguide components and thin-film circuits will be featured.

Attenuators, Connectors/Cables/Adapters, Isolators/Circulators, Mixers/Modulators/Detectors, MMICs, Resistors/Capacitors/Inductors, Printed Circuit Boards, Software, Terminations, Waveguide and Waveguide Components

Technical Services Laboratory Inc. 2716
Ft. Walton Beach, FL

P. Petropoulos, A. Corbin

Featured products include solid-state transmitters and amplifiers for IFF, TACAN, TCAS, Mode-S and radar. Pulsed power levels are from 20 to 4000 W; duty cycles are from one to 10 percent; pulse widths are available to 120 μs.

Amplifiers, Power Supplies

Techtrol Cyclonetics Inc. 1125
New Cumberland, PA

C. Sunday, P. Bates

Techtrol Cyclonetics is the industry leader in ultra-low noise crystal oscillators, sources, discrete and phase-locked multipliers. A new miniaturized low noise crystal oscillator will be featured.

Oscillators, Systems and Subsystems

Tektronix Inc. 2606
Beaverton, OR

V. Savara

Tektronix will announce new capabilities for spectrum analyzers, plus showcase measurement tools for third-generation technologies, including spectrum analyzers, signal generators and mobile phone testers.

Test and Manufacturing Equipment

Teledyne Electronic Technologies 1312
Los Angeles, CA

D. German, P. Holmes, B. Kilgraff, B. Macias, D. Seeholzer

The company is an electronic manufacturing services provider focusing on multichip modules and hybrids supporting analog and digital circuits, memories, microprocessors, signal converters, decoders, RF and microwave circuits, medical electronics and fiber-optic/lightwave modules.

Hybrids, Optoelectronic Components/Fiber Optics

Telegartner Inc. 704
Franklin Park, IL

R. Souders, K. Ludwig

Coaxial connectors (BNC, TNC, UHF, Mini-UHF, N 7/16, 1.6/5.6, SMA, SMB, SMC, SSMB, MCX and MMCX), surge suppressors, connectors for corrugated cables (1/4" through 1-5/8") and coaxial cable assemblies will be featured.

Connectors/Cables/Adapters, Optoelectronic Components/Fiber Optics

[Continued on page 162]

MINIATURE

SURFACE MOUNT VCO's from $12.95 (qty. 5-49)

The big news is Mini-Circuits miniature family of ***50 to 2500MHz*** ROS voltage controlled oscillators! Each unit is housed in a shielded 0.5"x0.5"x0.18" non-hermetic industry standard package for highly efficient wash-thru capability, reliability, and cost effectiveness. Models with "PV" suffix typically operate from a 5 volt power supply and require 5V tuning voltage to cover the frequency range. This makes them ideal for integration with monolithic PLL chips and commercial synthesizers in the 245 to 1600MHz band. The series also features broad band 12V models optimized for 50 to 2500MHz linear tuning, up to one octave band widths, and low phase noise. Support your customers demands for smaller size and better performance, switch to ROS VCO's today!

ACTUAL SIZE

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

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-660PV	640-660	5	-107	-17	5	15	19.95
ROS-725PV	710-725	5	-105	-19	5	15	19.95
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	16	-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-1000V	900-1000	12	-102	-30	5	25	15.95
ROS-1100V	1000-1100	12	-103	-26	5	25	15.95
ROS-1410	850-1410	11	-99	-8	12	25	19.95
ROS-1720	1550-1720	12	-101	-17	12	25	19.95
ROS-2500	1600-2500	14	-90	-14	12	25	21.95

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

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US 182 INT'L 183

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

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

Temex Electronics Inc. 1226
Phoenix, AZ

H. Adjemian, J. Riter P. Ekpenyong

Temex Components designs and manufactures a broad family of capacitors, trimmers, isolators and materials, varactors and PIN diodes, SAW and crystal filters, XO, VCXO, TCXO, VTCXO, OCXO, VCO, Rubidium clocks and many other types of products. As one of the manufacturing arms of Tekelec-Temex, a multinational, we have operations in three continents. One is Phoenix, AZ. Our manufacturing operations are ISO 9001 and ISO 14001 registered. Please visit us at our Web site: www.tekelec-temex.com.

Diodes/FETs/Transistors, Filters, Isolators/Circulators, Materials, Oscillators, Resistors/Capacitors/Inductors, SAW Devices

Tensolite High Density Interconnect Systems 2701
Williston, VT

W. Jensen

The company is a designer and manufacturer of leading-edge, high density interconnects comprising high performance cable and high density terminations for high performance data transmissions applications.

Connectors/Cables/Adapters, Materials, Power Supplies, Printed Circuit Boards, Services, Shielding, Tubes

Tensolite High Performance Cable 2701
St. Augustine, FL

W. Jensen

The company is a leading designer and manufacturer of miniature coaxial, RF coaxial, aerospace and electronic high speed cables.

Connectors/Cables/Adapters, Services, Tubes

Tensolite QMI RF/Microwave 2701
Wilmington, MA

W. Jensen

Tensolite QMI RF/Microwave is an advanced manufacturer of 50 and 75 Ω RF and microwave interconnects and cable assemblies.

Connectors/Cables/Adapters, Materials, Services, Terminations, Test and Manufacturing Equipment, Tubes, Waveguide and Waveguide Components

Texas Instruments 1321
Dallas, TX

Texas Instruments is a global semiconductor company and the world's leading designer and supplier of digital signal processing and analog technologies, the engines driving the digitization of electronics. The company offers a comprehensive portfolio of wireless system solutions including RF, digital and analog processors, applications and system software, microcontrollers, ASIC and power management products. More information is located at www.ti.com.

Oscillators, RFICs, Signal Processing Components, Software, Synthesizers, Systems and Subsystems

Thin Film Concepts Inc. 1129
Elmsford, NY

L. Weinman, J. Murphy

Thin-film coating and photolithography services for electronics and communication applications will be featured as well as circuits, hybrids, sensors, heatsinks and other thin-film devices. Prototype and production capability. ISO 9002-registered firm.

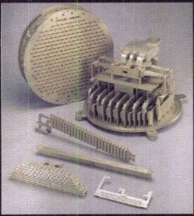
Hybrids, Materials, Optoelectronic Components/Fiber Optics, Resistors/Capacitors/Inductors, Services

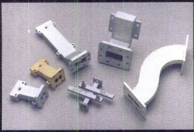
Thin Film Technology Inc. 336
Buellton, CA

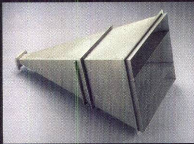
J. Wafer

[Continued on page 164]

CMT WAVEGUIDE COMPONENTS AND ASSEMBLIES







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Quality First
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Engineered like no other Waveguide Assemblies

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golf umbrella

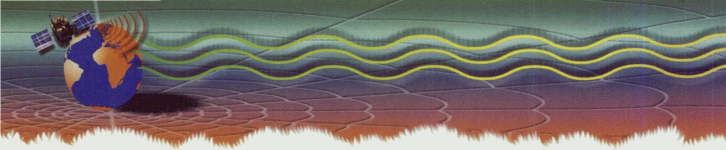
Continental Microwave & Tool Company, Inc.

A Chelton Microwave Company

Continental Microwave & Tool Company, Inc., 11 Continental Drive,
Exeter, NH 03833 Tel: 603-775-5200 Fax: 603-775-5201
e-mail sales@contmicro.com www.contmicro.com

ISO 9001 Certified

CIRCLE 56 ON READER SERVICE CARD



WDM optical filters and dielectric solder dams for BGAs (ball grid arrays) will be featured.

Attenuators, Couplers, Filters, Hybrids, Isolators/Circulators, Materials, Optoelectronic Components/Fiber Optics, Printed Circuit Boards, Resistors/Capacitors/Inductors, Services

Thomson-CSF Microelectronique **2912**
Massy, France

G. Dhiver

Millimeter-wave T/R modules for point-to-point and point-to-multipoint applications (frequency range: up to 60 GHz) will be featured.

Hybrids, Millimeter-wave Components, Oscillators, Services, Systems and Subsystems

Thomson Microsonics **2912**
Sophia, France

H. Sandager

RF SAW filters, including CSP package technology, will be featured.

SAW Devices

Thunderline-Z **2515**
Hampstead, NH

C. Tremblay, M. Cullen

Surface-mount feed throughs, GPO packages and waveguide windows will be featured

Hybrids, Materials, Terminations

Times Microwave Systems **1327**
Wallingford, CT

B. Krimsier, F. Kaczor, D. Dubuc, D. Murray

EW and microwave cable and cable assemblies; a multiport interconnect system; LMR communication cable and connectors; self-locking connectors; and Testmate test cable assemblies wil be featured.

Connectors/Cables/Adapters

Toshiba America Electronic Components Inc. **2231**
Irvine, CA

D. Lynn, M. Wood

Diodes/FETs/Transistors, MMICs

TRAK Ceramics Inc. (TCI) **1908**
Hagerstown, MD

D. Ottey, T. Saia

TCI is featuring a new line of low cost monoblock filters for wireless application, a new line of high Q temperature-stable dielectric materials for PCS and cellular filter applications, and several new low line width GARNET materials for isolators and circulators.

Filters, Materials

TRAK Communications **1908**
Tampa, FL

D. Fuller

TRAK Com is featuring the latest designs in RF components and subsystems including ferrite products, filter products, antennas, synthesizers, and GPS time and frequency systems.

Antennas/Radomes, Filters, Isolators/Circulators, Mixers/Modulators/Detectors, Oscillators, Power Dividers, Signal Processing Components, Synthesizers, Systems and Subsystems, Waveguide and Waveguide Components

Trans-Tech **1909**
Adamstown, MD

S. Wichtendahl, B. Hudson, B. Miller, R. Langman

Introducing Trans-Tech's new 2 mm SMT ceramic bandpass filters. Decreased package size will allow designers a smaller footprint with increased electrical performance for PCMCIA-type applications.

Antennas/Radomes, Filters, Materials

Trilithic Inc. **705**
Indianapolis, IN

B. Malcolm, R. Hollas, D. O'Connor, S. Johnson

Trilithic announces the availability of RSA series 3 GHz single and dual concentric rotary attenuators and PS-2.5 high performance switches operating to 2.5 GHz for RF wireless, R&D, ATE and production requirements.

Attenuators, Filters, Power Dividers, Systems and Subsystems, Switches, Terminations

TriQuint Semiconductor Inc. **2219**
Hillsboro, OR

R. Hamilton, R. Christ, D. Green

Millimeter-wave Components, MMICs, Optoelectronic Components/Fiber Optics, RFICs

Tronser Inc. **1017**
Cazenovia, NY

J. Dowd, M. Tronser

New products include specialty screw machine products.

Resistors/Capacitors/Inductors

Tru-Connector Corporation **731**
Peabody, MA

T. O'Neil, D. Sander, A. Laflin, B. Burke, B. Wheeler, S. Sherman

Tru-Connector offers QDM connectors with a positive locking quick-disconnect design and BNC/TNC interface dimensions that can be installed and removed without tools. Featuring a female connector with a mating groove that accepts the male, which is manually pulled back and released to allow three self-contained balls to be seated by clicking into place, the units provide a secure quick-disconnect connection. These connectors are rated for 1000 VRMS, operate DC to GHz and have a 50 Ω impedance. They fit 0.100″ through 0.425″ diameter cables and cannot be cross threaded or vibrate loose.

Connectors/Cables/Adapters

TRW **517**
Redondo Beach, CA

R. Bent, M. Quijije, D. Strait, J. Stokes

TRW's indium phosphide chips are now the fastest in the world. Learn more at the TRW booth.

Amplifiers, Millimeter-wave Components, MMICs, Services, Waveguide and Waveguide Components

T-Tech Inc. **1121**
Atlanta, GA

M. Richardson, W. Gifford

Printed Circuit Boards, Software

UltraSource Inc. **1220**
Hollis, NH

S. Broderick, M. Casper, W. Mraz

Custom thin-film hybrid circuits, metallized ceramic substrates, thin-film and thick-film etching services, dicing services, and alumina and silicon resistor chips will be featured.

Hybrids, Materials, Resistors/Capacitors/Inductors, Services

United Monolithic Semiconductors **534**
Orsay, France

J.M. Hovillon, P. Labasse

UMS is a leader in the GaAs MMIC market for professional and civil millimeter-wave applications. UMS also offers pHEMT, MESFET and HBT technologies as open service. Some recently released products include power amplifiers (34 to 40 GHz), attenuators (DC to 40 GHz), and low noise amplifiers and mixers (23 to 26.5 GHz and 22 to 26 GHz).

Amplifiers, Attenuators, Diodes/FETs/Transistors, Millimeter-wave Components, Mixers/Modulators/Detectors, MMICs, Optoelectronic Components/Fiber Optics, Oscillators, Phase Shifters, Switches

UTE Microwave Inc. **1535**
Asbury Park, NJ

L. Nilson, A. Owens, J. Riley

Featured products include high power strip line mountable circulators and isolators for UHF communication and TV bands, cellular, PCS and radar applications.

Isolators/Circulators

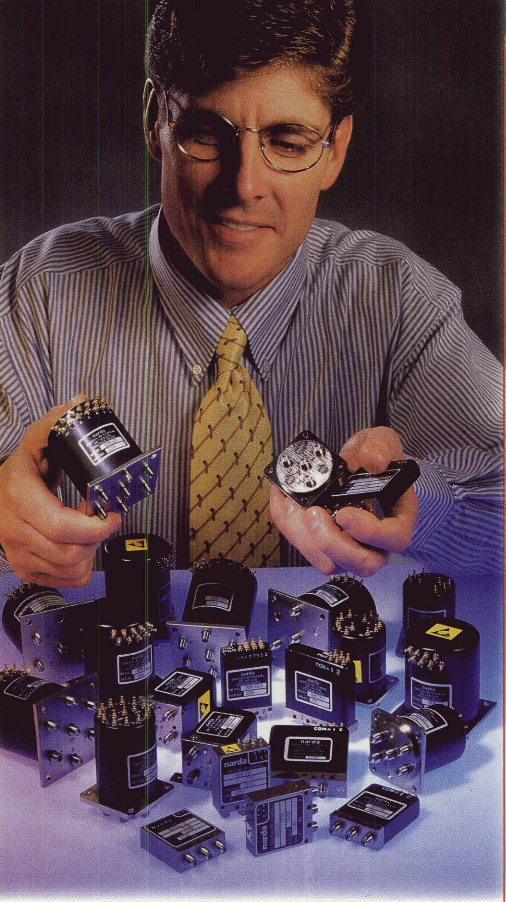
Vector Fields Inc. **2803**
Aurora, IL

D. Carpenter, J. Oakley, J. Whitney

Vector Fields announces CONCERTO, a new software package for high frequency design and analysis. Applications include antennas, resonators, microstrips, waveguides and microwave heating.

Software

[Continued on page 166]



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

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

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

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

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

NQA ISO9001 REGISTERED COMPANY

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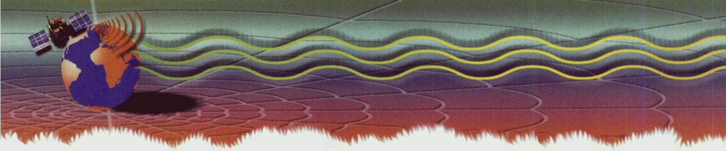
an L3 communications company

It's Narda to be precise.

www.nardamicrowave.com



Vectron International **1609**
Norwalk, CT

The Vectron International group designs, manufactures and markets frequency generation and control products using the very latest techniques in both standard crystal and SAW-based designs from DC to microwave frequencies. Products include crystals, crystal oscillators, VCXOs, TCXOs, OCXOs, SAW filters and components, and clock and data recovery modules for telecommunication and data communication applications.

Filter, Millimeter-wave Components, Optoelectronic Components/Fiber Optics, Oscillators, SAW Devices

Vertex RSI, a Tripoint Global co. **1721**
Duluthe, GA

M. Stupnik, K. Stupnik

SATCOM feed components will be featured.

Antennas/Radomes, Filters, Millimeter-wave Components, Power Dividers, Waveguide and Waveguide Components

Victory Industrial Corporation **1117**
Taipei, Taiwan, ROC

M.H. Chen

Featured products include LMDS antennas, VSAT antennas, filters/diplexers and passive W/G components.

Antennas/Radomes, Couplers, Filters, Isolators/Circulators, Waveguide and Waveguide Components

Voltronics Corporation **636**
Rockaway, NJ

N. Perrella

Precision multiturn trimmer capacitors, DRO and microwave tuners, and single-turn surface-mount and PC-mount ceramic trimmer capacitors will be featured.

Resistors/Capacitors/Inductors

Watkins-Johnson Company (WJ) **1709**
Milpitas, CA

P. Roberts

For more than 40 years, Watkins-Johnson Company has taken the lead in manufacturing high performance RF components including low cost GaAs FETs, amplifiers and mixers as well as integrated assemblies including converters, power amplifiers and repeaters. Markets cover wireless telecommunication infrastructure: cellular ISM, PCS, WLL and U-NII bands, CATV headend and distribution, cable modems, WLAN and others requiring high dynamic range RF products.

Amplifiers, Diodes/FETs/Transistors, Mixers/Modulators/Detectors, MMICs, RFICs, Systems and Subsystems

Weinschel Corporation **2025**
Frederick, MD

R. Stephens, G. Smith, B. Knill, J. Dholoo, L. Pregley, D. Powers

Weinschel Corporation has designed and manufactured quality RF and microwave attenuation products for more than 43 years and offers the widest selection of connectorized attenuation products available anywhere. Product lines include fixed attenuators (many dB values with models capable of handling up to 1000 W), variable attenuators, step attenuators (manual, motorized and programmable), terminations and loads, precision adapters and connectors (all types, including blind-mate and planar crown connector systems), directional couplers, power splitters and dividers, and custom RF and microwave components for application-specific requirements.

Attenuators, Connectors/Cables/Adapters, Couplers

Werlatone Inc. **212**
Brewster, NY

P. Kuring, C. Schuster

Since 1965. Wideband combiners, dividers, hybrids 90°/180° and directional couplers from DC to 4.2 GHz at power levels from 10 W to 50 kW.

Couplers, Hybrids, Power Dividers, Power Combiners

West·Bond Inc. **513**
Anaheim, CA

J. Price, R. Straight, P. Martin, M. Ritchie, B. King

www.westbond.com, since 1966. Ultrasonic wire bonders, eutectic and epoxy die bonders, pull and shear test equipment, and accessories for all microwave, hybrid and RF production will be featured.

Power Supplies, Systems and Subsystems, Test and Manufacturing Equipment

Williams Advanced Materials **241**
Buffalo, NY

J. Alfano, J. Snyer T. Hill, S. Nelson

Williams is a full-service supplier of packaging and thin-film materials. Products include sputtering targets, evaporation materials, backing plates, bonding wire, lids, solder, braze materials, bonding pads, high purity specialty alloys, power straps, and refining and recycling services.

Hybrids, Materials, Oscillators, SAW Devices, Services

Wireless Design & Development **137**
Morris Plains, NJ

V. Peters

Wireless Design and Development is a wireless technology tabloid that reaches more than 45,000 design engineers every month. Published by Cahners Business Information.

Publications

W.L. Gore & Associates Inc. **1412**
Newark, DE

D. Kelly, T. Whitten

W.L. Gore & Associates Inc. specializes in optimal performing microwave cable assemblies and materials for use in test, space and defense applications.

Connectors/Cables/Adapters

Xemod **2611**
Santa Clara, CA

M. Condon, M. Foster, R. Clark

Featured products include new models for the 2110 to 2170 MHz band and improved performance in the DCS1800 and PCS1900 bands.

Amplifiers, Diodes/FETs/Transistors, Signal Processing Components

XL Microwave Inc. **832**
Oakland, CA

S. Brock, D. Thornton

Featured products include the Path Align-R™ (microwave antenna path alignment test set), a rubidium frequency standard and a 60 GHz frequency counter with power meter.

Power Supplies, Synthesizers, Test and Manufacturing Equipment

Xpedion Design Systems **2503**
Santa Clara, CA

R. Curtin

Xpedion introduces GoldenGate,™ a family of simulation and modeling software for RF and microwave design. GoldenGate supports linear, nonlinear and envelope transient simulation to reduce design time and improve performance for wireless systems and IC design teams. GoldenGate is integrated with leading EDA and communication system design environments running Unix and Windows.

Software

Zeland Software **1306**
Fremont, CA

A. Meyer

Featured products include the LINMIC+/N microwave and RF design suite ((M)MIC CAD software, Windows and Unix).

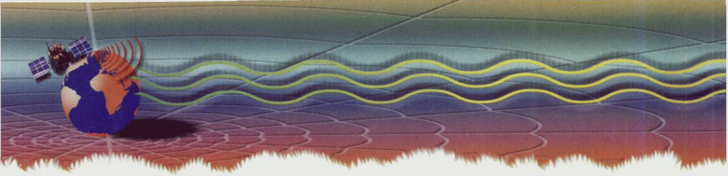
Services, Software

Zeta **2001**
San Jose, CA

D. Martell, S. Wright

Zeta is a leading supplier of microwave products used worldwide, including crystal-stabilized sources, frequency multipliers, comb generators, frequency synthesizers, frequency converters and microwave subsystems.

Amplifiers, Oscillators, Synthesizers, Systems and Subsystems



2000 IMS EXHIBITORS

The following list is complete as of press time, but may not include all companies.

A-Alpha Waveguide	3011
Accumet Engineering Corp.	220
ACE Technology	525
Advanced Control Components Inc.	339
Advanced Noise Technologies	1125
Advanced Switch Technology	133
Advanced Technology Group Inc.	1020
Advance Reproductions Corp.	316
ADVANTECH	3004
Aeroflex Comstron	1809
Aeroflex Incorporated	1809
Aeroflex Lintek Corp.	1809
Aeroflex/MIC Technology	1809
Aerowave Inc.	2307
Agilent Technologies (formerly HP)	1421
AIL Systems Inc.	2804
Airpax Corp./EPP	620
A.J. Tuck Co.	605
AKON Inc.	1136
Alan Industries Inc.	920
Alberta Microelectronic Corporation	2917
Alcatel	414
Alpha Industries	1904
AMCOM Communications Inc.	1100
American Technical Ceramics	510
AMITRON	717
AML Communications Inc.	2900
AMOTECH Co. Ltd.	3928
Amphenol CNP	2216
Amplifier Research	1005
Amplifonix Inc.	1016
AmpliX Wireless & Satcom	604
ANADIGICS Inc.	2237
Anaren Microwave	711
Anatech Ltd.	132
Anritsu Company	2125
Ansoft Corporation	2005
Antcom Corporation	3005
API Delevan	3017
Aplac Solutions Corporation	1212
Applied Engineering Products	2313
Applied Microwave & Wireless	1218
Applied Specialties Inc.	1025
Applied Thin-Film Products	107
Applied Wave Research Inc.	2401
APTA Group Corp.	1106
ARC Technologies Inc.	1219
Arlon Materials for Electronics	225
Artech House	814
Assemblies Inc.	1504
Astrolab Inc.	1305
Atlantic Microwave Corp.	406
ATN Microwave Inc.	919
A.T. Wall Company	1012
Avnet Electronics Marketing	2907
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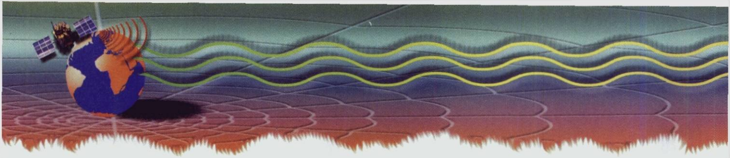

HTA Photomask 735
Hybond Inc. 2904
Hypertronics Corp. 2610
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IMI Inc. 2407
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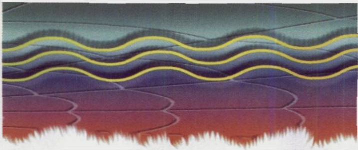

Microwave db 1021
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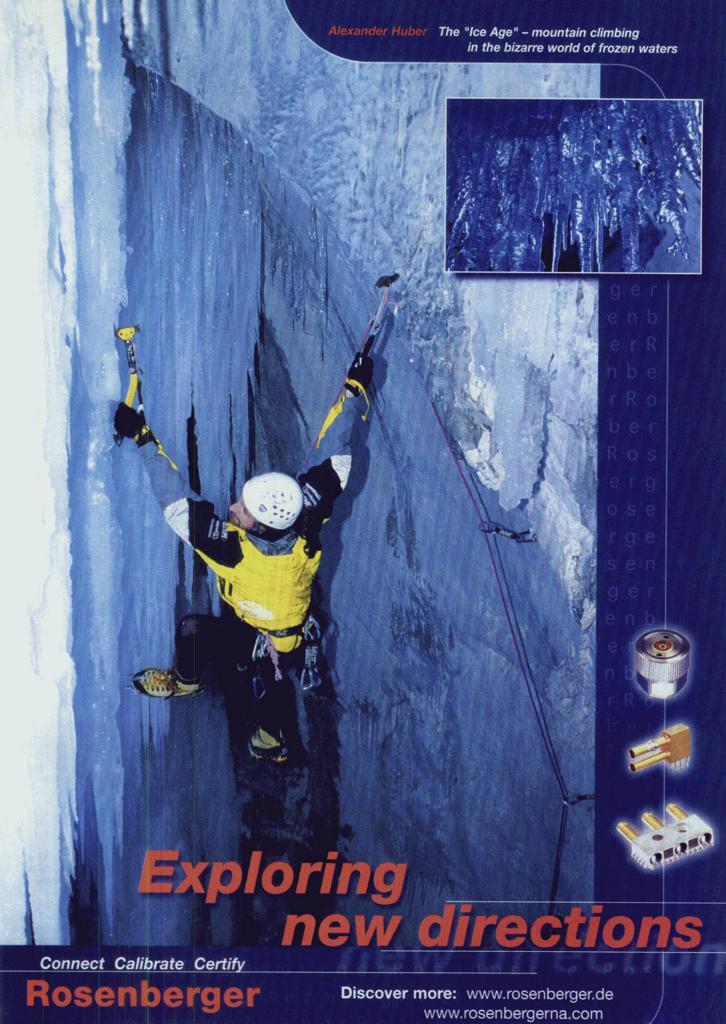
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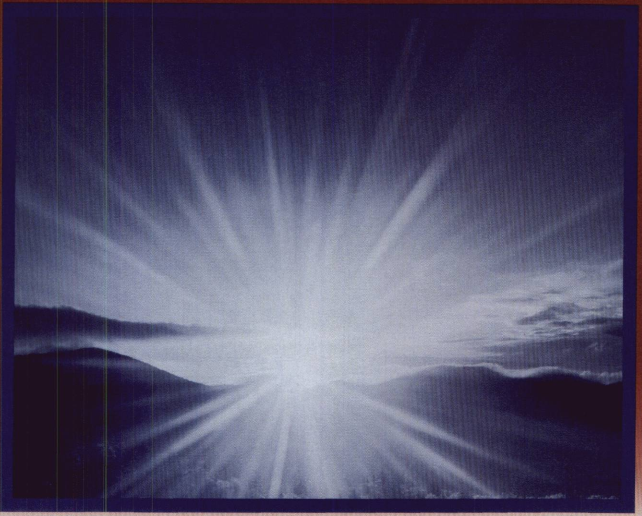
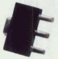


More power equals more freedom.

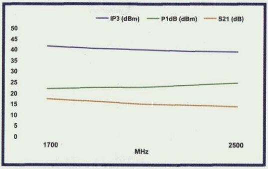
Introducing the SXT-289. A new wideband GaAsHBT power amplifier.

Stanford Microdevices introduces the SXT-289 — the perfect driver amplifier for today's and tomorrow's advanced communication infrastructure equipment.



With power to spare, giving you freedom from design constraints, this amplifier was designed and manufactured using state-of-the-art Gallium Arsenide heterojunction bipolar transistor (GaAs HBT) process technology. These devices are ideal for use as a driver stage for power amplifiers installed in cellular PCS infrastructure equipment and conform to TDMA, CDMA and PCS 1900 modulation standards. The SXT-289 operates from a single 5VDC supply and offers exceptional linearity performance in a small form-factor plastic SOT-89 with backside ground.

For more information on the SXT-289 or any of our other products, visit our website today and experience RF Innovation from Stanford Microdevices.



Typical device performance. Bias =5V @ 110mA typ.

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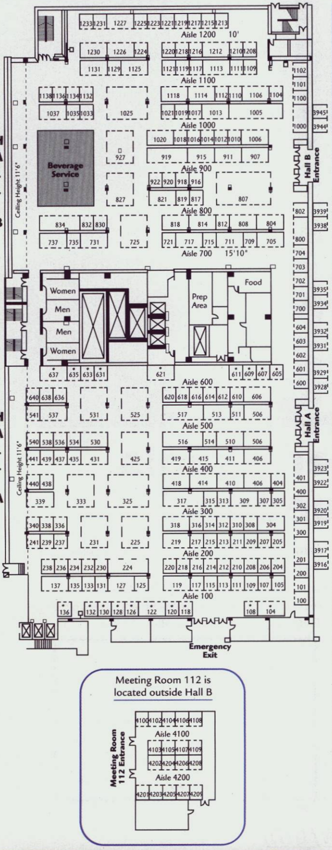
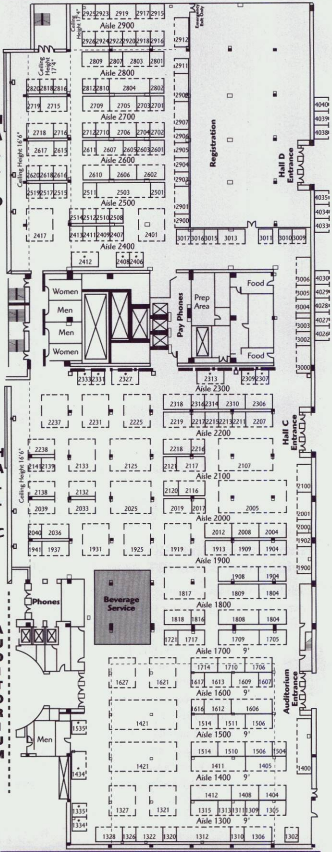


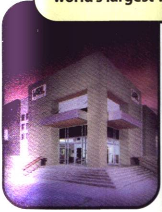
LEVEL 1



LEVEL 2

Everyday at Vari-L innovative engineering designs are coupled with state-of-the-art manufacturing technologies to create high performance, cost-effective RF and microwave solutions for the world's largest wireless equipment companies.

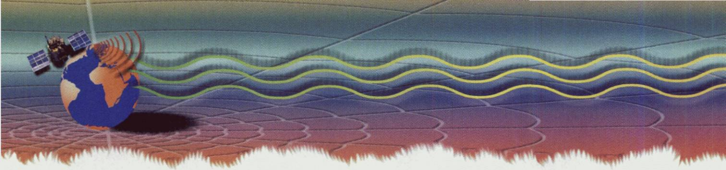
VARIL



At Vari-L, we are dedicated to research and development. Our exceptional commitment to innovation has resulted in eight new patents in the last three years alone. Since 1953, our products have been utilized in many diversified and demanding applications ranging from satellite and aerospace systems, CATV and fiber optic transmission systems to wireless base stations and handsets.

Our intensive investment in state-of-the-art manufacturing technology gives us the ability to offer low cost product realization through automated assembly, handling and testing. Recent expansions in our automated production systems have created a projected Year 2000 manufacturing capacity in excess of 12 million units housed within Vari-L's 80,000-square foot facility in Denver, Colorado.

Over 90% of our shipments are custom solutions tailored specifically to a customer's RF/microwave signal sources or signal processing project requirement. At Vari-L, our continued focus on research and development and commitment to enhancing manufacturing technology is intended to ensure that "We have a part in your future."



2000 IEEE MTT-S IMS TECHNICAL PROGRAM

SUNDAY, JUNE 11, 2000

8:00 AM–12:00 PM

WSG: SPATIAL AND QUASI-OPTICAL POWER COMBINING ARRAYS

A strong need exists to obtain practical radiating power levels from solid-state sources at microwave and millimeter-wave frequencies. Spatial and quasi-optical power combining techniques also offer an attractive means for performing many mm-wave array functions. These techniques represent a significant step in further miniaturization of microwave and millimeter-wave modules for commercial as well as military communication applications. During the past year several groups in academia and industry have achieved substantial power levels by combining the power from many solid-state devices at microwaves and < 150 W at X-band, UC Santa Barbara/Hughes Research Labs; 60 W at V-band, Lockheed Martin/Sanders; 25 W at Ka-band, Lockheed Martin/NCSU; and 5 W at W-band, CALTECH.

In this workshop successful circuit design approaches as well as CAE tools employed for both circuit-level as well as electromagnetic modeling of quasi-optical circuits and systems will be presented. Deliberations in the workshop will emphasize circuit/electromagnetic field interaction and modeling, 3-D interconnects, the design of efficient coupling systems, electrothermal issues and circuit/device tolerances. Furthermore, issues involving functionality of the quasi-optical systems such as frequency multiplication and beam steering and transmit/receive arrays will be discussed. Sufficient time will be provided for active audience participation through verbal/written comments and questions.

WSH: ANTENNAS AND PROPAGATION FOR WIRELESS COMMUNICATION

This one-day tutorial/workshop will provide a fundamental and broad introduction to antenna properties, antenna design considerations and RF propagation issues. The workshop will begin with the basic concepts and definitions used in the antenna and propagation industry. Antenna characteristics such as SWR, radiation pattern, polarization, axial ratio, directivity, gain and EIRP will be defined and their impact on wireless system performance illustrated. Additionally, an overview of different antenna types including wire, portable, microstrip, circularly polarized and aperture will be presented. The basic concepts associated with the design and performance of antenna arrays also will be discussed. RF propagation issues such as path loss, multipath fading, polarization distortion, noise and interference, and diversity implementation will be described and their impact on system performance illustrated. An overview of the different types of antennas used in today's wireless communications systems also will be presented. The workshop will conclude with some practical examples of the concepts presented and demonstrations of actual antenna design using some commercially available antenna design software.

8:00 AM–5:00 PM

WSA: SILICON/SILICON GERMANIUM BICMOS PROCESSES AND CIRCUIT TECHNIQUES FOR RFICS

What composes a radio frequency (RF) bipolar CMOS (BiCMOS) process? What advantages do silicon and silicon germanium (SIGe) RF BiCMOS processes give to an RFIC designer? What does SiGe do to enhance RF BiCMOS? What types of circuits can be constructed on RF BiCMOS? If CMOS is the technology for RF, why are people using BiCMOS? Why is RF integrated circuit (RFIC) BiCMOS process technology continuing to be developed? Modern cost-driven communications systems rely on low cost silicon IC technologies for all functions, from the front-end receiver and transmitter to the baseband signal processing. Today's silicon BiCMOS offers bipolar devices for superior RF and analog circuit functions and CMOS for the ever-increasing digital interface requirements. These devices are combined in high frequency RFICs to provide low cost, complex analog and digital functions.

This workshop will begin by describing typical Si and SiGe BiCMOS processes that are specifically tailored for RFICs. Not all BiCMOS processes are capable of working well for RFICs, but must often be customized to the particular requirements of high frequency analog circuit applications. The process descriptions will delve into the operating characteristics of the active devices (bipolar and MOS transistors, varactors, etc.), passive components (capacitors, inductors, resistors, etc.) and other process-related advantages and limitations of BiCMOS processes used for RF circuits. Often these RFIC BiCMOS processes are coupled with analog design techniques that are often unfamiliar to the RF circuit designer. These circuit techniques are employed in addition to familiar RF design techniques to take full advantage of process characteristics. The second half of the workshop will concentrate on RFIC BiCMOS circuit techniques employed by several successful RFIC designers.

WSB: EFFICIENCY & LINEARITY ENHANCEMENT METHODS FOR PORTABLE RF/MW POWER AMPLIFIERS

The digital modulation formats utilized in present second-generation cellular systems, proposed 3G cellular systems and many other wireless applications require linear power amplifiers in the transmitter unit of the mobile radio. The battery-powered nature of these radios places a premium on the power amplifier exhibiting maximum efficiency with an acceptable level of linearity – both of which must be balanced against cost and size constraints to be a viable solution. The point at which the amplifier should exhibit maximum efficiency is not necessarily at the highest transmit power level. The use of power control in certain systems (i.e., IS-95B) where the radio transmits at power levels tens of decibels from maximum for extended periods of time (back-off) may place a significantly higher weighting on amplifier efficiency under power back-off rather than at peak conditions. The goal of improving the inherent design trade-off between efficiency and linearity has spawned a great deal of interest in applying more advanced amplifier architectures, including supply modulation (envelope following, envelope tracking), phasing (LINC), feedback (polar, cartesian, harmonic), Doherty and load modulation to name but a few. The workshop will be both tutorial and advanced in nature; the operation of various emerging amplifier architectures will be reviewed and their performance potential, cost and size attributes for wireless applications examined.

WSC: MICROWAVE FILTER SYNTHESIS AND EQUIVALENT CIRCUIT EXTRACTIONS

Network synthesis using modern methods based on transformed variables will be present-

[Continued on page 182]

Imagine the possibilities.

Introducing our newest NGA InGaP HBT amplifier family with low thermal resistance for higher reliability and improved linearity with broader bandwidth.

Stanford Microdevices introduces the NGA-100 through 600 Series InGaP HBT amplifiers designed for today's and tomorrow's advanced communication infrastructure equipment. Design and fabricated with state-of-the-art InGaP/GaAsHBT technology for higher reliability, these devices are ideal for use as driver stages for higher power applications. Available in small-form factor plastic packages, the NGA series are biased with a single voltage and provide wide bandwidth, high gain and exceptional linearity.

For more information on these new InGaP amplifiers, visit our website today. Imagine the possibilities with RF innovation from Stanford Microdevices.

NGA - InGaP MMIC 50 Ohm Gain Block Amplifiers

Model	Freq Range (GHz)	Vd (V)	Id (mA)	Gain (dB)	PldB (dBm)	IP_3 (dBm)	Thermal Resistance (°C/W)
NGA-186	0.1-6.0	4.1	50.0	12.5	14.6	32.9	120
NGA-286	0.1-6.0	4.0	50.0	15.5	15.2	32.0	120
NGA-386	0.1-5.0	4.0	35.0	20.8	14.5	25.8	144
NGA-486	0.1-6.0	5.0	80.0	14.8	18.3	39.5	118
NGA-586	0.1-6.0	5.0	80.0	19.9	18.9	39.6	121
NGA-686	0.1-6.0	5.9	80.0	11.8	19.5	37.5	121

Data at 1 GHz and is typical of device performance.

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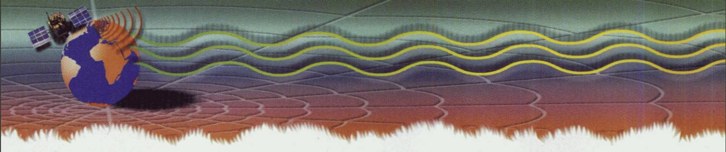

ed. This process automatically solves the previously difficult approximation problem and simplifies the theory to such an extent that it can no longer be considered a difficult topic. Examples to be presented include cross-coupled filters, physically asymmetric filters (such as singly terminated structures) and other new realizations. The process of equivalent circuit element extraction using electromagnetic simulations also will be described. This process allows very fast optimization of synthesized practical filters to yield precise responses. The synthesis of different physical filter configurations using various transmission media and topologies such as dual-mode, dielectric resonator, coaxial cavity (combline) and ridge waveguide filters will be discussed. Equivalent circuits of components (i.e., T-junctions) used in multiplexers realizations will be described.

WSD: BLUETOOTH TECHNOLOGY – FROM CONCEPT TO IMPLEMENTATION

Bluetooth technology answers the need for short-range wireless connectivity within three areas: data and voice access points, cable replacement and ad hoc networking. Its specification defines a system solution comprising hardware, software and interoperability requirements. The Bluetooth radio operates in a globally available 2.4 GHz ISM band, ensuring communication compatibility worldwide. All of these factors are spurring the interest for this enabling technology. This workshop will present an overview of Bluetooth technology. The history and current status of Bluetooth will be introduced. Potential applications of the technology will be presented. System-level specifications and considerations will be discussed. Bluetooth baseband and radio architecture will be addressed. Finally, circuit implementations of Bluetooth on different technologies (CMOS, BiCMOS and SOI) will be presented.

[Continued on page 184]

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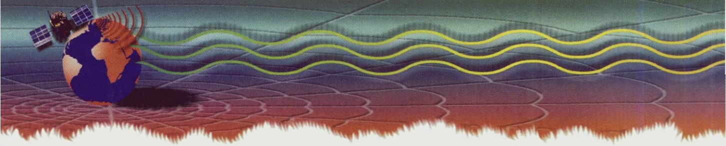


WSE: Millimeter-wave Packaging – Industry Practices and Emerging Technology

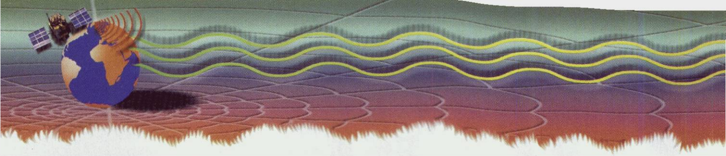
The wireless communications market has exploded during the last several years. As a result, frequency usage and commercial wireless applications have continued to move rapidly toward the millimeter-wave regime. Emergence of millimeter-wave wireless applications including LMDS (28 GHz), WLAN (60 GHz) and automotive collision radar (77 GHz) has brought new demands for low cost, miniaturized, high volume packages and multichip modules at millimeter-wave frequencies. To complicate the package designer's task, emerging technologies such as RF MEMS and optical components will need to be integrated into the multichip packages. As the level of integration and the operating frequency increase, coupling between components and parasitic reactance within the package will play a greater role in the package design. In this full-day workshop, participants will obtain a clear understanding of the issues involved in designing highly integrated packages, an in-depth understanding of the current manufacturing techniques that the packaging industry is using and an overview of the development of novel, millimeter-wave packaging technologies that will impact the future of millimeter-wave packaging.

WSF: An Introduction to the Theory and Practice of Numerical Electromagnetics

The proliferation of computer tools for microwave analysis, design and optimization is having a profound effect on the working environment of microwave engineers. While most practitioners can use such tools after a certain period of training, many remain skeptical as to the trustworthiness of numerical results and hesitate about the limits, errors and significance of the data generated. The key is to understand what goes on inside these tools and how they solve electromagnetic fields.

The purpose of this tutorial is to provide insight into the operating principles of electromagnetic simulators and show how these principles translate into their properties as engineering tools. The characteristics of frequency and time domain simulators based on finite element, finite difference and method of moment formulations will be presented in terms accessible to the practitioner, and the resulting performance profiles of simulators based on these methods will be demonstrated. This includes the pre- and postprocessing steps that relate geometry and material data with field information and microwave characteristics. Special emphasis will be placed on convergence, error control and validation using basic calibration elements. By solving a canonical set of structures whose properties are accurately known, the key aspects of the various methods and simulator types will be demonstrated. In this way, a solid foundation for user confidence and good technical judgment will be laid in a systematic manner. The tutorial will benefit: a) microwave engineers familiar with linear and nonlinear CAD who would like to learn more about field solvers, b) experienced users of electromagnetic simulators who seek a better understanding of their theoretical and computational foundations, and c) researchers familiar with computational electromagnetics who would like to learn more about the requirements, concerns and methodology of microwave practitioners. Specific commercial tools will be mentioned or used only for the purpose of providing typical examples. This in no way implies a commercial endorsement by the speakers.

[Continued on page 186]



1:00 PM–5:00 PM

WSI: Emerging Technology for High Power (> 100 W) Power Amplifiers

Many modern radio systems including cellular base stations, satellite communications, avionics communications and military data links require microwave power amplifiers that produce hundreds or thousands of watts of RF power. The design of power amplifiers to work at these power levels requires consideration of many complex interactions between the electrical and thermal properties of the devices used. Today, such power levels are often achieved through the use of device technology that was developed more than a decade ago. Several new technologies are emerging from research facilities that have the potential to revolutionize this field. These technologies include wide bandgap semiconductor devices (SiC and GaN) as well as advanced cooling techniques. This workshop will first include an overview of the current state-of-the-art techniques applied in production high power amplifiers. Wide bandgap semiconductor developments then will be presented and their potential effects on this field discussed. Advanced cooling technologies and their potential impact also will be covered.

WSJ: New Developments in Mixed-mode Techniques for Nonlinear Circuit Design

The well-established mixed-mode harmonic balance (HB) techniques describe dispersive and distributed elements of a nonlinear circuit directly in the frequency domain. In addition, they are able to minimize the number of variables in the circuit either by treating the linear components as a subnetwork or by using the sparsity of a modal admittance matrix. It follows that these techniques are able to analyze and optimize steady-state, quasi-periodic, RF and microwave nonlinear circuits.These approaches are especially successful when applied to large microwave and wireless circuits in monolithic integrated technology.

This workshop will present in-depth tutorial discussions as well as new developments in mixed-mode techniques for analyzing nonlinear circuits. It will also provide discussions on problems of consistent time domain modeling and new ideas for circuit simulation algorithms. Furthermore, this workshop will supply a forum for discussion on current important issues, possible solutions and development directions in the future. As a very important part of the workshop, results and inquiries from participants will be welcome during the concluding discussions. Participants are strongly encouraged to bring transparencies and to explain their point of view.

WSK: Micro-/Millimeter-wave Transceivers for Mass Production – Design, Technology, Implementation

Production of micro-/millimeter-wave transceivers in quantities higher than 100,000 units is becoming a more and more challenging request not only for automotive and industrial sensors but also for telecommunication systems such as PTP, PTMP/LMDS and WLAN. Such systems require bidirectional transreceivers for customer premise equipment at consumer cost and with characteristics equivalent to or better than conventional PTP microwave radio links. To achieve these goals a proper combination of design and industrial technologies is required.

In the workshop technical and industrial experts will present and discuss the implementation and production processes of several micro-/millimeter-wave transceivers in frequency bands up to 60 GHz. Different aspects will be covered and discussed, including product applications and market forecasts in micro-/mil-

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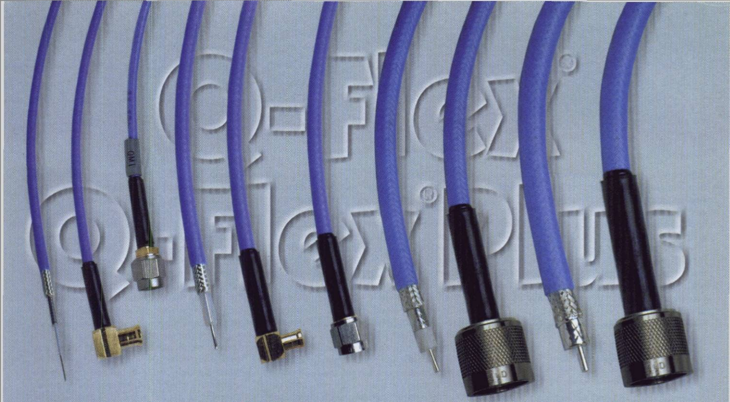

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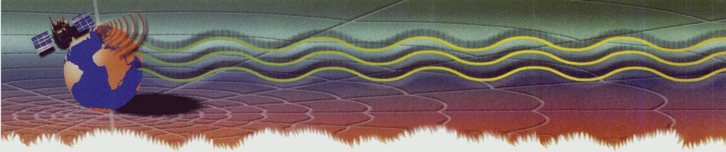

limeter-wave radar sensors and communications, a comparison of technology approaches suitable for mass production (metal-organic and multilayer substrates, flip chip+MMIC+coplanar, injection molding, flat antennas), system requirements and transceiver architecture trade-offs, a low cost building platform for different frequency allocations, industrialization and fully automated production and testing, production results and statistics, and cost targets from pilot phase to standard production.

MONDAY, JUNE 12, 2000

8:00 AM–12:00 PM

WMI: DIGITAL RECEIVERS FOR MILITARY AND COMMERCIAL APPLICATIONS

Several wideband and narrowband digital receiver systems have been developed for both military and commercial applications during the past few years. The wideband receivers are designed to provide higher performance. They also need to be more reliable and easier to maintain. An example of this is the digital channelized receiver, which has provided better frequency resolution and signal arbitration compared to its analog counterparts. This is made possible because of the use of digital filters, which are generally less sensitive to temperature variation and have no drift problems. With the incorporation of the digital signal processing techniques, modern digital receivers for both communication and radar intercept applications are also more capable compared to their analog predecessor. On the other hand, due to the drastic improvement in processing speed, narrowband receivers can be implemented in software. This leads to a reduction in hardware and, at the same time, provides great versatility for a variety of applications. The result is a reduction in the receiver cost when produced in large quantities.

This workshop will bring together leading digital receiver experts. It will begin with tutorial talks on folding and interpolating (for wideband) and sigma-delta over-sampling (for large dynamic range) ADCs to provide a basic understanding of the crucial elements of digital receivers. This will be followed by talks on wideband communication and electronic warfare receivers. In addition, talks on narrowband receivers implemented using a software approach for GPS and communication receivers for commercial applications also will be presented. The workshop is aimed at providing basic digital receiver concepts as well as the latest developments in both the military and commercial world.

8:00 AM–5:00 PM

WMA: RF POWER AMPLIFIERS, CLASSES A THROUGH S – HOW THEY OPERATE, HOW TO DESIGN THEM AND WHEN TO USE EACH

This full-day course is for beginner through advanced design engineers and their supervisors who are concerned with designing any type of RF power amplifier product (i.e., radio transmitter or RF power source for induction heating, dielectric heating, plasma generation or illumination). Learn how all types of linear and nonlinear RF power amplifier circuits operate, how to design them and when to use each, and be able to design manufacturable RF power amplifiers that work satisfactorily under all foreseen normal and abnormal operating conditions.

With at least 10 lettered classes of RF power amplifiers and several combinations of those classes, many engineers are confused about RF power amplifiers. The complexity of the subject is compounded by the fact that the RF power transistor acts either as a high resistance current source or as a low resistance switch, or (in some amplifiers) as a high resistance current source during part of the on interval and as a low resistance switch during another part of the on interval (mixed-mode operation). The circuit topology does not define unambiguously the transistor operating mode or the amplifier class of operation; examples are shown. This tutorial will review:

- Saturated (switching-mode) and unsaturated (linear) families, amplifier classes A through S
- Transistor Utilization Factor = (Pout per transistor)/(Ipeak * Vpeak) for each class of operation
- BJTs, MOSFETs and MESFETs operating in current source (linear) mode, switching mode and mixed-mode operation
- Interactions between the power transistor and external circuit (determining transistor and circuit operating conditions)
- Controlling RF output amplitude vs. modulating information onto an amplitude envelope
- Benefits and shortcomings of each circuit
- Reasons for oscillation and how to ensure stability
- Suitable application areas for each circuit
- Linear amplifier systems using RF power amplifier circuits as building blocks
- CAD of switching-mode RF power amplifiers

WMB: WAVELETS FOR EM, DEVICE AND CIRCUIT MODELING

The use of wavelets in scientific computations is an area that has been exploding in significant results and applications, much faster than written scientific documentation can keep up. The application of wavelets for the solution of problems in electromagnetics and RF circuits has been a very recent and exciting activity that has demonstrated the potential to lead toward a formalism that unifies all the existing techniques either in the frequency or time domain. The capability of wavelet expansions to represent different levels of resolution in a natural manner at spatially or temporally separate parts of a problem has been effectively exploited in the signal processing and image analysis communities. These same capabilities can be employed to reduce computation time and computer memory requirements by orders of magnitude in the modeling of electromagnetic structures and of RF devices and circuits.

Multiresolution techniques, based on wavelet expansions, provide a rigorous approach to the adaptive refinement of the computation in regions of space or time where the fields or circuit parameters or their derivatives are large and to the economy of computational resources where they are not needed. For example, a pulse in a three-dimensional EM structure can be followed with a refined computation, equivalent to a refined grid, allowing the remainder of the structure to be simulated using the equivalent of a much coarser grid. Wavelet techniques also provide a natural way to self-consistently solve circuit problems where the time scales of different parts of the circuit are radically different. For example, thermal transport equations can be easily solved simultaneously with the nonlinear equations for the electrical parts of a circuit. In the multiresolution techniques a zero-order scaling function at a given level of detail, together with its associated wavelets of orders zero through n, is a natural way to express increasing levels of detail in a scene, a signal or an EM field pattern.

There is a great deal of flexibility in choosing or constructing the scaling function and wavelets so that special properties can be built in that will facilitate particular applications. Specifically, they can be localized in both time and frequency (or space and spatial frequency) and can be constructed to have useful mathematical properties such as orthogonality and normality in order to take advantage of the extensive framework of well-developed mathematical operational techniques. There is a strong potential for interest by industry and the government in this new technology. The goals of this workshop are to introduce computational EM professionals to a rapidly progressing new subfield in the electronics disciplines, to acquaint RF professionals with the major impacts that this technical area will have on RF applications and to provide practical "how to" information for researchers interested in incorporating these techniques into their work.

WMC: APPLICATIONS OF ARTIFICIAL NEURAL NETWORKS TO RF AND MICROWAVE DESIGN

The recent introduction of artificial neural networks (ANN) to the microwave field marks the birth of an unconventional alternative to modeling and design optimization problems in RF and microwave CAD. ANN can learn and generalize from data, allowing model development even when component formulas are unavailable. ANN models are easier to update as technology changes. ANNs are also universal approximators, allowing re-use of the same modeling technology for both linear and nonlinear problems and at both device or circuit levels. However, ANN models are simple and model evaluation is very fast.

Recent works have led to the use of ANNs for modeling microstrip lines, vias, CPW discontinuities, printed antennas, spiral induc-

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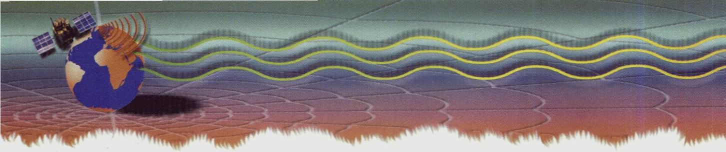

tors, FETs and VLSI interconnects; for speeding up harmonic balance simulations and optimizations; and for Smith chart representation and automatic impedance matching. These pioneering works herald a brand new opportunity to conquer some of the toughest RF and microwave CAD problems today and tomorrow. This tutorial introduces the fundamentals of using ANNs for RF and microwave modeling and design. The course will also bring the audience to the forefront of this emerging field with state-of-the-art research results.

The tutorial will cover:

- Basics of neural networks
- Neural networks for EM modeling
- Neural models for passive components
- Neural models for printed antennas
- Neural models for nonlinear components
- Neural network based circuit simulation and optimization
- Issues in developing neural network models
- Neural network structures and training

WMD: Future Trends in Ferrite Devices and Technology

Future trends in ferrite technology include challenges in applications, manufacturing techniques and materials, and cost is a critical factor in both commercial and defense applications. Commercial communication and vehicular radar systems call for reconfiguration of standard ferrite devices to meet size, weight and integration specifications. Multifunction defense systems are driving device performance to 5:1 bandwidths at 100 W power levels, all within the space allowed in a phased array antenna. Future space and satellite interconnects will require broadband operation at millimeter and submillimeter wavelengths. Candidate technologies for some applications will include tapecasting, low temperature co-fired ceramics, hexagonal ferrites and other types of functional materials. Integration, additional functionality and user-friendly CAD tools will complement the above manufacturing and material developments. Novel applications are anticipated in several areas including solitons, gyroelectric media and frequency-selective MSW devices.

WME: Advances in Ceramic Interconnect Technologies for Wireless, RF and Microwave Applications

The workshop will build on the success of a similar one organized for the Anaheim event in 1999. At this event almost 100 delegates attended and a show of hands at the end indicated unanimous support for a similar event in 2000. The purpose of the workshop will be to acquaint engineers with the capabilities of ceramic technologies for realizing wireless and microwave circuits and systems. For the year 2000, greater emphasis will be placed on appropriately moderated panel sessions based on the topics presented by the speakers.

The reason for running the workshop is that ceramic technologies are generally less familiar to design engineers and yet offer significant benefits in terms of circuit performance, weight and reliability. These benefits need to be communicated to design engineers to allow them to realize appropriate circuit and system solutions. Newer technologies are advancing these benefits further while at the same time driving costs down. Eminent speakers will be selected to describe and discuss the technologies, applications and the economics of ceramic solutions.

WMF: EM-based CAD of Printed Circuit Components, Waveguide Networks and Antennas - State-of-the-art and Promising Techniques for the Next Decade

During the last decade, much effort has been devoted to the development of electromagnetic (EM) simulators for analyzing mi-

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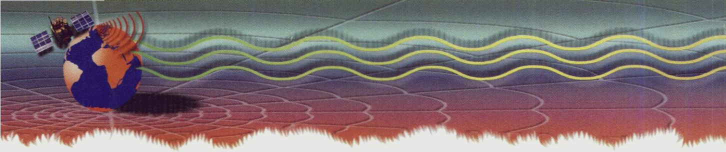

crowave circuits and antennas using field theoretical approaches. The natural next step is the reliable CAD of components and systems for wireless and space communications applications based on EM field simulators and proven optimization techniques. The focus of this workshop will be the presentation of the state-of-the-art and recent progress in the development of advanced EM techniques and their use for performance assessments and the design of key components relevant to communication systems for the 21st century. Examples will be given from the application of such CAD capability to a variety of practical component design problems, such as printed circuit antennas and arrays, microwave circuits, planar circuit interconnects, waveguide filters, diplexers, feed networks, and horn and slot antennas. The techniques and examples directly address the industrial demand for faster design cycles and reduced time to market for communication systems products.

A balance between theory, applications and practical discussions of issues is intended so that the workshop will appeal to a wide range of engineers. Attendees are encouraged to bring questions, proposals and/or a few view graphs to describe their problem. The workshop will include the presentation of software vendors on the status of the implementation of advanced techniques in commercially available CAD tools.

WMG: Space-based Radar Microwave Links

Recent Air Force interest in multifunction space-based radar (SBR) systems necessitates the further development of wideband, analog, microwave-photonics technology for fiber-optic antenna element-processor interconnection. Of particular interest are the microwave electronics-photonic device performance trades in view of the potential 30 GHz bandwidth required. This workshop will consist of tutorial sessions on the basic AF SBR program, SBR microwave/photonics requirements and some system trade study results, a review of past microwave photonics efforts, the Air Force Research Lab's in-house Microwave Links program and a basic review of microwave link engineering for SBR applications. In addition, reviews of a number of current key research efforts in the SBR technical area will be presented, including ARPA's R-FLICS program.

WMH: RF Front End Architectures

System engineers usually design their systems on the basis of available technologies: Technology follows architecture and architecture follows system functionality. Developments of high frequency semiconductor technologies are to a large amount independent of the system applications - they are driven by improvements in yield, materials, device and circuit design. This workshop shall contribute to an architecture bridge between technology and systems in order to facilitate the introduction of revolutionary system applications: the development of digitized front-end solutions for the high frequency range. The speakers will contribute to some specific aspects of multistandard-capable digital (software) radio approaches in the micro-and millimeter-wave range:

- System requirements, analysis and specifications
- 3D electromagnetic simulations (i.e., high Q MEMS elements)
- FDTD simulations of transitions (i.e., MEMS parts of the circuit to SiGe parts)
- Semiconductor technology aspects (integration density, speed, etc.)
- Thermal analysis
- Flip chip assembly techniques
- Micromachining of passive microwave components

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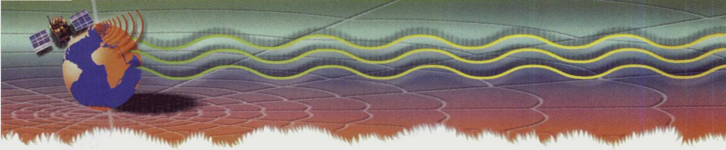

12:00–1:15 PM

PMA: Will SiGe Step on the GaAs?

Research and development of silicon germanium (SiGe) technology has been ongoing for the last 12 years. Repeated promises of performance superior to GaAs at reduced cost have not materialized in that time frame. Also during that time, conventional silicon BJTs, GaAs MESFETs, HEMTs and HBTs have continued to mature - to provide better and better performance at lower and lower cost. In the past year we have just begun to see some product introductions using SiGe. Questions that remain to be answered before the success of this technology can be fully assessed are both technical and financial in nature:

- For RF applications, is a bipolar device with high ft of significant value when it sits on a highly parasitic substrate?
- How does current SiGe circuit performance compare to existing GaAs and Si technologies?
- Have the advances of conventional silicon and GaAs parts eliminated any significant need for this technology?
- Can SiGe processes mature fast enough to displace conventional transistor technologies while they continue to improve?
- If SiGe does find a market niche, what will keep competing companies from attacking large portions of that market using more conventional, less expensive epitaxial silicon BJTs?
- What are the specific applications and circuit functions that require the promised benefits of SiGe?
- Do these applications comprise enough market demand to justify the infrastructure required to fabricate SiGe parts?

1:00 PM–5:00 PM

WMJ: Smart Antennas

Smart antennas are considered to be the last major technological innovation that has the potential for leading to large increases in wireless communication systems performance. Temporal processing techniques have already been extensively exploited for wireless applications, while spatial processing techniques have not been exploited to the same extent. Smart antennas have the following advantages in commercial or military wireless systems: increased coverage, increased communication quality, increased capacity, lower handset power consumption, user location by direction finding and interference reduction to other users. Related techniques for clutter cancellation in a radar system can be achieved with smart-antenna-like space-time adaptive processing, while other techniques for radar are unique in their own regard.

This workshop will begin with tutorial presentations that introduce the concept of smart antennas and the role they play, particularly in commercial wireless communication. Tutorial content will establish an understanding of digital beamforming and various forms of space and/or time adaptive processing as applied mainly to wireless systems. The workshop also will place the commercial activity within the context of ongoing work in military communications and radar systems. The second half of the workshop will focus on smart antenna technologies available today or under development for future deployment.

WMK: Ultrawideband Systems and Applications

Ultrawideband (UWB) signals occupy more than 100 percent instantaneous bandwidth and are generated using intense, short, video-

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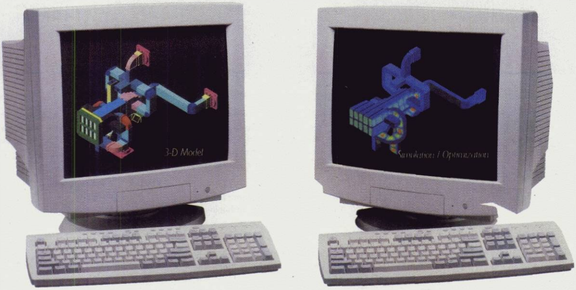

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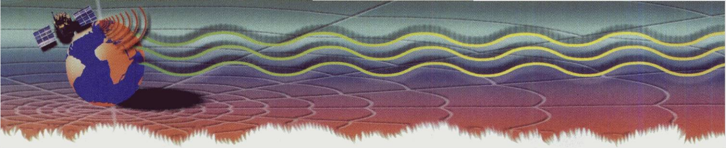

like pulses. These UWB signals have unique characteristics that make them suitable for covert communication and special radar applications. With the development of wideband microwave components and suitable software algorithms, UWB systems are attaining high levels of performance and economy. In addition, because of their low power spectral density, they may not require licensing and have caused minimal interference to other services. This workshop will discuss the history, communication, radar and future applications of this technology. A demonstration of a UWB communication system will be conducted.

TUESDAY, JUNE 13, 2000

8:00–10:00 AM

TU2A: *PLENARY SESSION*

Chair: Richard A. Sparks

All Microwave Week registrants and guests are invited to attend the IMS 2000 Plenary Session, which will begin at 8:00 AM on Tuesday, June 13 with welcoming remarks by Symposium Chairman Glenn Thoren and MTT-S President Roger Sudbury. IEEE Award recipients will be recognized, including Class of 2000 IEEE Fellows; recipients of the IEEE Third Millennium Medals; Prof. Roger Harrington, recipient of the IEEE Electromagnetics Award; and Prof. Arthur Oliner, recipient of the IEEE Heinrich Hertz Medal.

Mr. Byron J. Anderson, senior vice-president and general manager of Agilent Technologies, will present the keynote address, "Accelerating the Web-meets-Wireless Revolution." No one disputes that the convergence of the digital and wireless worlds means unprecedented business opportunities, especially as wireless devices in all shapes and sizes become everyday consumer necessities. For microwave and RF designers, however, the Web-meets-Wireless revolution brings with it many formidable challenges. Mr. Anderson will explore these challenges with an insightful look into the elements driving this revolution and what "hot" technologies are available to help designers deliver on the high expectations that come with this latest wave of wireless innovation.

10:10–11:50 AM

TU2A LOW NOISE TECHNOLOGY
JOINT IMS-RFIC SESSION

Chair: L. Boglione · Co-Chair: E. Niehenke

The session on low noise technology offers an opportunity to catch up on new developments in devices and circuits, MICs and MMICs, at microwave and millimeter-wave frequencies, in communication and radiometry applications. Recent advances will be described in this session, including low-noise devices in SiGe, low power dissipation lNA MMICs for wireless communication applications, coplanar waveguide MMICs usable for millimeter-wave applications, MMIC chips making efficient use of chip area, on-wafer components for noise calibration, and producibility of low noise MIC LNAs.

TU2A-1: **HBT Low-noise Performance in an 0.18 mm SiGe BiCMOS Technology**
D.R. Greenberg, D.A. Ahlgren, G. Freeman

TU2A-2: **Design of GaAs MMIC Transistors for the Low Power Low Noise Applications**
Z.M. Nosal

TU2A-3: **High Gain-density K-band p-HEMT LNA MMIC for LMDS and Satellite Communication**
M. Hirata, Y. Mimino, K. Nakamura

TU2A-4: **High Performance 60-GHz Coplanar MMIC LNA Using InP Heterojunction FETs with AlAs/InAs Superlattice Layer**
E. Mizuki, H. Miyamoto, Y. Makino

TU2A-5: **Design and Performance of Wideband, Low-noise, Millimeter-wave Amplifiers for Microwave Anisotropy Probe Radiometers**
M.W. Pospieszalski, E.J. Wollack, N. Bailey

TU2A-6: **Design and Characterization of MMIC Active Cold Loads**
P.M. Buhles, S.M. Lardizabal

TU2B MILLIMETER-WAVE SIGNAL SOURCES

Chair: R. Alm · Co-Chair: J.F. Luy

As both military and commercial radar and communication systems move into the 21st century, millimeter-wave applications are playing an ever-increasing role. Millimeter-wave signal sources face challenges in phase noie, tuning range and cost parameters. This session highlights developments in state-of-the art millimeter-wave signal sources as applied to subsystems designed for today's and tomorrow's practical applications. The technology presently includes GaAs MMIC, HBT and SiGe implementations.

TU2B-1: **Low Phase Noise 58 GHz SiGe HBT Push-push Oscillator with Simultaneous 29 GHz Output**
F.X. Sinnesbichler, B. Hautz, G.R. Olbrich

TU2B-2: **A 94-GHz HEMT Oscillator Using High Order Subharmonic Synchronization**
S. Kudszus, A. Tessmann, A. Halsmann, M. Neumann, W.H. Haydl, T. Berceli

TU2B-3: **Low Phase Noise Signal Generation Circuits for 60 GHz Wireless Broadband System**
P. Kangaslahti, J. Riska, M. Karkkainen, P. Alinikula, V. Porra, P. Kangaslahti

TU2B-4: **A Low Phase-noise 38-GHz HBT MMIC Oscillator Utilizing a Novel Transmission Line Resonator**
K. Hosoya, S. Tanaka, Y. Amamiya, NEC Corp., Japan

TU2B-5: **A Power Combined W-band HBT Oscillator**
K. Uchida, H. Matsuura, T. Yakihara

TU2C MILLIMETER-WAVE PACKAGING

Chair: R.W. Jackson · Co-Chair: J. Pavio

In this session papers are presented on new developments in millimeter-wave packaging. Interest in this area originates from the desire to develop low cost, manufacturable modules for millimeter-wave applications such as automobile radar and fixed wireless (LMDS). Novel technology includes flip-chip transitions using thin-film microstrip. A technique is proposed for stacking silicon wafers to form a compact W-band package.

TU2C-1: **Low Cost Multilayer Ceramic Package for Flip-chip MMIC up to W-band**
M. Ito, K. Maruhashi, K. Ikuina

TU2C-2: **Millimeter-wave Ceramic Package for a Surface Mount**
S. Koriyama, K. Kitazawa, N. Shino

TU2C-3: **Development of a 36 GHz Millimeter-wave BGA Package**
H. Liang, J. Laskar, Mike Hyslop

TU2C-4: **Optimized Flip-chip Interconnect for 38 GHz Thin-film Microstrip Multichip Modules**
N.H. Huynh, W. Heinrich, K. Hirche, W. Scholz, M. Warth, W. Ehrlinger

TU2C-5: **RF W-band Wafer-to-wafer Transition**
K.J. Herrick, L.P.B. Katehi

TU2D ADVANCED TOPICS IN NONLINEAR CAD

Chair: P. Draxler · Co-Chair: T. Brazil

Non-linear simulation techniques are being challenged by continuous in-circuit complexity, advanced modulation formats and highly non-linear behavior. This session addresses some key concerns in contemporary nonlinear simulator technology: extended behavioral modeling. Model reduction techniques, nonlinear noise simulation and the application of c circuit simulation techniques to the emerging area of RF MEMS will be covered.

TU2D-1: **Accurate RF and Microwave System Level Modeling of Wide Band Nonlinear Circuits**
E. Ngoya, J.M.N. Bus, N. Le Gallou, P. Reig

TU2D-2: **Circuit Reduction Technique for Finding the Steady State Solution of Nonlinear Circuits**
E. Gad, R. Khazaka, M. Nakhla

[Continued on page 198]


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contact: Hill Engineering Division
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Tel: 978-887-5754 Fax: 978-887-7244
E-mail:sales@hilleng.com
Web: www.hilleng.com

TU2D-3: **Determining the Steady-state Responses in RF Circuits Using GMRES, CGS and BICGSTAB Solutions in sSPICE for Linux**
M.A. Kleiner, M.N. Afsar

TU2D-4: **Rigorous RF and Microwave Oscillator Phase Noise Calculation by Envelope Transient Technique**
E. Ngoya, J. Rousset, D. Argollo

TU2D-5: **Techniques for Oscillator Nonlinear Optimization and Phase-noise Analysis Using Commercial Harmonic-balance Software**
S. Ver Hoeye, A. Suarez, J. Portilla

TU2D-6: **Large-displacement Modeling and Simulation of Micromechanical Electrostatically Driven Resonators Using the Harmonic Balance Method**
T. Veijola, T. Mattila, O. Jaakkola

TU2E Advanced Concepts in Frequency Domain Numerical Techniques

Chair: M. Salazar-Palma · Co-Chair: H.Y.D. Yang

Non-linear simulation techniques are being challenged by continuous in-circuit complexity, advanced modulation formats and highly non-linear behavior. This session addresses some key concerns in contemporary non-linear simulator technology: extended behavioral modeling. Model reduction techniques, non-linear noise simulation and the application of c circuit simulation techniques to the emerging area of RF MEMS will be covered.

TU2E-1: **Efficient MM/FE GSMS Technique for the CAD of Broadband Lateral Coax Feeds in Rectangular Waveguide**
R. Beyer, F. Arnd

TU2E-2: **Modeling of Arbitrary Shaped Radiating Structures by the Wave Concept Iterative Process**
E. Richalot, M.F. Wong, H. Baudrand

TU2E-3: **Macro-elements for Efficient FEM Simulation of Small Geometric Features in Waveguide Components**
Yu Zhu, A.C. Cangellaris

TU2E-4: **The Perfectly Matched Layer as Lateral Boundary in Finite-difference Transmission-line Analysis**
T. Tischler, W. Heinrich

TU2E-5: **Analysis of Planar Microwave and Millimeter-wave Circuits with Anisotropic Layers Based on Generalized Transmission Line Equations and on the Method of Lines**
R. Pregla

TU2E-6: **Applying Wavelets to Electromagnetic Field Simulation: The Method of Lines**
O. Pertz, A. Beyer

12:00–1:15 PM

PTB: High Data Rate Communication – Preparing the Future

This panel will address the actual preparations for high data rate communication expected to become a reality during the first decade of the next century. The demand for services is expected to increase by a factor of 10 to 100 throughout all communications systems, from user-specific systems for networking to short- and long-haul transmission links, with system requirements expected to reach gigabit and terabit data rates.

The questions asked of the panelists will include:

- What are the major system trends to achieve/fulfill the future needs?
- Earth-bound systems: Cable or microwave based?
- Spaceborne systems: Who will win the race ?
- What is the specific market segment that you/your company intend to address?
- How is your company preparing to meet the needs of this expanding communications market?

[Continued on page 200]

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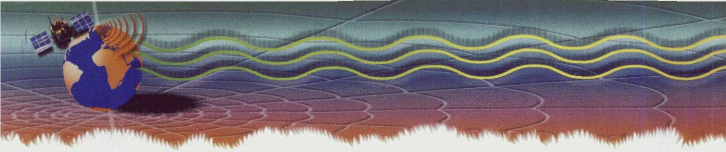


- What are the actual steps you/your company are taking now to meet the new technology and the sales volume needs?

RF and Microwave Education Forum

"Integration of CAD and Measurements in RF and Microwave Education"

Organizers: Larry Dunleavy and Tom Weller

RF and microwave educators, and others with serious interest in education matters, are invited to this forum for a stimulating hour of discussion on issues of current importance, to network with others with similar interests and to contribute, as well as hear, ideas about RF and microwave education. This year's theme will explore the trade-off between time spent learning operating details and the benefits added by the inclusion of modern CAD and instrumentation as part of the educational experience. How should universities weigh the balance between their primary mission of teaching fundamentals and theory with conveying practically important exposure to modern engineering tools? Is there a danger in students placing too much reliance on CAD? How can we teach them when to believe and when to question CAD simulations? Instrumentation is expensive; is CAD exposure enough? What new educational challenges are presented by the transition from the traditional RF and microwave component treatments of many schools to the need to embrace more of a system view in preparing the next generation of RF/microwave/wireless engineers? How do recent changes in the industry and available CAD and measurement tools affect in-house training approaches and needs?

Short talks by four key speakers will start and stimulate the discussion. This period will be followed by informal, interactive attendees' comments (maximum one slide, please). For further details and to confirm your intention to offer some informal comments, please contact Larry Dunleavy at dunleavy@eng.usf.edu or Tom Weller at weller@eng.usf.edu.

1:20–3:00 PM

TU3A Wireless Circuit Techniques

Joint IMS-RFIC Session

Chair: N. Camilleri · Co-Chair: K.B. Ashby

This session addresses several novel circuit techniques for wireless RFIC design. RF circuits require several types of support circuitry to effectively enable the development of complex system functions on an IC. This session addresses this topic by presenting a circuit technique for an IF coil-less discontinuity, a PA regulator subsystem circuitry and an ESD protection technique for RFICs. The session also addresses the effects of offsets on RFICs by even-order distortion.

TU3A-1: (Invited) **FM Demodulation Using an Injection-locked Oscillator**
Eric Main

TU3A-2: (Invited) (1:45 PM) **A Fast Response, Programmable PA Regulator Subsystem for Dual Mode CDMA/AMPS Handsets**
R. Griffith

TU3A-3: **A Comparison Study of ESD Protection for RFICs: Better Performance and Less Parasitic**
H.G. Feng, K. Gong, A.Z. Wang

TU3A-4: **Effects of Offsets on Bipolar Integrated Circuit Mixer Even Order Distortion Terms**
W.E. Main

TU3B MEMS Switches/Phase Shifters

Focused Session

Chair: B.E. Sigmon · Co-Chair: D. Peterson

This session is one of a group on MEMS technology and focuses on switches and phase shifters. Other oral and Interactive Forum sessions deal with MEMS components including mixers and frequency multipliers.

TU3B-1: **MEMs Microswitch Arrays for Reconfigurable Distributed Microwave Components**
C. Bozler, R. Drangmeister, S. Duffy, M. Gouker, J. Knecht, L. Kushner, R. Parr, S. Rabe, L. Travis

TU3B-2: **A Low Voltage Actuated Micromachined Microwave Switch Using Torsion Springs and Leverage**
D. Hah, E. Yoon, S. Hong

TU3B-3: **One- and Two-bit Low-loss Cascadable MEMS Distributed X-band Phase Shifters**
J.S. Hayden, G.M. Rebeiz

TU3B-4: **Design of Low Actuation Voltage RF MEMS Switches**
S. Pacheco, L.P.B. Katehi, C.T. Nguyen

TU3B-5: **High-isolation Inductively-tuned X-band MEMS Shunt Switches**
J.B. Muldavin, G.M. Rebeiz

TU3B-6: **Characterization of Source-to-drain Capacitance (CDS) Effect of GaAs pHEMT for Microwave and Millimeter-wave Switch**
Y. Chung, G. Ryu, D. Kim, J. Lee, W. Hong, K. Seo

TU3C Filters (1)

Chair: A.E. Atia · Co-Chair: M. Guglielmi

This session presents several innovations in filter technologies ranging from tunable active filters to filters for wireless applications. Miniaturization, improved performance and new manufacturing techniques will be emphasized.

TU3C-1: **A Tunable X-band Active Notch Filter with Low-distortion Passband Response**
C. Rauscher

TU3C-2: **Quasi Dual-mode Resonators**
R.R. Mansour, S. Ye, S.F. Peik

TU3C-3: **A First Practical Model of Very Small and Low Insertion Loss Laminated Duplexer Using LTCC Suitable for W-CDMA Portable Telephones**
T. Ishizaki, T. Yamada, H. Miyake

TU3C-4: **Low-profile TM-mode Dielectric Disk Resonator BPF for W-CDMA**
A.C. Kundu

TU3C-5: **A New Circuit Configuration to Obtain Large Attenuation with a Coupled-resonator Band Elimination Filter Using Laminated LTCC**
H. Miyake, S. Kitazawa, T. Ishizaki

TU3C-6: **A Miniaturized Bandpass Filter with Double Surface Electrodes**
T. Tsujiguchi, H. Matsumoto, T. Nishikawa

TU3D Monolithic and Semiconductor Technology

Chair: Z. Barda · Co-Chair: T. Lee

This session combines reported advances in passive components and fabrication technology with papers applying this technology in leading-edge MMICs. Two papers deal with inductor design and novel fabrication techniques to reduce coupling while a third presents interesting work on integrated ferromagnetic thin-film inductors. In the MMIC area, a high performance K-band phase shifter is reported as well as a micromachined CPW waveguide-based distributed amplifier.

TU3D-1: **Magnetic RF Integrated Thin-film Inductors**
M. Yamaguchi, M. Baba, K. Suezawa

TU3D-2: **Fabrication of High Frequency Passives on BICMOS Silicon Substrates**
R. Volant, R. Goves, S. Subbanna, E. Begle, J. Malinowski, D. Laney, L. Larson

TU3D-3: **A Compact and Wideband GaAs pHEMT Distributed Amplifier IC Based on a Micro-machined CPW**
S.G. Yang, K.S. Seo

TU3D-4: **A Compact 5-bit Phase Shifter MMIC for K-band Satellite Communication Systems**
C.F. Campbell, S.A. Brown

TU3D-5: **RF Loss and Cross Talk on Extremely High Resistivity (10K-1M Ohm-cm) Si Fabricated by Ion Implantation**
Y.H. Wu, A. Chin, K.H. Shih

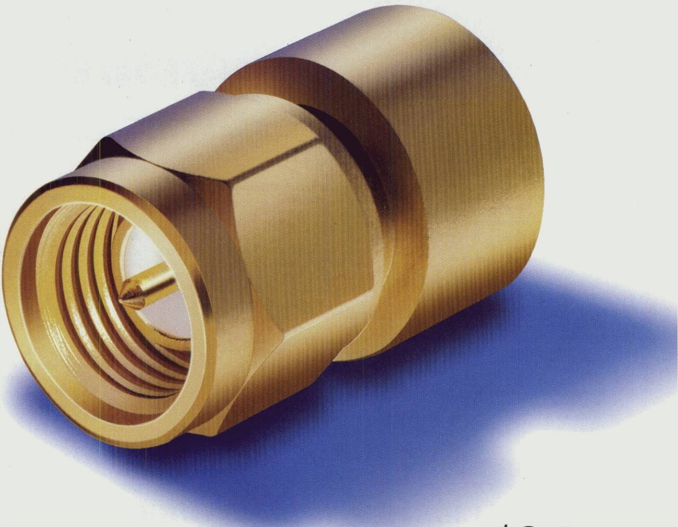
TU3D-6: **Design Guide of Coupling between Inductors and Its Effect on Reverse Isolation of CMOS LNA**
C.S. Kim, M. Park, C.H. Kim

TU3E Advances in Time Domain Modeling

Chair: A. Cangellans · Co-Chair: A. Beyer

Transient electromagnetic modeling is recognized as a critical enabling technology for

[Continued on page 202]



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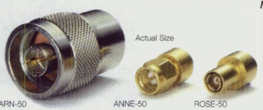

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DC to 6	28

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

ROSE-50
SMB Plug Connector
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$7.35 qty.1000

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

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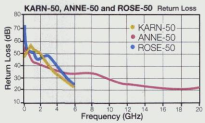

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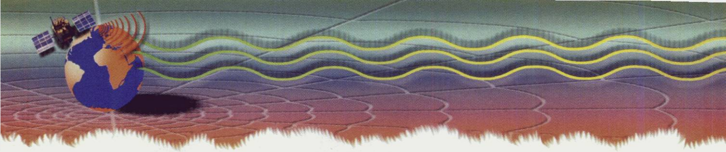


the simulation and design of complex integrated components, devices and circuits. The papers presented in this session focus on advances toward the enhancement of modeling versatility, computational efficiency and robustness. More specifically, the scientific contributions in this session include: a) application of multiresolution techniques to the enhancement of computational efficiency of finite time domain and TLM methods; b) a new algorithm for unconditionally stable FDTD simulation; c) the application of diakoptics to the finite element time-domain modeling of microwave circuits; and d) the application of wavelets to the efficient modeling of electrically-large optical waveguides.

TU3E-1: **Unconditionally Stable FDTD Algorithm for Solving Three-dimensional Maxwell's Equations**
T. Namiki

TU3E-2: **Finite Element Time Domain Based Diakoptic Method for Microwave Circuit Analysis**
R. Coccioli, Y. Qian, B. Houshmand

TU3E-3: **Application of Wavelet-Galerkin Method to Electrically-large Optical Waveguide Problems**
M. Fujii, W.J.R. Hoefer

TU3E-4: **Multi-resolution 2D-TLM Technique Using Haar Wavelets**
I. Barba, J. Represa, M. Fujii

TU3E-5: **An Extension of the MRTD Technique to the Fast Computation of the Radiation from Planar Open Structures**
G.C. Carat, R. Gillard, J. Citerne, J. Wiart

TU3E-6: **Characterization of Micromachined Transmission Lines Using MRTD (Multiresolution Time-domain Technique)**
N. Bushyager, M.M. Tentzeris

TU3E-7: **Improved Autoregressive (AR) Signal Modeling for FDTD Resonance Estimation**
A. Lauer, I. Wolff

2:30–5:00 PM

TUIF Interactive Forum

Chair: D. Swanson · Co-Chair: D. Teeter

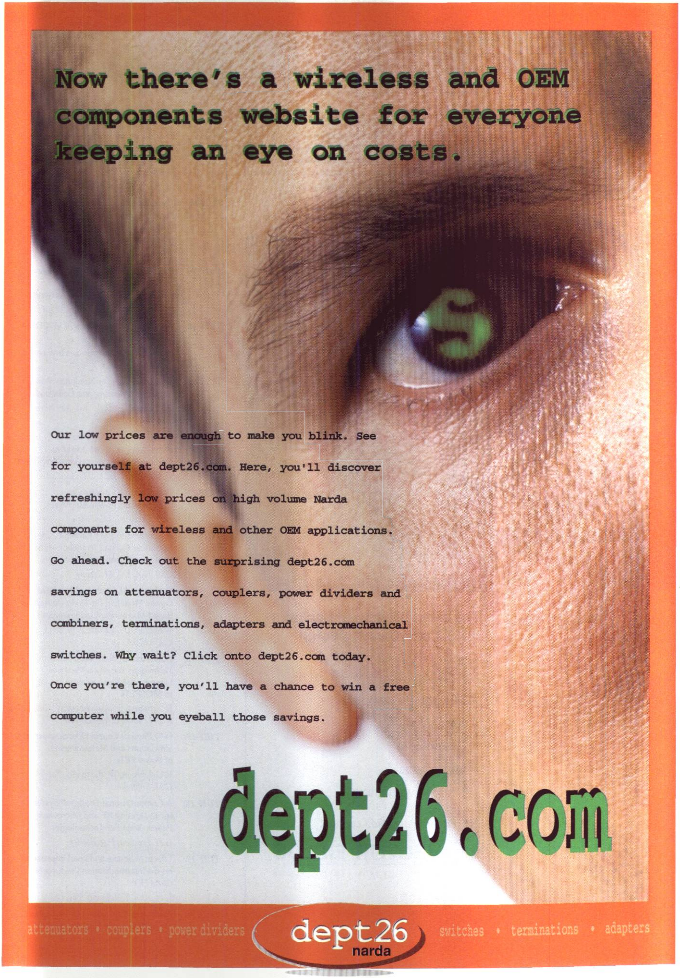
TUIF-1: **Low-power Active Mixer for Ku-band Application Using SiGe HBT MMIC Technology**
K.B. Schad, H. Schumacher, A. Scheppen

TUIF-2: **A mm-wave Monolithic Gilbert Cell Mixer**
A.W. Dearn, L.M. Devlin

TUIF-3: **Approximate Analytical Modeling of Current Crowding Effects in Multi-turn Spiral Inductors**
W.B. Kuhn, N.M. Ibrahim

TUIF-4: **Novel Alternative Design Methods Based upon Combined Amplification, Matching and Filtering Approaches in MMIC Technology**
J. Tissier, W. Mouzannar, L. Billonnet, B. Jarry, P. Guillon

[Continued on page 204]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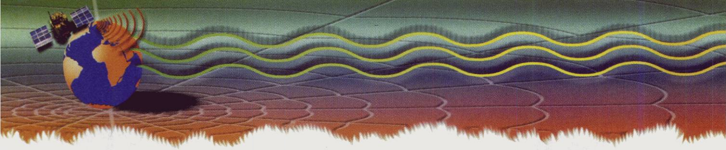


TUIF-5: **Monolithic Upconversion and Reference Downconverter IC for Power Amplifier Linearization Using GaAs HBTs**
C. Bingoel, H. Hein, E. Gamm, F. Oehler, W. Doser, K. Riepe, H. Blanck

TUIF-6: **A Unified Approach of Near- and Far-carrier PM Noise Calculation in Large Multitone Autonomous and Forced Circuits at RF and Microwaves**
P. Bolcato, R. Larcheveque, J.C. Nallatamby, M. Prigent, J. Obregon

TUIF-7: **Analysis of mm-wave Nonlinear Circuits by Combining Genetic Algorithm and Harmonic Balance Technique**
M. Bozzi, L. Perregrini, A.R. Ruiz Laso

TUIF-8: **The Estimation of Volterra Transfer Functions with Applications to RF Power Amplifier Behavior Evaluation for CDMA Digital Communication**
T.H. Wang, T.J. Brazi

TUIF-9: **Fast Prediction of the Performance of Wireless Links by Simulation-trained Neural Networks**
A. Neri, C. Cecchetti, A. Lipparini

TUIF-10: **Linearity Considerations of W-CDMA Front-ends for UMTS**
H. Pretl, L. Maurer, W. Schelmbauer, R. Weigel, B. Adler, J. Fenk

TUIF-11: **Optimal Filters for Nonlinear Power Amplifier Modeling and Equalization**
C.P. Silva, C.J. Clark, A.A. Moulthrop, M.S. Muha

TUIF-12: **Computer-aided Optimization of Adjacent Channel Power in Nonlinear Communications Amplifiers**
V. Borich, J.R. East, G.I. Haddad

TUIF-13: **Two-tone IMD Asymmetry in Microwave Power Amplifiers**
N.B. Carvalho, J.C. Pedro

TUIF-14: **A New Method in Characterizing the Nonlinear Current Model of MESFETs Using Single-tone Excitation**
C.W. Fan, K.K.M. Cheng

TUIF-15: **Generalized Distributed Nonlinear Device Modeling for Krylov-subspace Based Microwave Circuit Analysis**
V. Rizzoli, D. Masotti, F. Mastri, C. Cecchetti

TUIF-16: **Evaluation of Non-linear Modeling Techniques Based on Vectorial Large-signal Measurements as Applied to MOSFETs**
D. Schreurs, S. Vandenberghe, K.U. Leuven, E. Vandamme

TUIF-17: **Fully Physical Coupled Electro-thermal Simulations and Measurements of Power FETs**
R.G. Johnson, W. Batty, A.J. Panks, C.M. Snowden

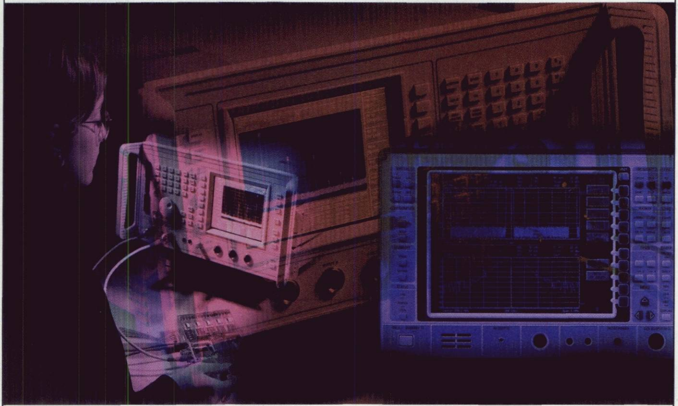
TUIF-18: **A Computational Load-pull System for Evaluating RF and Microwave Power Amplifier Technologies**
G.H. Loechelt, P.A. Blakey

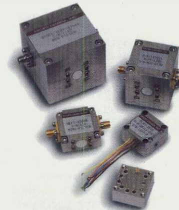
TUIF-19: **Effects of Source and Load Impedance on the Intermodulation Products of GaAs FETs**
K.H. Ahn, Y.H. Jeong, S.H. Lee

TUIF-20: **Additional Conditions to Formation of the Maximally Flat Waveforms in a Class F Power Amplifier**
A.N. Rudiakova, V.G. Krizhanovski

[Continued on page 206]

Next Generation, Low Cost YIG Components for Test and Measurement





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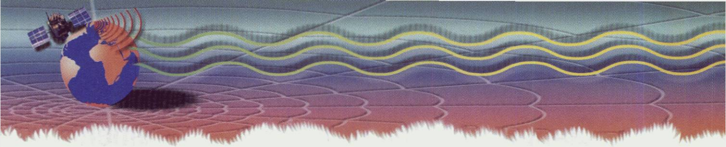

TUIF-21: **On Robust Suppression of Third-order Intermodulation Terms in Small-signal Bipolar Amplifiers**
G.V. Klimovitch

TUIF-22: **Performance Improvement of Feedforward Power Amplifiers by Using a Novel Injection Combining Technique**
A. Kouki, N. Outaleb

TUIF-23: **Adaptive Algorithms for Feed-forward Power Amplifier Linearizer**
Y. Chen, B. Ng, A. Kot

TUIF-24: **Adaptive Baseband/RF Predistorter for Power Amplifiers through Instantaneous AM-AM and AM-PM Characterization Using Digital Receiver**
E.G. Jeckeln, M.A. Sawan, F.M. Ghannouchi, F. Beauregard

TUIF-25: **Microwave Power Amplifiers with Digitally-controlled Power Supply Voltage for High Efficiency and High Linearity**
M.Ranjan, G. Hanington, P. Asbeck, K.H. Koo, C. Fallesen

TUIF-26: **Nonlinear Analysis of Microwave Frequency Synthesizers: Stability and Incidental Frequency Modulation**
S. Sancho, A. Surez, T. Fernandez

TUIF-27: **A Programmable High-isolation Monolithic Millimeter-wave SPST Switch**
S. Nam, D.L. Raynes, I.D. Robertson

TUIF-28: **1–26 GHz High Power p-i-n Diode Switch**
S.W. Paek, K.I. Jeon, D.W. Kim, C.R. Lim, J.H. Lee, W.S. Lee, K.W. Chung, H.I. Kang, J.E. Oh, M.D. Chung

TUIF-29: **38 GHz MMIC PHEMT-based Tripler with Low Phase-noise Properties**
A. Boudiaf, ATN Microwave, D. Bachelet, C. Rumelhard

TUIF-30: **Broadband, Planar, Doubly Balanced Star Mixers**
C.Y. Chang, C.W. Tang, D.C. Niu

TUIF-31: **A Passive-type Even Harmonic Quadrature Mixer Using Simple Filter Configuration for Direct Conversion Receiver**
M. Shimozawa, T. Katsura, N. Suematsu, K. Itoh, Y. Isota, O. Ishida

TUIF-32: **CMOS Resistive Ring Mixer MMICs for GSM 900 and DCS 1800 Base Station Applications**
P.A. Gould, Bell Labs, C. Zelley, J. Lin

TUIF-33: **Analysis and Experimental Waveform Study on Inverse Class-F Mode of Microwave Power FETs**
C.J. Wei, Y.A. Tkachenko, R. McMorrow, P. DiCarlo, D. Bartle

TUIF-34: **A 2 W, High Efficiency, 2–8 GHz, Cascode HBT MMIC Power Distributed Amplifier**
J.P. Fraysse, M. Campovecchio, R. Quere, J.P. Viaud, P. Auxemery

TUIF-35: **Push-pull Power Amplifier Integrated with Quasi-Yagi Antenna for Power Combining and Harmonic Tuning**
W.R. Deal, Y. Qian, T. Itoh

TUIF-36: **A 20 GHz Doherty Power Amplifier MMIC with High Efficiency and Low Distortion Designed for Broadband Digital Communication Systems**
C. McCarroll, G. Alley, S. Yates

TUIF-37: **A 5 to 27 GHz MMIC Power Amplifier**
K.I. Jeon, J.H. Lee, S.W. Paek, D.W. Kim, W.S. Lee

TUIF-38: **RF Power Amplifier Integration in CMOS Technology**
Y.E. Chen, M. Hamai, D. Heo, A. Sutono, S. Yoo

TUIF-39: **Demonstration of a High Efficiency Nonuniform Monolithic Gallium Nitride Distributed Amplifier**
B. Green, K. Chu, L.F. Eastman, S. Lee, K.J. Webb

TUIF-40: **A Ka-band HBT MMIC Power Amplifier**
S. Tanaka, S. Yamanouchi, Y. Amamiya, T. Niwa, K. Hosoya

TUIF-41: **An S-band High-power Broadband Transmitter**
B.B. Baturov, A.V. Vinogradnyi, G.A. Koshevarov, L.Y. Melnikov

TUIF-42: **Ka-band, 30 Watt Solid State Power Amplifier**
N. Escalera, W. Boger, J. Dobosz, P. Denisuk

TUIF-43: **Designing Commercially Viable mm-wave Modules**
N. Jain

TUIF-44: **Submillimeter Quasioptical Semiconductor Isolators**
V.K. Kiseliov, V.K. Kononenko, Y.M. Kuleshov

TUIF-45: **A 230 GHz Low Noise Subharmonically Pumped SIS Mixer**
K. Xiao, H. Ogawa, A. Mizuno, Y. Fukui

TUIF-46: **Low Cost Millimeter-wave Aperture Coupled Antenna Array on Polymer Membrane Substrate**
S. Perrot, C. Person, C. Quendo, M. Ney

TUIF-47: **Improved Photonic Bandgap Cavity and Metal Rod Lattices for Microwave and Millimeter Wave Applications**
M.A. Shapiro, W.J. Brown, C. Chen, V. Khemani, I. Mastovsky, J.R. Sirigiri, R.J. Temkin

TUIF-48: **Rectangular Phased Array Antennas Fed by Single-crystal YIG Phase Shifters**
H. How, P. Shi, C. Vittoria, M.H. Champion

TUIF-49: **Reconfigurable Transmission-type Beamformer**
J. Mazotta, L.Y. Chen, J.C. Chiao

TUIF-50: **Characterization of a Multi-mode Microstrip Aperture for Phased Array Applications**
J. Sor, Y. Qian, T. Itoh

TUIF-51: **Measurement of the Phase and Amplitude Distributions of Coupled Oscillator Arrays**
P.F. Maccarini, T.P. Dao, A.S. Nagra, A. Borgioli, R.A. York

TUIF-52: **Range Demonstration of an Ultra-wideband, Continuous, Time Steered Array Using a Fiber-optic, Cascaded Grating Prism**
J.B. Medberry, P.D. Biernacki, P.J. Matthews

3:30–5:10 PM

TU4A Integrated Transceivers
Joint IMS-RFIC Session

Chair: S. Kiaei · Co-Chair: D. Lovelace

This session presents highly integrated transceivers. Technology for low noise RF systems in SiGe are also presented. Highly integrated multi-mode, multi-band ICs for CDMA and 2.4 GHz ISM applications are presented. The final paper demonstrates application of 25 GHz Si-bipolar technology.

TU4A-1: (Invited) **SiGe Bipolar Technologies for Low Phase Noise RF and Microwave Applications**
M. Regis, M. Borgarino, L. Bary, O. Llopis, J. Graffeuil

TU4A-2: **A Highly Integrated Dual Band Tri-mode Transceiver Chipset for CDMA TIA/EIA-95 and AMPS Applications**
B. Agarwal, S. Lloyd, P. Piriyapoksombut

TU4A-3: **A Highly Integrated Radio for High Performance Low Cost 2.4 GHz ISM Cordless Applications**
P. Good, H.S. Cho, J.K. Cheng

TU4A-4: **An RF Transceiver for WDCT in a 25 GHz Silicon Bipolar Technology**
G. Li Puma, K. Hadjizada, W. Geppert, S. van Waasen, W. Mevissen, W. van Schwartzenberg, S. Heinen

TU4B Micromachining and MEMS Technology
Focused Session

Chair: G. Rebeiz · Co-Chair: H.A. Hung

This session focuses on micromachining and MEMS technology as used in the microwave (to W-Band) frequency range. Topics include high performance passive components (inductors and tunable capacitors), switches and transmission line structures. The papers discuss design techniques in addition to fabrication process technology.

[Continued on page 208]


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TU4B-1: **Fabrication of High-performance On-chip Suspended Spiral Inductors by Micromachining and Electroless Copper Plating**
H. Jiang, Y. Wang, J.L.A. Yeh, N.C. Tien

TU4B-2: **Post-processed RF Micromechanical Switches on Commercial RFICs**
L.R. Sloan, S.L. Hietala, C.P. Tigges, G. Schuster, C.E. Sandoval

TU4B-3: **Fully Integrated Micromachined Capacitive Switches for RF Applications**
J.Y. Park, G.H. Kim, K.W. Chung

TU4B-4: **X-band and K-band Lumped Wilkinson Power Dividers with a Micromachined Technology**
L.H. Lu, P.K. Bhattacharya, G.E. Ponchak

TU4B-5: **Micromachined Branch Line Coupler in CMOS Technology**
O. Mehmet, E. Zaghloul, U.C. Kozat

TU4B-6: **Micromachined Circuit Combining Networks for W-band Applications**
K.J. Herrick, L.P.B. Katehi

TU4B-7: **A New Micromachined Overlay CPW Structure with Low Loss over Wide Impedance Ranges**
H. Kim, S. Jung, J. Park, C. Baek, Y. Kim, Y. Kwon

TU4B-8: **Multilevel Finite Ground Coplanar Line Transitions for High-density Packaging Using Silicon Micromachining**
J.P. Becker, L.P.B. Katehi

TU4C Filters (2)

Chair: H.C. Bel · Co-Chair: S.J. Fiedziuszko

One of the main thrusts in filters today is miniaturization and integration driven by the continuing wireless emphasis. Included in this session are filters targeted at diverse applications such as high temperature superconductors (HTS), cellular/PCS equipment, millimeter waves and Bluetooth.

TU4C-1: **Compact Multi-level Folded-line Bandpass Filters**
R.K. Settaluri, A. Weisshaar, V. Tripathi

TU4C-2: **Aperture Compensation Technique for Innovative Design of Ultra-broadband Microstrip Bandpass Filter**
L. Zhu, H. Bu, K. Wu

TU4C-3: **Transmission Line Filters with Advanced Filtering Characteristics**
J.S. Hong, M.J. Lancaster

TU4C-4: **Third Integrated Narrowband Filters for Millimeter-wave Wireless Applications**
E. Rius, C. Person, T. Le Nadan

TU4C-5: **A Design of the Novel Coupled Line Bandpass Filter Using Defected Ground Structure**
J.S. Yun, J.S. Park, D. Ahn, G.Y. Kim, K.Y. Kang

TU4C-6: **Microstrip Triangular Patch Resonator Filters**
J.S. Hong, M.J. Lancaster

TU4C-7: **Edge-coupled Coplanar Waveguide Bandpass Filter Design**
T. Weller

TU4C-8: **Development of Integrated Three Dimensional Bluetooth Image Reject Filter**
A. Sutono, J. Laskar, W.R. Smith

TU4D Microwave Digital Circuits

Chair: K.C. Wang · Co-Chair: A. Oki

Market demand for microwave digital circuits has been increasing rapidly, and significant progress has been made in recent years. Among the areas of current and future interest are digital frequency synthesizers, mixed-mode ICs for optical communication, wide bandwidth and high dynamic-range A/D and D/A converters, digital modulation and coding techniques, and algorithms for high speed processing. In this session we present four outstanding papers on optical communication and frequency synthesis.

The first paper describes a 40 GHz/s monolithic digital OEIC module implemented with 0.1 μm InP HEMT technology. The authors demonstrated 40 Gbit/s error-free operation of the OEIC module for an RZ data stream for the first time. Compact differential VCOs at W-band are presented in the second paper. The VCOs, implemented with InP-based HBTs, operated at maxium frequencies of 83, 88, and 97 GHz with approximately a 10 percent tuning range. The third paper presents a 50 GHz digital phase-locked loop using superconducting rapid single flux quantum (RSFQ) logic. The authors operated at 50 GHz clock phase-locked to a MHz frequency external source with a locking range of ±1.5 percent. A 13 GHz PLL module is described in the fourth paper. It is realized with a mixed technology of pHEMT-MMICs and SMT components for high volume manufacturing. The authors used a circuit envelope engine to simulate the PLL performance with efficient use of memory and CPU time.

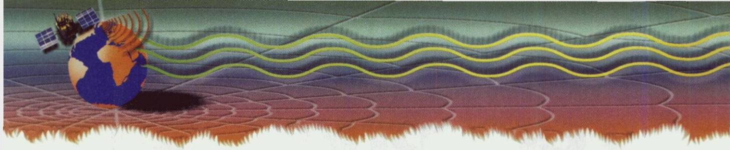
TU4D-1: **A 40-Gbit/s Monolithic Digital OEIC Module Composed of Uni-traveling-carrier Photodiode and InP HEMT Decision Circuit**
K. Murata, N. Shimizu, H. Kitabayashi

TU4D-2: **Compact Differential InP-based HBT VCOs with a Wide Tuning Range at W-band**
Y. Baeyens, R. Pullella, C. Dorschky

TU4D-3: **A 50 GHz Monolithic RSFQ Digital Phase Locked Loop**
D.K. Brock, M.S. Pambianchi

TU4D-4: **A 13 GHz Phase-locked Loop Development for Micro- and Millimeter-wave Applications**
T. Hongsmatip, F. Carrez, J. Fenton

[Continued on page 210]



TU4D-5: **Prospects of Silicon-germanium Based Technology for Very High-speed Circuits**
S. Subbanna, R. Groves, R. Volant

TU4E Applications of Time Domain Modeling

Chair: R. Vahldieck · Co-Chair: L. Roselli

Time domain modeling of electromagnetic fields is becoming an indispensable tool in the design and the analysis of microwave circuits. Papers in this session demonstrate the applicability of methods like the FDTD, TLM and FETD to problems in the area of non-linear element representation, direct synthesis of microwave filters by inverse scattering, modeling of semiconductor devices and hybrid modeling of wire structures in a complex environment.

TU4E-1: **Time Domain Global Modeling of EM Propagation in Semiconductor Using Irregular Grids**
H.P. Tsai, R. Coccioli, T. Itoh

TU4E-2: **A Global Finite Difference Time Domain Analysis of a Silicon Nonlinear Transmission Line**
W. Thiel, W. Menzel, M. Birk

TU4E-3: **Interpolating Wavelet Scheme toward Global Modeling of Microwave Circuits**
S.Goasguen, S.M. El-Ghazaly

TU4E-4: **Direct Synthesis of Microwave Filters Using Inverse Scattering TLM (Transmission Line Matrix) Method**
R. de Padua, L.R.A.X. de Menezes

TU4E-5: **Extension of the Lumped Network (LN)-FDTD Approach to the Modeling of Nonlinear Elements**
G. Emili, F. Alimenti, L. Roselli

TU4E-6: **Methods for the Modeling of Thin Wire Structures with the TLM Method**
S. Lindenmeier, P. Russer, C. Christopoulos

TU4E-7: **The Inclusion of Fringing Capacitance and Inductance in FDTD for the Robust Accurate Treatment of Material Discontinuities**
C.J. Railton

7:00–9:30 PM

RUMP SESSION

RTA: Wide Bandgap Microwave Power Transistors — Current Status and Prospects for the Future

Wide bandgap semiconductors (SiC and GaN) are now demonstrating some of the dramatic microwave power performance that has long been projected. Recent results include AlGaN HEMTs with power densities of 9.8 W/mm (approximately 10 times that of GaAs pHEMTs) and a total power of 14 W from a single 4 mm device at X-band. SiC SITs and MESFETs have also continued to progress, but mainly at below C-band. This panel will address the status of the wide bandgap semiconductor transistors with an emphasis on GaN. Issues of substrate quality, availability, cost and time to market will be considered. Finally, the panel will address the potential for military and commercial markets.

WEDNESDAY, June 14, 2000

8:00–9:40 AM

WE1A New Transmission Line Elements

Chair: C.K.C. Tzuang · Co-Chair: M. Dydyk

This session reports the latest innovative development in transmission line elements for microwave and millimeter-wave applications. The first paper presents a new platform for an NRD guide for a millimeter-wave circuit. The second paper investigates the asymmetric coupled lines on standard CMOS technology. The third paper reports a new low impedance line for MMIC without dielectric process. The fourth paper presents a broadband CPW-to-waveguide transition using an innovative Yagi-type antenna. The fifth paper reports a new quadrature branch-line coupler based on via-hole transitions. The last paper discusses a new mechanism for exciting leaky modes on microstrip.

WE1A-1: **Engraved NRD Guide for Millimeter-wave Integrated Circuits**
Y. Cassivi, D. Deslandes, K. Wul

WE1A-2: **Characterization of Asymmetric Coupled CMOS Lines**
U. Arz, M. Rudack, D. Treytnar, H. Grabinski, D.F. Williams, D.K. Walker, J.E. Rogers

WE1A-3: **A Novel Low Impedance Line for MMIC Using Air-gap Stacked Structure**
G.H. Ryu, D.H. Kim, J.H. Lee, K.S. Seo

WE1A-4: **A Broadband CPW-to-waveguide Transition Using Quasi-Yagi Antenna**
N. Kaneda, Y. Qian, T. Itoh

WE1A-5: **Novel Quadrature Branch-line Coupler Using CPW-to-microstrip Transitions**
J.H. Lee, H.Y. Lee

WE1A-6: **Excitation of the Microstrip Higher Order Leaky Modes by Aperture-coupling Method**
T.L. Chen, Y.D. Lin

WE1B Mixer Techniques

Chair: B. Nelson · Co-Chair: L. Reynolds

This session covers mixer design approaches with an emphasis in the commercially emerging Ka-band applications. The papers include interesting topics in direct conversion, subharmonically pumped mixers; ultra-small MMIC mixers; and integrated mixers with patch antennas.

WE1B-1: **A Novel DC-offset Cancellation Technique for Even-harmonic Direct Conversion Receivers**
B. Matinpour, S. Chakraborty, M. Hamai, C. Chin, J. Laskar

WE1B-2: **A Novel Uniplanar Balanced Subharmonically Pumped Mixer for Low-cost Broadband Millimeter-wave Transceiver Design**
H. Gu, K. Wu

WE1B-3: **A Ku-band Frequency Converter Using 0.25 μm pHEMT Technology**
R.S. Virk, E. Camargo, H. Shimizu, S. Ichikawa

WE1B-4: **A New Millimeter-wave MMIC Mixer for Sensor Applications**
I. Angelov, M. Garcia, H. Zirath, J. Swedin, G. Huss

WE1B-5: **Ultra-small MMIC Mixers for K- and Ka-band Communications**
C.J. Trantanella

WE1C Superconducting Components and Technology

Chair: G. Lyons · Co-Chair: R. Mansour

Progress continues in the development and application of high-temperature superconducting (HTS) components and subsystems. This session includes a report on the first demonstration of HTS filters in HF band, overcoming the traditional limitation of resonator size in this band. A European superconductor space experiment represents the continued demonstration of HTS subsystems flying on space platforms. Much of the session is devoted to ongoing development of HTS filters for wireless communications, improving the selectivity, compactness and complexity of the filters. More fundamental research also continues and is represented in the session by work on HTS nonlinear transmission lines for pulse sharpening.

WE1C-1: **A Narrow-band HTS Bandpass Filter at 18.5 MHz**
K.D. Mossman, G.L. Matthaei, G.L. Hey-Shipton

WE1C-2: **Superconductors and Cryotechnology for Space Communications – Adaptation of a New Technology for Applications**
M. Klauda, T. Kasser, B. Mayer, C. Neumann, F. Schnell

WE1C-3: **Highly Selective HTS Band Pass Filter with Multiple Resonator Cross-Couplings**
K.F. Raihn, R.L. Alvarez, J.R. Costa, G.L. Hey-Shipton

WE1C-4: **High Temperature Superconducting Nonlinear Transmission Lines**
C.M. Coutts, S.K. Chaudhuri, R.R. Mansour

[Continued on page 212]

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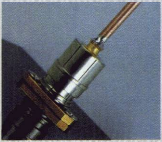

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WE1C-5: **Superconducting Filter for IMT-2000 Band**
G. Tsuzuki, M. Suzuki, N. Sakakibara

WE1C-6: **Superconducting Microstrip Line Band-pass Filter for Mobile Applications**
H. Kayano, H. Fuke, F. Aiga, Y. Terashima, H. Yoshima

WE1C-7: **A HTS Microwave Narrow-band Filter Using Dual-mode Multi-zigzag Microstrip Loop Resonators**
Z.F. Jiang, Z.M. Hejazi, P.S. Excell

WE1D Microwave Photonics: Devices and Systems

Chair: D. Jager · Co-Chair: C. Gee

High speed microwave photonic devices and systems in this session include high power photo receivers beyond 40 GHz for applications in wideband fiber-optic communication systems. In addition to state-of-the-art photonic devices, the design and characterization of field demonstrations of wideband, high dynamic range links over nearly 1000 km distances are presented. Finally, the session concludes with an optical RF phase shifter for providing continuing phase control over almost 60° at 1.2 GHz.

WE1D-1: **High-power Waveguide Integrated Photodiode with Distributed Absorption**
H. Jiang, P.K.L. Yu

WE1D-2: **40 GHz Broadband Optical Receiver Combining a Multimode Waveguide Photodiode Flip-chip Mounted on a GaAs-based HEMT Distributed Amplifier**
A. Leven, V. Hurm, W. Bronner, K. Kubler, H. Walcher, R. Kiefer, J. Fleiáner, J. Rosenzweig, M. Schl

WE1D-3: **Bias Free Optical Control of Microwave Circuits and Antennas Using Improved Optically Variable Capacitors**
A.S. Nagra, O. Jerphagnon, P. Chavarkar, R.A. York, M. Van Blaricum

WE1D-4: **Wide-band Analog-digital Photonic Link with Third-order Linearization**
T.R. Clark, M. Currie, P.J. Matthews

WE1D-5: **Design and Characterization of a Fiberoptic RF Remoting Link**
M.D. Abouzahra, F.C. Robey, S. Henion

WE1D-6: **Integrated Optic RF Phase Shifter for Continuous Beam Steering at 1–1200 MHz**
A. Mitchell, K. Ghorbani, R. Waterhouse

WE1E X-band T/R Modules: Semiconductors, Packaging and Assembly Issues Special Session

Chair: B. Kopp

This session will begin with an overview of major semiconductor, packaging and assembly issues for X-band T/R modules. The overview will be followed by a detailed treatment of each of these issues from experts in each area. Issues covered include GaAs MMIC size reduction and integration, GaN and SiC thermal design, ball grid array and flip chip assembly, the use of low cost packaging in high performance modules and duplexer effects on reliability and performance. The session will conclude with projections of future technology and issues for space-based antennas.

WE1E-1: (Invited) **X-band Transmit/Receive Module Overview**
B. Kopp

WE1E-2: (Invited) **Wide-band Semiconductors for X-band Amplifiers**
S.T. Allen, S.T. Sheppard, R.A. Sadler, W.L. Pribble, T.S. Alcorn, J.W. Palmour

[Continued on page 214]

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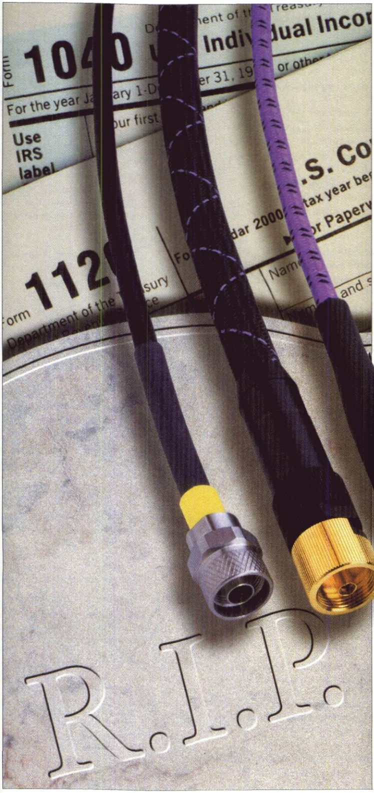

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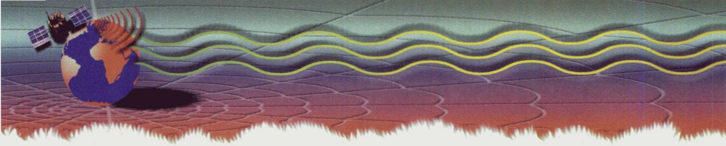


WE1E-3: (Invited) X-band GaAs MMIC Size Reduction and Integration
E. Griffin

WE1E-4: (Invited) Microwave Flip Chip and B&A Technology
J.M. Bedinger

WE1E-5: (Invited) Advanced Technology for Future Space Based Antennas
S. Kiss, T. Kemerley

10:10–11:50 AM

WE2A Advances in Microwave Signal Generation

Chair: A. Boudiaf · Co-Chair: S. Wetenkamp

In this session, three papers investigate the potential for SiGe-HBT technology in signal generation. A set of fully integrated VCOs in the 5–7 GHz frequency range are presented. Another set of VCOs are demonstrated at 22 and 25 GHz. For synthesizer applications, two papers are presented; a 20 GHz SiGe dual-radius prescaler and an assembled E-band system. Another competing technology based on CNOS/SOI presents an integrated 5 GHz LC-tan K VCO shows good performance.

WE2A-1: Low Phase Noise, Low Power IC VCOs for 5–7 GHz Wireless Applications
H. Jacobsson, S. Gevorgian, B. Hansson, C. Hedenas, M. Mokhtari, T. Lewin, W. Rabe, A. Schappen

WE2A-2: SiGe MMICs Beyond 20 GHz on a Commercial Technology
C.N. Rheinfelder, J.F. Luy, H. Kuhnert, W. Heinrich, A. Schappen

WE2A-3: A Low Power 20 GHz SiGe Dual-modulus Prescaler
H.Knapp, T.F. Meister, M. Wurzer, K. Aufinger, S. Boguth, L. Treitinger

WE2A-4: A Low-voltage 6 GHz-band CMOS Monolithic LC-tank VCO Using a Tuning-range Switching Technique
A. Yamagishi, T. Tsukahara, M. Harada, J. Kodate

WE2A-5: Building of a Highly Precise and Compact Synthesizer in E-band by Means of Gunn Oscillator and MMIC Chipset
R. Tempel, U. Stehr, G. Langgartner, J. Herrmann, W. Simon, I. Wolff

WE2B Nonlinear Transistor Modeling

Chair: J. Atherton, · Co-Chair: W. Curtice

This session features non-linear modeling for a wide variety of transistor types from MOSFETs to HBTs, HEMTs and MESFETs. A wide range of material systems, including silicon and GaAS, and recent developments in wide bandgap SiC and GaN-based device models are represented.

WE2B-1: An Improved Deep Sub-micron MOSFET RF Nonlinear Model with New Breakdown Current Model and Drain to Substrate Nonlinear Coupling
D. Heo, E. Gebra, E. Chen, S. Yoo, M. Hamian

WE2B-2: Accurate Large-signal Modeling of SiGe HBTs
F.X. Sinnesbichler, G.R. Olbrich

WE2B-3: Scalable GaInP/GaAs HBT Large-signal Model
M. Rudolph, R. Doerner, P. Heymann, K. Beilenhoff

WE2B-4: Influence of Collector Design on InGaP HBT Linearity
M. Iwamoto, T.S. Low, C.P. Hutchinson, J.B. Scott, A. Cognata

WE2B-5: Validation of an Analytical Large Signal Model for AlGaN/GaN HEMTs
B.M. Green, H. Kim, K.K. Chu, H.S. Lin, V. Tilak

WE2B-6: Characterization and Modeling of Nonlinear Trapping Effects in Power SiC MESF
D. Siriex, D. Baraland, R. Sommet, O. Noblanc, C. Brylinsky

WE2C HF/VHF/UHF Power Amplifiers and Linearizers

Chair: F. Raab · Co-Chair: J. Modelski

The papers in this session deal with high-efficiency power amplifiers and linearization techniques for HF, VHF and UHF.

WE2C-1: Circuit Design Technique for High Efficiency Class F Amplifiers
A.V. Grebennikov

WE2C-2: Analysis of Class-F and Inverse Class-F
A. Inoue, T. Heima, A. Ohta, R. Hattori, Y. Mitsui

WE2C-3: Class-E Switching-mode High-efficiency Tuned RF/Microwave Power Amplifier: Improved Design Equations Include Effects of Load-network Finite Loaded Q and Resulting Harmonic Currents in Load Network
N.O. Sokal

WE2C-4: Class E RF/Microwave Power Amplifier: Linear "Equivalent" of Transistor's Nonlinear Output Capacitance, Normalized Design and Maximum Operating Frequency vs. Output Capacitance
A. Mediano, P. Molina-Gaudo

WE2C-5: Stabilizing Circuit for Class-E Amplifier
W.H. Cantrell, Motorola

WE2C-6: A Simple Method to Cut Down Configuration of Feedforward Power Amplifier
X. Zhu, J. Zhou, W. Hong

WE2D Active Quasi-optics and Spatial Power Combining

Chair: D. Rutledge · Co-Chair: M. DeLisio

Active quasi-optics and spatial power combining amplifiers are now producing significant output powers at millimeter wavelengths. We report 25 W at 34 GHz from a hybrid spatial-power combining array, and 5 W at 37 GHz from a single-chip grid amplifier. In addition, a reflection-mode grid amplifier has demonstrated 15 dB gain at 10 GHz.

WE2D-1: A 25 Watt and 50 Watt Ka-band Quasi-optical Amplifier
S. Ortiz, A. Mortazawi, E. Schlecht

WE2D-2: Electromagnetic Modeling and Experimental Verification of a Complete Waveguide-based Aperture-coupled Patch Amplifier Array
A.B. Yakovlev, S. Ortiz, M. Ozkar, A. Mortazawi, M.B. Steer

WE2D-3: A 5-Watt, 37-GHz Monolithic Grid Amplifier
B.C. Dickman, D.B. Rutledge, E.A. Sovero

WE2D-4: A 16-element Reflection Grid Amplifier
F. Lecuyer, R. Swisher, I.F.F. Chio, A. Guyette, A. Al-Zayed, W. Ding, M. DeLisio, K. Sato, A. Oki, A. Gutierrez, R. Kagiwada, J. Cowles

WE2D-5: A Three-dimensional Retrodirective Self-oscillating Mixer Array
M.K. Derek, A. Yo, W.A. Shiroma

WE2D-6: A 1.6 W Power Amplifier Module at 24 GHz Using New Waveguide-based Power Combining Structures
J. Jeong, Y. Kwon, S. Lee, C. Cheon, E.A. Sovero

WE2D-7: K-band Spatial Combiner Using Active Array Modules in an Oversized Rectangular Waveguide
R.A. York

WE2E Phased Arrays

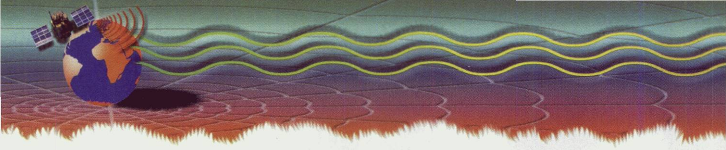
Chair: K. Tomiyasu · Co-Chair: D. Parker

The phased array session presents information on a variety of subjects. The effect of element to element variability is considered. A Novel piezoelectric device phase shifter is described. True time delay (TTD) phase shifters are presented for use in reconfigurable beam forming. The use of optical components for control of arrays is also described.

WE2E-1: Oscillator Reproducibility Consideration in Coupled Oscillator Phase-steering Arrays
J. Shen, L.W. Pearson

WE2E-2: A Phased-array Antenna Using a Multi-line Phase Shifter Controlled by a Piezoelectric Transducer
T.Y. Yun, K. Chang

[Continued on page 216]



WE2E-3: **A Beam-steerer Using Reconfigurable PBG Ground Plane**
B. Elamaran, I.M. Chio, L.Y. Chen, J.C. Chiao

WE2E-4: **Demonstration of a Reconfigurable Beamformer for Simplified 2-D, Time-steered Arrays**
D.A. Tulchinsky, P.J. Matthews

WE2E-5: **Optically Smart Active Antenna Arrays**
D.Z. Anderson, V. Damiao, E. Fotheringham, D. Popovic, S. Romisch

WE2E-6: **A Transmit/Receive Active Antenna with Fast Low-power Optical Switching**
J.E. Vian, Z. Popovic

12:00–1:15 PM

PWC: RF MEMS for Tunable Applications

The field of RF MEMS has seen many advances in the past three years, and several components such as MEMS switches, phase shifters and low-loss filters with excellent characteristics have been built from 1 to 50 GHz. MEMS components offer the capabilities of very loss operation and, therefore, very high-Q operation in applications such as tunable filters, tunable oscillators and tunable matching networks. In addition, MEMS components can sustain high voltages across the resonators, thereby resulting in high input saturation powers and low intermodulation products. Finally, MEMS components can be manufactured on low dielectric constant substrates (LTCC, quartz, etc.), which are compatible with high-Q resonators.

The panel will present recent advances in high-Q MEMS varactors, tunable filters and oscillators from 200 MHz to 10 GHz as well as their impact on commercial and defense applications. The panelists will present MEMS-varactor tunable filters from 50 to 2000 MHz and 1 to 2 GHz RFIC oscillators using lumped element techniques. In addition, 3 to 10 GHz tunable filters and oscillators using distributed techniques will be covered. Several related items will be discussed: the achievable varactor Q in MEMS technology, the tuning range of MEMS varactors and switched capacitor banks, mechanical noise and its effect on the phase noise of MEMS-based oscillators, and recent government programs involving MEMS-based tunable systems.

PWD: Devices for High Speed Fiber Optics – Technology Needs and What's Next?

Fiber optics has often been described as a "killer technology." Driven by general communication needs and, in recent years, the Internet, system capacity has increased rapidly, pushing bandwidths into the millimeter range or beyond. From a microwave point of view, the bandwidth requirements for communications transmitters are typically five orders of magnitude – truly an enormous value. All optical methods are under consideration as well. Furthermore, data communications (which are growing rapidly) are now larger than voice traffic, which implies new network architectures and, hence, new products. These factors place great stress on device technology. Traditional communications needs are primarily addressed above, but other applications such as those of wireless distribution are also pushing toward higher speeds. This panel session will examine device design itself, material systems for discrete devices, material systems for OEICs and other needs for next-generation and future high-speed, fiber-optic applications.

1:20–3:00 PM

WE3A Power Amplifiers and Handsets

Chair: A. Platzker · Co-Chair: D. Teeter

This session contains six papers on advancements in power amplifier technology for wireless applications. Silicon device technology is now emerging as a true competitor to GaAs for low voltage, high efficiency, RF power amplifiers. Alternate circuit topology such as the push-pull configuration are being demonstrated. We are now also starting to see the first demonstration of power amplifiers for W-CDMA applications. As transistor technology for wireless systems matures, advanced system techniques such as envelope tracking are being utilized to further enhance the operating efficiency of the handset.

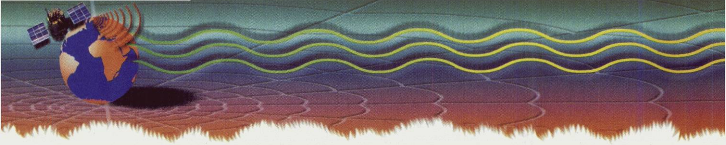
WE3A-1: **A Monolithic 2.5 V, 1 W Silicon Bipolar Power Amplifier with 55% PAE at 1.9 GHz**
W. Simbarger, A. Heinz, H.D. Wohlmuth, J. Bock, K. Aufinger

WE3A-2: **A SiGe HBT Power Amplifier with 40% PAE for PCS CDMA Application**
X. Zhang, C. Saycocie, S. Munro, G. Henderson

WE3A-3: **An Integrated 900-MHz Push-pull Power Amplifier for Mobile Applications**
M.J. Matilainen, K.L.I. Nummila, E.A. Jarvinen, S.J.K Kalajo

WE3A-4: **An L-band High Efficiency and Low Distortion Power Amplifier Module Using an HPF/LPF Combined Interstage Matching Circuit**
K. Mori, S. Shinjo, Y. Ikeda, F. Kitabayashi

[Continued on page 218]



WE3A-5: **42% High Efficiency Two-stage HBT Power Amplifier MMIC for W-CDMA Cellular Phone System**
T. Iwai, K. Kobayashi, Y. Nakasha, T. Miyashita, S. Ohara

WE3A-6: **High Efficiency CDMA RF Power Amplifier Using Dynamic Envelope Tracking Technique**
J. Staudinger, B. Gilsdorf, D. Newman, G. Norris, G. Sadowniczak

WE3B CAD, Modeling and Optimization Technology

Chair: K.C. Gupta · Co-Chair: A. Pavio

This session highlights recent advances in modeling, sensitivity analysis and optimization techniques for microwave CAD. The first two papers make use of computational neural networks for RF and microwave design. This is followed by a paper on nonlinear statistical modeling and yield estimation for microwave circuits. Optimization using analytically calculated gradients in the finite element method for electromagnetic simulation is another interesting contribution. The final paper in this session deals with sensitivity analysis of transmission-line networks using model reduction techniques.

WE3B-1: **Neural Frequency-Space Mapping EM Optimization of Microwave Structures**
M.H. Bakr, J.W. Bandler, M.A. Ismail, J.E. Rayas-Sanchez, Q.J. Zhang

WE3B-2: **A New Macromodeling Approach for Nonlinear Microwave Circuits Based on Recurrent Neural Networks**
Y. Fang, Mustapha C.E. Yagoub, F. Wang, Q.J. Zhang

WE3B-3: **A Novel Nonlinear Statistical Modeling Technique for Microwave Devices**
J.F. Swidzinski, K. Chang

WE3B-4: **Optimization of Microwave Circuits Using Analytically Calculated Gradients in the Finite Element Method**
P. Harscher, R. Vahldieck, S. Amari

WE3B-5: **Efficient Sensitivity Analysis of Transmission-line Networks Using Model Reduction Techniques**
R. Khazaka, P. Gunudi, M. Nakhla

WE3C Ferrite and SAW Devices

Chair: J. Owens · Co-Chair: R. Weige

This session looks at a range of device applications of ferrite and SAW structures. The first paper presents the results of studies to reduce spike leakage in magnetostatic wave frequency selective limiters. The second paper is a theoretical and experimental study of a new analysis technique for six-port circulators. The last ferrite paper looks at a monolithic hybrid Y junction circulator at millimeter-wave frequencies utilizing Ba hexaferrite. The first SAW paper looks at a tunable electro-acoustic high Q SAW VCO, which is compatible with CMOS processing. The second SAW paper studies a new high Q grating mode SAW VCO resonator structure.

WE3C-1: **Spike Leakage and Suppression in Frequency Selective Limiters**
S.N. Stitze

WE3C-2: **Analysis of Six-port Disk Circulator Using Subdivided Ports**
K. Gaukel, B. El-Sharaway

WE3C-3: **MMW Monolithic Y-junction Circulator on Single-crystal SC-doped Ba-hexaferrite**
P. Shi, X. Zuo, N. McGruer, H. How, S. Olive

WE3C-4: **High Q VCO (Voltage Controlled Oscillator) Using Electro-acoustic Device Compatible with CMOS Integrated Circuit Technology**
H.C. Pilsoon, Choi, Hyun, E. Yungsong, L. Kwyro

WE3C-5: **A Miniature High-Q Grating-mode-type SAW Resonator and a Wide-band 1-GHz SAW-VCO for Mobile Communications**
A. Isobe, M. Hikita, K. Asai, A. Sumioka

WE3D Biological Effects and Medical Applications
Special Session

Chair: A. Rosen · Co-Chair: Y. Kotsuka

The application of RF/microwaves in therapeutic medicine has moved from the drawing board to FDA-approved human trials, and new ideas are constantly being developed. In addition, new ideas in the detection are being developed, and new concerns about RF/microwaves are being voiced. Hence, the papers that will be presented in this session naturally fall within two areas: biological effects and medical applications.

Biological effects papers include safety questions associated with cellular telephones. Medical applications papers include a thermoacoustic tomography (TCT) technique for imaging of breast cancer utilizing 434 MHz, various applications for RF (500 kHz) and microwave technologies in urology and cardiology, and a radiometric sensing adjunct to mammography.

WE3D-1: (Invited) **Microwave Treatments for Prostate Disease**
F. Sterzer, D. Mawhinney, J. Mendecki, E. Friedenthal

WE3D-2: (Invited) **Advances in Catheter Ablation for Treatment of Cardiac Arrhythmias**
A.J. Greenspoon

WE3D-3: (Invited) **Radiometric Sensing: An Adjuvant to Mammography to Determine Breast Biopsy**
K.L. Carr, P. Cevasco, J. Shaeffer

WE3D-4: (Invited) **Thermoacoustic CT**
R.A. Kruger

WE3D-5: (Invited) **Cellular Telephones: Hazards or Not?**
A. Vander Vorst

2:30–5:00 PM

WEIF Interactive Forum

Chair: Dan Swanson · Co-Chair: Doug Teeter

WEIF-1: **Properties of CPW in the Sub-mm Wave Range and Its Potential to Radiate**
J. Zehentner, J. Machac

WEIF-2: **New Closed-form Electromagnetic Green's Functions in Layered Media**
A.C. Cangellaris, V. Okhmatovsky

WEIF-3: **Equivalent Network for Rectangular-waveguide H-plane Step Discontinuity – Multi-transmission Line and Multi-port Ideal Transformer**
J.P. Hsu, T. Hiraoka, H. Honma

WEIF-4: **Full-wave Analysis of a Periodic Array of Rectangular Lossy Conductive Thick Patches**
L. Pierantoni, L. de Luca, T. Rozzi

WEIF-5: **Leaky Modes of Vertically Stacked Microstrips at Higher Order**
C.K. Tzuang, K.F. Huang

WEIF-6: **New Efficient Design of Microwave Inhomogeneous Media Filters**
F. Bilotti, A. Toscano, L. Vegni

WEIF-7: **Reconstruction of Permittivity Profiles in Cylindrical Objects Illuminated by Higher Order Modes**
M.J. Akhtar, A.S. Omar

WEIF-8: **Full-wave Characterization of an Edge-coupled Coplanar-waveguide Structure with Backed Conductor**
C.L. Liao, C.H. Chen

WEIF-9: **Reconstruction of the Non-minimum Phase Function from Amplitude Only Data**
J. Koh, T.K. Sarkar

WEIF-10: **BI-RME Modeling of 3D Waveguide Components Enhanced by the Ewald Technique**
M. Bressan, L. Perrigrini, E. Regine

WEIF-11: **Multiport Analysis of Arbitrary Circular-rod Insets in Rectangular Waveguide by the Generalized Admittance Matrix**
G.G. Gentili, L. Accatino

WEIF-12: **Mix-RWG Current Basis Function and Its Simple Implementation in Method of Moments**
T.J. Yu, L. Carin, B. Zhu, W. Ca

WEIF-13: **Time Domain Characterization of Planar Microwave Transformers Using the SCN-TLM Method**
J. Rebel, P. Russer, H.D. Wohlmuth

WEIF-14: **A Higher-order FDTD Using Sinc Expansion Function**
J. Zhang, Z. Chen

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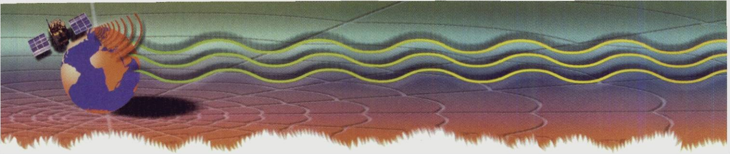

WEIF-15: Development of a Three-dimensional Unconditionally Stable Finite-difference Time-domain Method
Z. Chen, F. Zheng, J. Zhang

WEIF-16: Visualization of Near-field and Far-field in the Time Domain
P.P.M. So, E.Q. Hu, M. Fujii, W. Liu, W.J.R. Hoefer

WEIF-17: Optimal Shape Design of Passive Device Using FDTD and Design Sensitivity Analysis
Y.S. Chung, S.Y. Hahn, C. Cheon

WEIF-18: The Application of the Wave Potential Functions to the Analysis of Transient Electromagnetic Fields
N. Georgieva, Y. Rickard

WEIF-19: Determination of Optimum Conductivity Profile for PML and PML-D Using Multiple Variables Pade Approximation
J. Cao, A. Rong, H. Wang, X. Chen

WEIF-20: General Design Equations of Three-port Unequal Power Divider Terminated by Arbitrary Impedances
H.R. Ahn, I. Wolff

WEIF-21: 40 to 90 GHz Impedance-transforming CPW Marchand Balun
K.S. Ang, I.D. Robertson, K. Elgaid, I.G. Thayne

WEIF-22: A Very-small-sized Reversed-phase Hybrid Ring
I. Ohta, T. Kawai, Y. Kokubo

WEIF-23: A Whispering Gallery Mode Sapphire Resonator with Semi Spherical Enclosure
C. Wang

WEIF-24: Low Loss Passive Microwave Components in Standard Silicon Technology
H. Berg, Chalmers H. Jacobsson, T. Lewin, K. Berg

WEIF-25: Accurate Analysis of Silicon, VLSI-technology Compatible Spiral Inductors
B. Guasticchi, L. Roselli, G. Stopponi, P. Ciampolin

WEIF-26: A New Network Model for Miniaturized Hairpin Resonators and Its Applications
S.Y. Lee, C.M. Tsai

WEIF-27: Improvements in Losses and Size of Frequency Tunable Coplanar Filter Structures Using MMIC Negative Resistance Chips for Multistandard Mobile Communication Systems
G. Tanne, E. Rius, F. Mahe, S. Toutain, F. Biron

WEIF-28: Low Temperature Cofired Ceramic (LTCC) Ridge Waveguide Multiplexers
Y. Rong, K.A. Zaki, M. Hageman, D. Stevens, J. Gipprich

WEIF-29: Application of the Planar I/O Terminal to Dual Mode Dielectric Waveguide Filters
K. Sano, M. Miyashita

WEIF-30: Synthesis of Cascaded Quadruplet Filters Involving Complex Transmission Zeros
O. Sen, Y. Sen, N. Yildirim

WEIF-31: The Design of a Half-wavelength Resonator BPF with Attenuation Poles at Desired Frequencies
M. Matsuo, H. Yabuki, M. Makimoto

WEIF-32: Microwave Breakdown in Output Multiplexers Filters
C. Boussavie, D. Baillargeat, M. Aubourg, S. Verdeyme, P. Guillon, A. Catherinot, S. Vigneron, B. Theron

WEIF-33: A Design Procedure for Co-existing Multi-mode Waveguide Bandstop Filters
C.A.W. Vale, P. Meye

WEIF-34: Anisotropic Permittivity Extraction from Phase Propagation Measurements Using an Anisotropic Full-wave Green's Function Solver for Coplanar Ferroelectric Thin Film Devices
C.M. Krowne, S.W. Kirchoefer, J.M. Pond

WEIF-36: A Novel HTS Microstrip Quasi-Elliptic Function Bandpass Filter Using Pseudo-lumped Element Resonator
B.K. Jeon, J.H. Kim, C.J. Lee, B.C. Min, Y.H. Choi, S.K. Kim, B. Oh

WEIF-37: A Novel Triple-push Oscillator Approach
Y.L. Tang, H. Wang

WEIF-38: 77 GHz Planar Gunn VCOs on AlN Substrates Using Novel Flip-chip InP Gunn Diodes
A. Nakagawa, K. Watanabe, T. Yashida, T. Deguchi, Y. Oki

WEIF-39: Impact of 1/f noise in Ka-band InGaP/GaAs HBT Frequency Sources
M.S. Heins, T. Juneja, D. Caruth, M. Hattendorf, M. Feng

WEIF-40: A Very High-Q-feedback Oscillator at 33 GHz Using MMMIC Amplifiers
H. Barth

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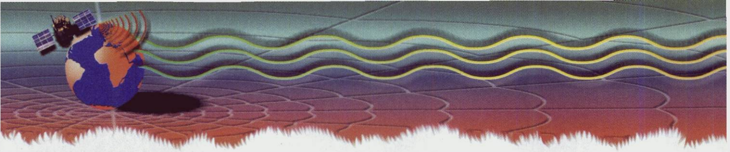

WEIF-41: **MEMS Devices for High Isolation Switching and Tunable Filtering**
D. Peroulis, S. Pacheco, K. Sarabandi, L.P.B. Katehi

WEIF-42: **Modeling of MEMS Capacitive Switches by TLM**
L. Vietzorreck, F. Coccetti, V. Chtchekaourov, P. Russer

WEIF-43: **Membrane-supported Ka Band Resonator Employing Organic Micromachined Packaging**
J.E. Harriss, L.W. Pearson, X. Wang, A.V. Pham, C.H. Barron, Jr.

WEIF-44: **A Parametric Model of MEMS Capacitive Switch Operating at Microwave Frequencies**
J.Y. Qian, G.P. Li

WEIF-45: **Noise Performance of Submicron HEMT Channels under Low Power Consumption Operation**
J.M. Miranda, J.L. Sebastian, H. Zirath, M. Garcia

WEIF-46: **On the Performance of Low Noise, Low DC Power Consumption Cryogenic Amplifiers**
I. Angelov, N. Wadefalk, J. Stenarson, E. Kollberg, P. Starski

WEIF-47: **Temperature-dependent Noise Parameters and Modeling of Inp/InAlAs/InGaAs HEMTs**
M.R. Murti, S. Yoo, A. Raghavan, S. Nuttinck, J. Laskar

WEIF-48: **Interlayer MEMS RF Switch for 3D MMICs**
Y.A. Wang, Q. Kang, B. Liu, A.M. Ferendeci, M. Mah

WEIF-49: **Simulation of Noise-power Ratio with the Large-signal Code CHRISTINE**
P.N. Safier, T.M. Antonsen, Jr., D.K. Abe, B.G. Danly, B. Levush, T.M. Antonsen, Jr.

WEIF-50: **ACeS Communications System Phase Noise and Transient Effects**
L. Dayaratna, L.G. Ramos

WEIF-51: **Optical Distribution of Local Oscillators for a Rotating Antenna**
M.B. Bibey, S. Formont, F. Deborgies, C. Moronvalle, A. Brillman

WEIF-52: **Data Transmission Using an Optical Microwave Link for Wireless Communications**
D.P. Descamps, V.J. Vindevoghel, V.E. Vestiel, V.J.P. Vilcot

3:30–5:10 PM

WE4A Power Amplifier Integrated Circuits

Chair: J. Schellenberg · Co-Chair: H.J. Kuno

This session presents recent progress in power amplifiers covering S- through W-band frequencies. The first paper describes an S-band MMIC HPA module delivering 43.3 dBm output power at 2.6–3.3 GHz followed by a presentation of a three-stage pHEMT power amplifier with 35 dBm output, 26 dB gain and 50–60 percent PAE. The next two papers cover the development of W-band MMIC amplifiers; one covering 75–110 GHz with 25–43 mW and the other delivering 2.4 W output power at 94 GHz. The session concludes with two papers describing progress in GaN power amplifiers; one describes an amplifier with 8.5 W output at 8 GHz while the other presents an achievement of 14 W over 6–10 GHz.

WE4A-1: **A Compact S-band MMIC High Power Amplifier Module**
T. Murae, K. Fujii, T. Matsuno

WE4A-2: **A 7.4 to 8.4 GHz High Efficiency PHEMT Three-stage Power Amplifier**
S.L.G. Chu, A. Platzker, M. Borkowski, R. Mallavarpu, M. Snow, A. Bowlby, D. Teeter, T. Kazior

WE4A-3: **Full W-band MMIC Medium Power Amplifier**
Y.C. Leong, S. Weinreb

WE4A-4: **Compact W-band Solid-state MMIC High Power Sources**
D.L. Ingram, Y.C. Chen, I. Stones, D. Yamauchi, B. Brunner

WE4A-5: **A 3–10 GHz LCR-matched Power Amplifier Using Flip-chip Mounted AlGaN/GaN HEMTs**
J.J. Xu, S. Keller, G. Parish, S. Heikman, U.K. Mishra, R.A. York

WE4A-6: **14-W GaN-based Microwave Power Amplifiers**
Y.F. Wu, D. Kapolnek, J. Ibbetson, P. Parikh, B.P. Keller

WE4B CAD Modeling of Passive Components

Chair: K. Nashadham · Co-Chair: A. Weisshaar

This session consists of four papers dealing with the development of physics-based CAD models for passive components. The first paper discusses the coherent integration of a full-wave EM simulation multivariable rational

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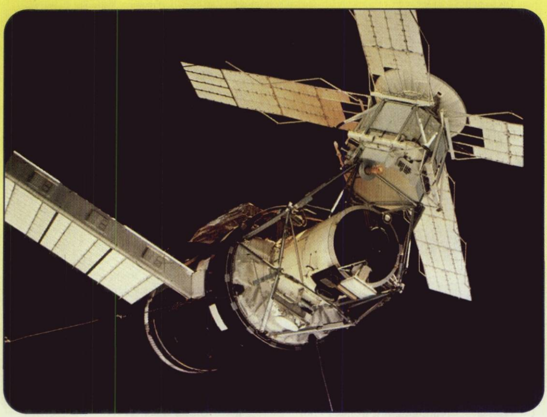

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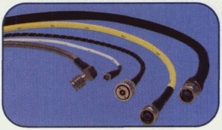

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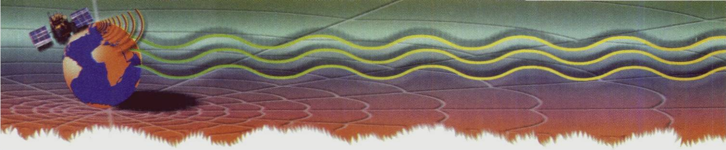

functions, dimensional analysis and frequency mapping to develop broadband CAD models for microwave passive components. The second paper describes a new hierarchical reduced-order modeling methodology for on-chip interconnects on silicon substrate, which includes both the substrate and conductor skin effects. The third paper presents a simplified approach to developing empirical CAD models for passive circuit components based on asymptotic bounds of electrical parameters. The fourth paper is concerned with the derivation of an equivalent circuit model for an aperture-coupled multilayer filter.

WE4B-1: **Broadband Physics-based Modeling of Microwave Passive Devices through Frequency Mapping**
J.W. Bandler, M.A. Ismail, J.E. Rayas-Sanchez

WE4B-2: **Reduced Order Modeling of Coupled On-chip Interconnects for Silicon-based RF Integrated Circuits**
J. Zheng, V.K. Tripathi, A. Weisshaar

WE4B-3: **Development of CAD Formulas of Integrated Circuit Components — Simplified Formulation Followed by Rigorous Derivation**
Y. Leonard, W. Chow, C. Tang

WE4B-4: **Unified CAD Model of Microstrip Line with Backside Aperture for Multilayer Integrated Circuit**
L. Zhu, H. Bu, K. Wu, M. Stubbs

WE4C Advances in Millimeter Waves and Submillimeter Waves

Chair: K. Agarwal · Co-Chair: S. Weinreb

Advances in HEMTs, MESFETs, varactor diodes, cryogenic mixers and lightwave systems are presented in this session. A 183 GHz InP HEMT receiver module is described along with 38, 77 and 148 GHz GaAs CPW MMIC amplifiers. Efficient varactor diode triplers with output frequencies up to 325 GHz are reported along with a Niobium-Nitride cryogenic mixer with record low noise at 2240 GHz. Finally, the performance of a wavelength-division-multiplexed communication system utilizing 60 GHz signals on optical fibers will be reported.

WE4C-1: **A 183 GHz Low Noise Amplifier Module for the Conical-scanning Imager Sounder (CMIS) Program**
R. Raja, M. Nishimoto, M. Barsky, M. Sholley, B. Osgood, R. Quon, G. Barber, P. Lui, P. Chin, R. Lai, F. Hinte

WE4C-2: **A Coplanar 148 GHz Cascode Amplifier MMIC Using 0.15 μm GaAs pHEMTs**
A. Tessmann, O. Wohlgemuth, W.H. Haydl, H. Massler, R. Reuter, A. Halsmann

WE4C-3: **Low-cost 38 and 77 GHz CPW MMICs Using Ion-implanted GaAs MESFETs**
D.C. Caruth, R.L. Shimon, M.S. Heins, H. Hsai, Z. Tang

WE4C-4: **A 33 GHz Power Amplifier Based on an Extended Resonance Technique**
A. Martin, A. Mortazawi

WE4C-5: **High Efficiency MMIC Frequency Triplers for Millimeter and Submillimeter Wavelengths**
N.R. Erickson, R.P. Smith, S.C. Martin

WE4C-6: **NbN Hot Electron Bolometric Mixer with Intrinsic Receiver Noise Temperature of Less than Five Times the Quantum Noise Limit**

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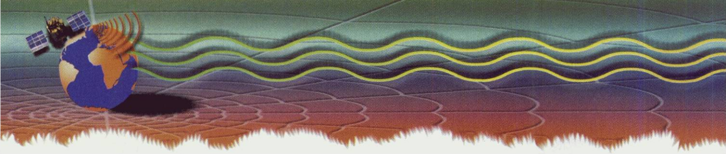


E. Gerecht, C.F. Musante, Y. Zhuang, M. Ji, K.S. Yngvesson, T. Goyette, J. Waldman

WE4C-7: **Experimental Investigation of WDM Channel Spacing in Simultaneous Upconversion Millimeter-wave Fiber Transmission System at 60 GHz Band**
K. Kojucharow, M. Sauer, H. Kaluzni, D. Sommer, C. Schaeffer

WE4D Biological Effects and Medical Applications

Chair: R. Bansal · Co-Chair: K. Carr

With the explosion in the use of microwave/RF communication links, this year's session features a number of papers dedicated to the techniques of calculating the interaction of electromagnetic fields with human tissue. The remaining papers deal with active time imaging and characterization as well as radiometry in the newborn.

WE4D-1: **Measurements of Thermal Effects Induced on a Human Head Exposed to 900 MHz Mobile Phones**
M.D. Taurisano, A. Vander Vorst

WE4D-2: **Evaluation of the Power Absorbed in a Human Head Model Exposed to Cellular Phones Equipped with Helical Antennas**
P. Bernardi, M. Cavagnaro, S. Pisa, E. Piuzzi

WE4D-3: **A Study of Uncertainties in Modeling the Handset Antenna and Human Head Interaction Using the FDTD Method**
K.S. Nikita, N.K. Uzunoglu, P. Bernardi, M. Cavagnaro, S. Pisa

WE4D-4: **Effect of the Human Tissue on EMI from a Cellular Telephone with a Hearing Aid**
K. Caputa, M.A. Stuchly, M. Skopek, H.I. Bassen

WE4D-5: **Algorithm for Retrieval of Deep Brain Temperature in New-born Infant from Microwave Radiometric Data**
S. Mizushina, K. Maruyama, T. Sugiura, G.M.J. Van Leeuwen, J.W. Hand

WE4D-6: **Microwave Breast Cancer Detection**
E.C. Fear, M.A. Stuchly

WE4D-7: **Characterization of Biological Tissues up to Millimeter Wave: Test Fixtures Design**
A.S. Daryoush

WE4E Packaging and Interconnects

Chair: M. Harris · Co-Chair: C.P. Wen

This session reports new results in advanced packaging and interconnect technologies. The first paper reports new field coupling transitions in multiplayer LTCC. This is followed by the application of digital PGA technology with operation to 20 GHz. The final paper reports a new precision MCM with an order of magnitude performance enhancement in passive components.

WE4E-1: **Interconnects and Transitions in Multilayer LTCC Multichip Modules for 24 GHz ISM-band Applications**
W. Simon, R. Kulke, A. Wien, M. Rittweger, I. Wolff

WE4E-2: **Application of Digital PGA Technology to 20 GHz Microwave Packages**
H. Liang, J. Laskar, H. Barnes, D. Estreich

WE4E-3: **Multi-layer Spiral Inductors in a High-precision Fully-planar MCM-D Process**
M. Gouker, K. Konistis, J. Knecht, L. Kushner, L. Travis

Thursday, June 15, 2000

8:00–9:40 AM

TH1A Wireless and Cellular Communications

Chair: R.G. Ranson · Co-Chair: J.K. McKinney

This session presents several advances in design that reflect the trends of the wireless communications industry. One common theme is the use of advanced integration and custom MMICs to address the drive to lower cost and smaller size. Papers cover a broad range of topics for both cellular handsets and wireless LAN applications. The first three papers illustrate advances in system integration. These are followed by an interesting development in handset PA switching and a novel integrated antenna/downconverter. The final paper addresses high linearity LO amplifier design.

TH1A-1: **An Integrated RF Front End for Multi-mode Handsets**
M. Bailey, P. Hagstrom

TH1A-2: **5.8 GHz OFDM GaAs MESFET MMIC Chip Set**
S. Yoo, D. Heo, C-H. Lee

TH1A-3: **A Calibratable 4.8 to 5.8 GHz MMIC Vector Modulator with Low Power Consumption for Smart Antenna Receivers**
F. Ellinger, U. Lott

TH1A-4: **A New Antenna Switching Architecture for Mobile Handsets**
J. Kucera, U. Lott, W. Bachtold

TH1A-5: **Quadrature Direct Conversion Receiver Integrated with Planar Quasi-Yagi Antenna**
S. Lin, Y. Qian, T. Itoh

TH1A-6: **A Silicon MMIC Active Balun/Buffer Amplifier with High Linearity and Low Residual Phase Noise**
J. Lin, O. Boric-Lubecke, C. Zelley

TH1B Couplers

Chair: E.J. Denlinger · Co-Chair: J. Taub

This session discusses novel designs and experimental results for both planar and waveguide couplers. The planar types include an octave-bandwidth magic-T, an octave band lumped element coupler, a wideband broadside coupler using Flex technology and a wideband 0-dB branch-line coupler. Waveguide couplers include a new hybrid type demonstrated in the millimeter-wave band, a dual polarization coupler suitable for beam forming networks and a tight coupling 3 dB device with > 40 dB isolation over a 23% bandwidth.

TH1B-1: **A Novel Planar Magic-T Using Microstrip-to-slotline Transition**
J.P. Kim, K.M. Park, W.S. Park

TH1B-2: **A Microwave Octave-band Lumped Element Quadrature Coupler**
D.P. Andrews, C.S. Aitchison

TH1B-3: **Novel HDI Microwave Chip on Flex (MCOF) Broadside Coupler Designs**
R.J. Teti, R.E. Hayes

TH1B-4: **Wideband 0-dB Branch-line Directional Couplers**
D. Kholodniak, G. Kalinin, E. Vernoslova, I. Vendik

TH1B-5: **A New Waveguide Directional Coupler/Hybrid Type — Favorably Suited for Millimeter Wave Applications**
U. Rosenberg, W. Speldrich

TH1B-6: **Enhanced Dual Polarization Directional Coupler for Dual Polarization Beam Forming Networks**
F. Alessandri, M. Dionigi, R. Ravanelli

TH1B-7: **Waveguide Branch Couplers for Tight Couplings**
T. Shen, K.A. Zaki

TH1C Broadband and High Efficiency Amplifiers and Novel Hybrid Module Techniques

Chair: G. Brehm · Co-Chair: F. Sullivan

Three amplifier papers address applications from 200 MHz to K-band. Topics include cascading gain stage approaches, broadband feedback design and high power, high efficiency compact design for wireless applications. A coplanar mode suppression technique is presented. A novel hybrid transformer technique is introduced. Advances in ferroelectric technology for tuning applications are covered.

TH1C-1: **The Gain Advantages of Four Cascaded Single Stage Distributed Amplifier Configurations**
B.Y. Banyamin, M. Berwick

TH1C-2: **Multi-octave 200 MHz to 20 GHz Amplifier for Extended Range Digital Log Video Amplifier Application**
B.S. Virdee, A.S. Virdee

TH1C-3: **A Compact PA MMIC Module for K-band High-speed Wireless Systems**
T. Satoh, T. Shimura, A. Betti-Brutto

[Continued on page 229]

TH1C-4: **Suppression of Resonant Leakage Effects in Coplanar MMIC Packages using a Si Sub-mount Layer**
H.S. Yoon, S.J. Kim, H.Y. Lee

TH1C-5: **Vertical Integrated Transformer Using Bondwires for MMICs**
B.W. Song, S.J. Kim, H.Y. Lee

TH1C-6: **Low Voltage Tunable Barium Strontium Titanate Thin Film Capacitors for RF and Microwave Applications**
A. Tombak, B. McChesney, T. Ayguavives, J.P. Maria, A. Kingon, A. Mortazawi, G. Stauf

TH1D Ferroelectric Devices
Focused Session

Chair: S. Stitzer · Co-Chair: L. Davis

This session highlights progress in the emerging area of ferroelectric devices and applications. The first paper describes a phased array antenna steered by ferroelectric phase shifters. Three papers address design and measurement of ferroelectric co-planar phase-shifters. Another contribution discusses analytical and experimental results on a ferroelectrically controlled Lange coupler. The final paper in the session discusses material-imposed limitations of the performance of tunable ferroelectric resonators.

TH1D-1: **A K-band Linear Phased Array Based on BaSrTiO Thin Film Phase Shifters**
R.R. Romanofsky, F.A. Miranda, J. Bernhard, G. Washington

TH1D-2: **Application of Ferroelectrics in Phase Shifter Design**
A. Kozyrev, V. Osadchy, A. Pavlov, L. Sengupta

TH1D-3: **Ferroelectric/Ferrite Tunable Phase Shifters**
S.W. Kirchoefer, J.M. Pond, H.S. Newman, W.J. Kim, J.S. Horwitz

TH1D-4: **A Ferroelectric Tunable Microstrip Lange Coupler for K-band Applications**
G. Subramanyam, F.A. Miranda, R.R. Romanofsky

TH1D-5: **Full Wave Analysis of Coplanar Phase Shifter Printed on High Purity Ferroelectric Material**
F. De Flaviis

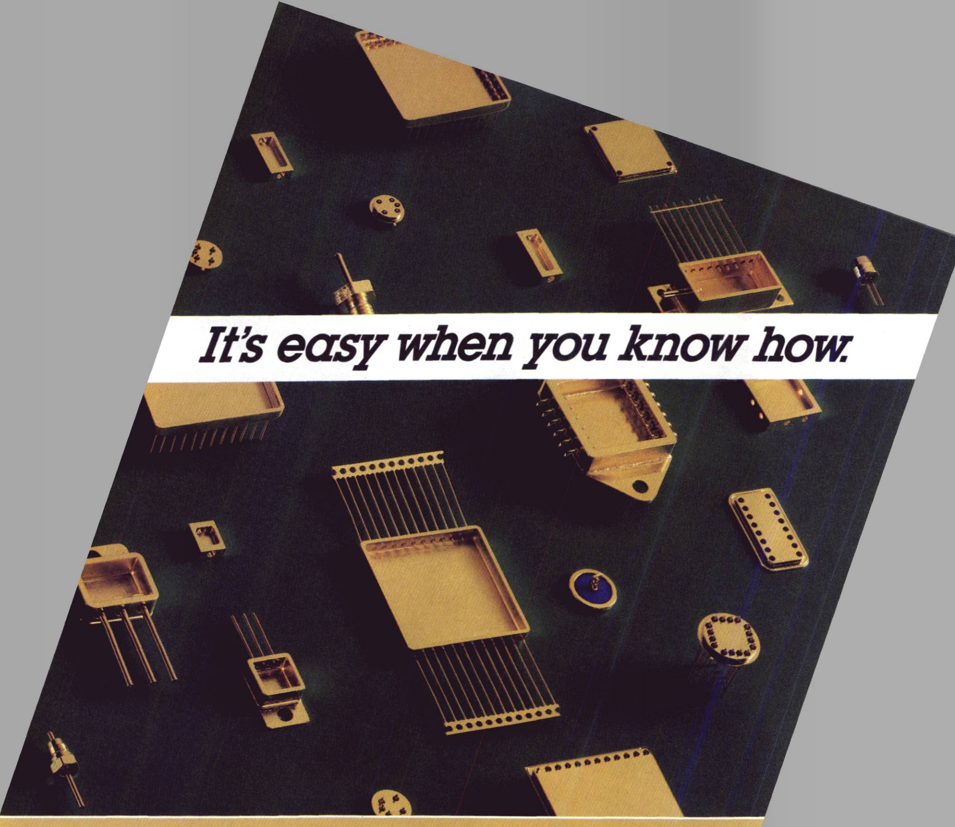
TH1D-6: **Limiting Characteristics of a Tunable Resonator with a Ferroelectric Capacitor.**
I. Vendik, O. Vendik, V. Sherman

TH1E Linear Models of Active Devices

Chair: K. Chang · Co-Chair: D.E. Root

This session deals with the linear modeling and parameter extraction of FETs and HBTs. The first two papers treat FET model scalability with geometry, parameter extraction techniques, element value bias-dependance and experimental validation with results up to 110 GHz. Bias-dependent model capacitances extracted along resistive load lines are considered by the third paper. Parameter extraction techniques for small periphery FETs is the subject of the fourth paper. A parametric estimation technique for more robust optimization-based FET extraction is presented in the fifth paper. The final two papers discuss different direct parameter extraction techniques for HBT linear equivalent circuit models.

[Continued on page 231]


It's easy when you know how.

TH1E-1: **A 110 GHz Scalable FET Model Based on 50 GHz S-parameter Measurements**
A. Cidronali, G. Collodi, A. Santarelli, G. Vannini

TH1E-2: **Bias-dependent Linear, Scalable Millimeter-wave FET Model**
J. Wood, D.E. Root

TH1E-3: **Empirical Loadline Capacitance Models for HEMT**
Y.C. Leong, S. Weinreb

TH1E-4: **Improved Parameter Extraction of Small-sized FETs for Low-power Applications**
F. Lenk, R. Doerner

TH1E-5: **A New Simplified and Reliable HEMT Modeling Approach Using Pinched Cold FET S-parameters**
W.N. Mwema

TH1E-6: **A New Analytical and Broadband Method for Determining the HBT Small-signal Model Parameters**
S. Bousnina, P. Mandeville, A.B. Kouki

TH1E-7: **Direct Extraction Method for Internal Equivalent Circuit Parameters of HBT Small-signal Hybrid-Pi Model**
Y. Suh, E. Seok, J.H. Shin, B. Kim

10:10–11:50 AM

TH2A Automotive Sensors and ID Systems

Chair: S. Kanamluru · Co-Chair: H. Kondoh

Sensor technology is progressing rapidly with the integration of techniques and technology developed for other applications. Novel developments in the communication industry such as I-Q modulators and the antennas are assimilated in auto sensors and ID tags. This session focuses on novel developments in coding, modulation and interference suppression and their application in sensors.

TH2A-1: **A Wireless Pressure Measurement System Using a SAW Hybrid Sensor**
G. Schimetta, R. Weigel, F. Dollinger

TH2A-2: **A Realtime Close-range Imaging System with Fixed Antennas**
B. Michael, W. Menzel

TH2A-3: **A Pre-crash Radar Sensor System Based on Pseudo-noise Coding**
V. Filimon, J. Buechler

TH2A-4: **Reduction of Interference in Microwave Automotive Radars**
M.I. Sobhy, E. Elsehely

TH2A-5: **A 76.5 GHz Vector Modulator and Its Application to a Digitally Modulated Automotive Collision Avoidance Radar**
D.S. McPherson, S. Lucyszyn, I.D. Robertson

TH2A-6: **Microwave Backscatter Modulation Systems**
M. Kossel, H. Benedickter, R. Kueng

TH2A-7: **A Novel Active Retrodirective Array for Remote Tagging and Wireless Sensor Applications**
Y. Qian, T. Itoh

TH2B Passive Components

Chair: A. Fathy · Co-Chair: K. Zaki

First, concepts of bandgap structures have been explored here to include intentional defects in both dielectric and metallo-dielectric lattices, demonstrating further potential applications of this technology. Second, the issue of tenability will be addressed in both dielectric

[Continued on page 233]

resonators using tuning disks and bandgap structures using piezoelectric transducer with wide tuning ranges while other properties are maintained. Third, novel techniques to design high performance circular waveguide polarizes and microstrip coupled line phase shifters with innovative phase equalization.

TH2B-1: **High Q Two Dimensional Defect Resonators – Measured and Simulated**
W.J. Chappell, M.P. Little, L.P.B. Katehi

TH2B-2: **Tunable Dielectric Resonators**
T. Shen, K.A. Zaki, C. Wang

TH2B-3: **An Electronically Tunable Photonic Bandgap Resonator Controlled by Piezoelectric Transducer**
T.Y. Yun, K. Chang

TH2B-4: **A Design of Novel Grooved Circular Waveguide Polarizers**
N. Yoneda, M. Miyazaki, H. Matsumura

TH2B-5: **Novel Technique of Phase Velocities Equalization for Microstrip Coupled Line Phase Shifters**
Y.C. Leong, S. Weinreb

TH2C Linear and Nonlinear Network Measurements

Chair: D. Williams · Co-Chair: Z. Skvor

This session will focus on advances in both linear and non-linear network measurements. The session will begin with advances in load pull measurements. It will then move to applications and calibration of non linear measurement systems. The session will conclude with papers on linear network measurements.

TH2C-1: **High Power Time Domain Measurement System with Active Harmonic Load-pull for High Efficiency Base Station Amplifier Design**
J. Benedikt, R. Gaddi, P.J. Tasker

TH2C-2: **An Active Pulsed RF and Pulsed DC Load-pull System for the Characterization of Power Transistors Used in Coherent Radar and Communication Systems**
C. Arnaud, D. Barataud, J.M. Nebus, J.P. Teyssier, J.P. Villotte, D. Floriot

TH2C-3: **Measurement Based Nonlinear Modeling of Spectral Regrowth**
W. VanMoer, Y. Rolain

TH2C-4: **A Low Cost AM/PM Sideband Generator for Low Noise Calibration.**
D.A. Bittler, F.H. Harris, D.W. Strack

TH2C-5: **Realistic Sampling Circuit Model for a Nose-to-nose Simulation**
K.A. Remley, D.F. Williams, D.C. DeGroot

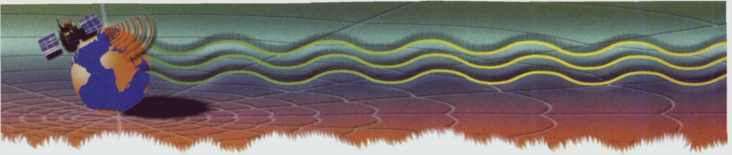
TH2C-6: **A Comprehensive Millimeter-wave Calibration Development and Verification Approach**
W.M. Okamura, M.M. DuFault, A.K. Sharma

TH2C-7: **A New Method for Characteristic Impedance Determination on Lossy Substrate**
A. Bracale, D. Pasquet, J.L. Gautier, N. Fel, V. Ferlet, J.L. Pelloie

TH2D Power Amplifier Linearization
Focused Session

Chair: M. Eron · Co-Chair: A. Katz

The ever-increasing demand for the transmission of greater amounts of information has created a need for highly linear amplifiers. This session highlights development in lineariza-



tion techniques for both low and high power amplifiers. Applications include new generation subscriber and base station cellular telephony, personal wireless and space communications equipment. Feedforward, digital and analog predistortion, and adaptive techniques are covered.

TH2D-1: **Digital Controlled Adaptive Feedforward Amplifier for IMT-2000 Band**
Y. Yang, J. Yi, Y. Kim

TH2D-2: **Optimization of Feedforward Amplifier Power Efficiency on the Basis of Input Power Statistics**
C.L. Larose, F.M. Ghannouchi

TH2D-3: **A 900 MHz 16-QAM Direct Carrier Modulation Transmitter Using Feedforward Linearization**
M. Chongcheawchamnan, M.J. Blewett, K.S. Ang, I.D. Robertson

TH2D-4: **Input Adaptive Linearizer System**
A. Katz, A. Guida, R. Dorva

TH2D-5: **A Linearized Power Amplifier MMIC for 3.5 V Battery Operated Wide-band CDMA Handsets**
G. Hau, T.B. Nishimura, N. Iwata

TH2D-6: **An 18 GHz-band MMIC Linearizer Using a Parallel Diode with a Bias Feed Resistance and a Parallel Capacitor**
K. Yamauchi, M. Nakayama, Y. Ikeda, H. Nakaguro, N. Kadowaki, T. Araki

TH2D-7: **Analog Predistortion Linearizer for High Power RF Amplifiers**
J. Yi, Y. Yang, Pohang M. Park

TH2D-8: **A Multicarrier Amplifier with Low Third-order Intermodulation Distortion**
W.J. Jenkins, A. Khanifar

TH2E Periodic Structures and New Techniques

Chair: A.A. Oliner · Co-Chair: T.K. Sarkar

The major contributions in this session involve novel propagation behavior in periodic structures. Two papers include structures with internal resonators, and three involve microstrip lines with periodically patterned ground planes. The remaining two papers deal with new guided wave techniques.

TH2E-1: **Surface-wave Band-gap and Leaky-waves on Integrated Circuit Structures with Planar Periodic Metallic Elements**
H.Y.D. Yang, R. Kim, D.R. Jackson

TH2E-2: **Surface-wave Suppression of Resonance-type Periodic Structures**
R.B. Hwang, S.T. Peng, C.C. Chen

TH2E-3: **Analysis and Application of Coupled Microstrips on Periodically Patterned Ground Plane**
F. Yang, R. Coccioli, Y. Qian, T. Itoh

TH2E-4: **Numerical and Experimental Characterization of Slow-wave Microstrip Line on Periodic Ground Plane**
C.C. Chang, R. Coccioli, Y. Qian, T. Itoh

TH2E-5: **Dispersion Characteristics of Microstrip with Periodic Perturbations**
C.K. Tzuang, Y.C. Chen

TH2E-6: **Revisiting Guided-wave and Leakage-wave Modal Properties in Near Cutoff Region with the Concept of Complex Effective Dielectric Constant**
X.Y. Zeng, S.J. Xu, K. Wu

TH2E-7: **Formulas of Microstrip with Truncated Substrate by Synthetic Asymptotes – A Novel Analysis Technique**
W.C. Tang, Y.L. Chow

12:00–1:15 PM

PTHE: Low Cost LMDS Terminals – Technology vs. Market Volume and Timing

LMDS systems for data communications to the home or small business are being rapidly deployed at various frequencies from 23 to 42 GHz. Using technology in common with the closely related point-to-point radio systems, a number of these systems have been built. However, extremely low cost is required for the widespread application of two-way user terminals for LMDS systems. This panel will address the various technologies being used for the RF sections of these terminals and provide views of the cost and availability of these technologies. It will also address the question "Are market volumes great enough to realistically support the extremely low cost targets sometimes quoted?"

1:20–3:00 PM

TH3A Applied Sensor Technology
Special Session

Chair: P. Hide · Co-Chair: T. Weller

There is a wide range of potential sensor applications on the basis of microwaves. Microwave technology offers what the customers needs, a reliable, robust and noncontact sensor function. The most popular product applications are tank level gauges, automotive radars and sensors for material detection. Microwave technology is now becoming available for mass products. Besides the development of production-compliant microwave hardware, smart sensor solutions are becoming possible with novel digital techniques. In this session, experts from industry and academia will report on recent developments related to microwave sensor applications.

TH3A-1: **A 76–77 GHz Pulsed-Doppler Radar Module for Autonomous Cruise Control Applications**
I. Gresham, N. Kinayman, B. Ziegner, S. Brown, T. Budka, A. Alexanian

TH3A-2: **Theoretical and Experimental Characterization of a Broadband Random Noise Radar**
R. Stephan, H. Loele

TH3A-3: **Low Power FMCW Radar System for Level Gaging**
D. Brumbi

TH3A-4: **A Pulse Radar Gauge for Level Measurement and Process Control**
J. Motzer

TH3A-5: **Multiparameter Microwave Sensors for Determining Composition or Condition of Substances**
F. Daschner, R. Knoechel, M. Kent

TH3A-6: **Distributed, Micropower Wireless Integrated Network Sensors (WINS)**
R. Rofougaran, F. Newberg, T. Lin

TH3B Trends in Frequency Multipliers and Switches

Chair: D. Peterson · Co-Chair: B.E. Sigmon

This session's focus is on new concepts and techniques for power generation, control and detection extending well into the millimeter-wave frequency range. Papers cover broadband frequency multiplication, low loss and novel phase shift techniques as well as a method for minimizing LO leakage in resistive mixers. The papers demonstrate the trend toward the continued use and application of MMIC technology at millimeter-wave frequencies.

TH3B-1: **Design and Stability Test of a 2–40 GHz Frequency Doubler with Active Balun**
F. van Raay, G. Kompa

TH3B-2: **Wideband Monolithic Millimeter-wave Phase Shifter with Minimum Insertion Loss Variation**
S. Nam, F.M. Ghannouchi

TH3B-3: **Millimeter Wave Broadband Frequency Tripler in GaAs/InGaP HBT Technology**
C. Beaulieu

TH3B-4: **A Ka-band MMIC Super Regenerative Detector**
N.B. Buchanan, V.F. Fusco

TH3B-5: **High Output Power, Broadband 28–56 GHz MMIC Frequency Doubler**
C. Fager, L. Landen, H. Zirath

TH3B-6: **L-band Glass-epoxy Five-bit Phase Shifter Module Using SW-BANK Chips and Low Cost LC Chips**
K. Nakajima, N. Suematsu, E. Taniguchi

TH3B-7: **A Novel Method for Nulling the LO Leakage in Resistive FET Mixers**
Y. Thodesen

TH3B-8: **High-power Millimeter-wave Planar Doublers**
G.L. Tan, G.M. Rebeiz

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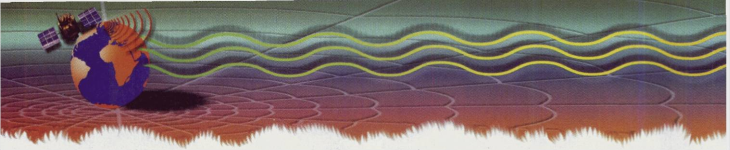

TH3C Optical Probing and Millimeter-wave Measurements
Joint IMS-ARFTG Session

Chair: R.D. Pollard · Co-Chair: C.M. Weil

After many years of development in on-wafer probing, there is growing interest in non-contacting measurements on microwave circuits. Further progress has been made with optical techniques, but the emergence of scanning probing microscopy shows considerable promise in these applications. As electro-optical and millimeter-wave technologies become more widely used, measurement techniques are being pushed to achieve performance and ease of use comparable with mainstream microwaves. This also generates demand for dielectric measurement at these higher frequencies. The session illustrates some of the measurement issues that arise when quasi-optical techniques are applied at sub-millimeter waves. Future developments are expected to extend the frequency range and applicability of these measurement techniques and, through the development of calibration methods, achieve improved accuracies.

TH3C-1: **A New, Simple Test Set for On-wafer Characterization of Millimeter-wave Electro-optic Devices**
M. Pirola, G. Ghione, A. Ferrero

TH3C-2: **A Bilateral Lightwave Network Analyzer**
B. Elamaran, R.D. Pollard, S. Iezekiel

TH3C-3: **Novel Electromagnetic Field Probe Using Electro/Magneto-optical Crystal Mounted on an Optical-fiber Facet for Microwave Circuit Diagnosis**
S. Wakana, T. Ohara, M. Abe

TH3C-4: **Non-contact Internal-MMIC Measurement Using Scanning Force Probing**
C.F. Falkingham, I.H. Edwards, G.E. Bridges

TH3C-5: **Contrast Quantification of Millimeter-wave Scanning Near-field Microscope with a Slit Probe**
T. Hamano, F. Watanabe, S. Nuimura

TH3C-6: **A Novel W-band Spectrometer for Dielectric Measurements**
M.N. Afsar, I.I. Tkachov, K.N. Kocharyan

TH3C-7: **A Near-field Alignment Technique at Millimeter and Sub-millimeter Wavelengths**
M.T. Chen, Academia Sinica, C.E. Tong, D.C. Papa, R. Blundell

TH3D Filters (3)

Chair: D. Schmitt · Co-Chair: M. Guglelimi

This session discusses advanced filter techniques and novel filter and resonator configurations.

TH3D-1: **Tuning & Measurements of Couplings and Resonant Frequencies for Cascaded Resonators**
A.E. Atia, H. Yao

TH3D-2: **Computer Diagnosis and Tuning of Microwave Filters Using Model-based Parameter Estimation and Multi-level Optimization**
M. Kahrizi, S. Safavi-Naeini, S.K. Chaudhuri

TH3D-3: **Filters With an Almost Constant Stopband**
R.V. Snyder

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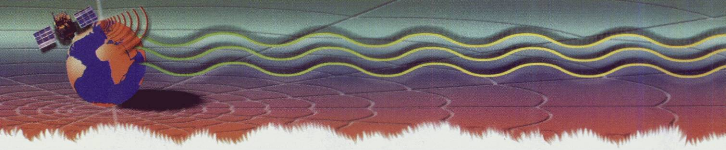


TH3D-4: **Full Wave Modeling of Electric Coupling Probes in Combline Resonators and Filters**
C. Wang, K.A. Zaki

TH3D-5: **Mobius Resonators and Filters**
J.M. Pond

TH3D-6: **Single-passband, Single-stopband Narrowband Filters**
H.C. Bell

TH3E New Propagation Effects on CPW and Microstrip

Chair: P. Lampariello · Co-Chair: J. Zehentner

Various new propagation effects on CPW and microstrip line are described in this series of papers. They include the effects produced by finite-width ground planes and by a top cover over the circuit, and new and unexpected modes on conductor-backed coplanar strips. There is also a novel structure combining NRD guide and microstrip line.

TH3E-1: **Dispersion and Radiation Characteristics of Conductor-backed CPW with Finite Ground Width**
W. Heinrich, F. Schnieder, T. Tischler

TH3E-2: **The Influence of a Top Cover on the Leakage from Microstrip Line**
F. Mesa, A.A. Oliner, D.R. Jackson

TH3E-3: **Behavioral Feature of the Space-wave Leaky Mode, the Surface-wave Leaky Mode and the Bound Mode**
M. Tsuji, H. Shigesawa

TH3E-4: **Mode-coupling Effect between Different Two Types of the Surface-wave Leaky Mode on Conductor-backed Coplanar Strips (CBCPS)**
M. Tsuji, H. Shigesawa

TH3E-5: **Low-loss Millimeter-wave Propagation Characteristics of NRD-guide Surface-mounted on Planar Substrate for Hybrid Integrated Circuit**
J. Tang, X.Y. Zeng, S.J. Xu

2:30–5:00 PM

THIF Interactive Forum

Chair: Dan Swanson · Co- Chair: Doug Teeter

THIF-1: **Frequency-space Mapping Optimization of Microwave Circuits Exploiting Surrogate Models**
M.H. Bakr, J.W. Bandler, J.E. Rayas-Sanchez, K. Madsen, J. Sondergaard

THIF-2: **Passive Model-reduction of Distributed Networks with Frequency-dependent Parameters**
A. Dounavis, E. Gad, R. Achar

THIF-3: **Frequency and Geometry Parameterization for 3D Microwave Circuit Design and Optimization Using Pole Expansion and Derivatives**
A. Gati, V.F. Hanna, G. Alquie

THIF-4: **Modeling Source Inductance in FETs**
D. Farias, F. Rose, J. Selin

THIF-5: **Microstrip-to-coplanar Waveguide Transition Full-wave Analysis Model**
D.F. Williams, W. Wiatr

THIF-6: **Electromagnetic Modeling of Linear pHEMTs for Millimeter Waves**
M. Farina,T. Rozzi

THIF-7: **Integrated Microstrip to NRD-guide Transition Using a Spurious Mode Suppressing Technique**
J. Tang, K. Wu

THIF-8: **Ultra Low-loss Transmission Lines on Low Resistivity Silicon Substrate**
H. Henri, S. Gonzague, C. Alain

THIF-9: **Computation of Causal Characteristic Impedances**
D.F. Williams, R.C. Wittmann

THIF-10: **Wide Bandwidth Microwave Phase Detection Using Optical Intensity Modulators**
P.P. Roberts, W.E. Wilson, G.E. Town

THIF-11: **Nonlinear Distortion Compensation of Microwave Fiber Optic Links with Asymmetric Adaptive Filters**
X.N. Fernando, A.B. Sesay

THIF-12: **Optoelectronic Mixing in a Self Oscillating InP/InGaAs Photo – Heterojunction Bipolar Transistor**
J. Lasri, A. Bilenca, G. Eisenstein

THIF-13: **Linearized Optical Directional-coupler Modulators for Analog RF/Microwave Transmission Systems**
C. Laliew, X. Zhang, A. Gopinath

THIF-14: **A Novel Fiber-optic Link with Remote Heterodyning for Phase Stabilized Transmission of Microwave and Millimeter Wave Signals**
A.N. Bratchikov, D.I. Voskresenskii, T.A. Sadekov

THIF-15: **General Accuracy Considerations of Microwave On-wafer Silicon Device Measurements**
T.E. Kolding

THIF-16: **Measurements of the Dielectric Constant of Low-loss materials Using Semi-confocal (Open-resonator) at 55–65 GHz.**
Y. Kantor, C. Jones

THIF-17: **Accurate Determination of Dielectric Constant of Substrate Materials Using Modified Wolff Model**
A.K. Verma

THIF-18: **Vector Signal Characterization of 38 GHz Power Amplifier with 200 Mbps QPSK Modulation**
G.S. Dow, J.M. Yang, K.H. Yen, R. Matreci, E. Spotted-Elk, S.C. Pettis, L. Trinh

THIF-19: **A Novel Setup for Co-channel Distortion Ratio Evaluation**
J.C. Pedro, N.B. Carvalho

THIF-20: **An Automatic Harmonic Selection Scheme for Measurements and Calibration with the Nonlinear Vectorial Network Analyser**
W. Van moer, Y. Rolain, J. Schoukens

THIF-21: **Effects of Pin Depth in LPC 3.5 mm, 2.4 mm and 1.0 mm Connectors**
B.B. Szendrenyi

THIF-22: **In-circuit Testing of Complex Circuits Using On-wafer Probing and Electromagnetic Coupled Ground Interconnects**
J. Kassner, W. Menzel

THIF-23: **A Modified Open-ended Coaxial Probe for Concave Surface Coating Materials Testing**
A.K.A. Hassan, D. Xu, L. Zhang, M. Niu, Y. Zhang

THIF-24: **Measurement of a DSB Modulated RF Signal by Use of Discriminant Filters and Envelope Detection.**
A. Barel, Y. Rolain

THIF-25: **Isolation in Three-dimensional Integrated Circuits**
A. Margomenos, L.P.B. Katehi, S. Valas, M.I. Herman

THIF-26: **Development of Microwave/Millimeter-wave Integral Passives for Multi-layer Organic MCMs**
S. Manohar, A. Pham, V. Krishnamurthy

THIF-27: **A New Concept of RF Feed-through Applied to Multi-chip Modules for Space Equipment**
P. Monfraix, T. Adam, C. Drevon

THIF-28: **Characterization of Surface Mount Packages at Microwave Frequencies Using Wafer Probes**
E.M. Godshalk

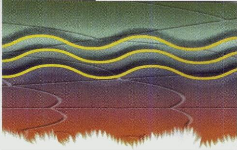
THIF-29: **Development of Finite Ground Coplanar (FGC) Waveguide 90 Degree Crossover Junctions with Low Coupling**
G.E. Ponchak, E. Tentzeris

THIF-30: **A Ku-band Frequency-tunable Active Matched Feedback MMIC Amplifier Using Variable-capacitance Elements**
K. Yamanaka, K. Sugaya, Y. Horiie

THIF-31: **Si/SiGe HBT Active Integrated Antenna on High Resistivity Silicon Substrate**
M.M. Kaleja, A. Gruebl, F.X. Sinnesbichler, G.R. Olbrich, E.M. Biebl, K.M. Strohm, J.F. Luy

THIF-32: **GaN Gunn Diodes for THz Signal Generation**
E. Alekseev, D.Pavlidis

[Continued on page 240]



THIF-33: **Three Dimensional Power Amplifier and Special Elements Design**
A.M. Darwish, A.K. Ezzeddine, H.C. Huang, M. Mah

THIF-34: **New Methodology for Microwave/Millimeter-wave MMIC Development**
K. Kamogawa, K. Nishikawa, I. Toyoda

THIF-35: **Survivability of InP HEMT Devices and MMICs under High RF Input Drive**
Y.C. Chen, M. Barsky, R. Tsai

THIF-36: **Global Electromagnetic Analysis to Help the Conception of an Active Module**
F. Bodereau, D. Baillargeat, S. Verdeyme, M. Aubourg, P. Guillon, G. Jarthon, E. Rogeaux, J.L. Cazaux

THIF-37: **A New Thin Film Passive Integration Technology for Miniaturisation of Mobile Phone Front End Modules; Integration of a Dual-band Power Amplifier, Switch and Diplexer for GSM**
A. de Graauw, C. Copetti, W. Weekamp

THIF-38: **Surface Integral Equation Modeling Approach to the Handset Antenna and Human Body Interaction**
B.M. Notaros

THIF-39: **Analysis of a Passive Spatial Combiner Using Tapered Slotline Array in Oversized Coaxial Waveguide**
P. Jia, Y. Liu, R.A. York

THIF-40: **Electro-thermal Modeling and Measurement of Thermal Time Constants and Natural Convection in Spatial Power Combining Grid Arrays**
W. Batty, A.J. Panks, R.G. Johnson, C.M. Snowden

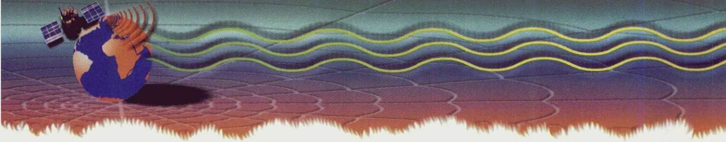
THIF-41: **Improved Balanced Crossed Dipole Quasi-Optical Frequency Doubler**
S. Helbing, F. Alimenti, M. Cryan

THIF-42: **Generation of Cs-Xe Discharge Plasma Slabs for Nonlinear Microwave Quasioptical Devices**
N.A. Bogatov, M.S. Gitlin, D.A. Dican

THIF-43: **Influence of Output Impedance on Power Added Efficiency of Si-bipolar Power Transistors.**
F. van Rijs, R. Dekker, H.A. Visser

THIF-44: **Low-cost Millimeter-wave Transmitter Architecture Using Software Radio Techniques**
M. Chongcheawchamnan, K.S. Ang, D. Kpogla, S. Lucyszyn, I.D. Robertson, S. Nam

[Continued on page 242]



THIF-45: **Effect of Out-of-band Terminations on Cross Modulation in CDMA Receivers**
V. Aparin

THIF-46: **A 2 GHz Band Even Harmonic Type Direct Conversion Receiver for W-CDMA Mobile Terminal Utilization**
K. Itoh, T. Katsura, H. Nagano, T. Yamaguchi, Y. Hamade, M. Goldfarb

THIF-47: **New Type of High Speed Pulse Radar Based on the NRD Guide Technology at 60 GHz Band**
F. Kuroki, M. Sugioka, T. Danhara

THIF-48: **Beam Steering Antenna for MMW Imaging Radar**
V.A. Manasson, R. Mino, L. Timashpolsky, L.S. Sadovnik, V.A. Yepishin

THIF-49: **Monolithic GaAs Surface Acoustic Wave Chemical Microsensor Array**
V.M. Hietala, S.A. Casalnuovo, E.J. Heller, G.C. Frye-Mason, J.R. Wendt, A.G. Baca

THIF-50: **Low-cost Automobile Crash Sensor Using a 61 GHz Active Integrated SIMMWIC Antenna**
M.M. Kaleja, R.H. Rasshofer, E.M. Biebl, J. Buechler, J.F. Luy

THIF-51: **76 GHz Post-wall Waveguide Fed Parallel Plate Slot Array with 45-degree Linear Polarization**
J. Hirokawa, M. Ando

3:30–5:10 PM

TH4A Novel Microwave Systems and Components

Chair: R. Gupta · Co-Chair: R. Kaul

In this Microwave Systems session, significant developments in components for LMDS and wireless applications as well as novel system concepts are presented. Two papers feature the integration of the antenna with the RF components. One LMDS paper presents the performance of a MMIC up- and downconverter chip. In addition, three novel systems involving a broadband receiver architecture with orthogonal IF signals, chaotic processes for a radar transceiver and self-phased arrays using IF processing are presented.

TH4A-1: **LMDS Up- and Down-converter MMIC**
L. Verweyen, M. Hassler, H. Tischer, W. Liebl, T. Grave, V. Guengerich, A. Tessmann, Y. Campos-Roca, A. Bessemoulin

TH4A-2: **A 25 GHz Down-converter Integrated with a CPW-fed Lens Antenna**
A. Yamada, T. Matsu

TH4A-3: **Chip Multilayer Antenna for 2.45 GHz-band Application Using LTCC Technology**
Y. Dakeya, T. Suesada, K. Asakura

TH4A-4: **A Novel Broadband Receiver Architecture for Wireless Communication and Radar Systems**
S.J. Spiegel, M. Ruberto, A. Madjar

TH4A-5: **Chaotic Radar Systems**
M.I. Sobhy, A.R. Shehata

TH4A-6: **Digital Communications Using Self-phased Arrays**
L.D. DiDomenico, G.M. Rebeiz

TH4B Very High Power Components

Chair: J. Goel · Co-Chair: R. Mallavarpu

This session presents several advances in high power GaAs FET and HFET technology, with emphasis on digital cellular base station applications. These include a new power benchmark of 240 W at 2.1 GHz, devices with improved linearity in a high efficiency operating mode and devices that operate with a 30 V supply and high power density. An S-band, 36 kW radar is presented with emphasis on modular system architecture and measured system characterization. The megawatt PIN diode switch paper covers new techniques and hardware, and the TWT modeling paper provides new tools for linearity prediction in an established technology area.

TH4B-1: **Low Distortion High Power GaAs Pseudomorphic Heterojunction FETs for L/S-band Digital Cellular Base Stations**
I. Takenaka, K. Ishikura, H. Takahashi

TH4B-2: **100 W L-band GaAs Power FP-HFET Operated at 30 V**
K. Matsunaga, K. Ishikura, I. Takenaka

TH4B-3: **A 240 W Push-pull GaAs Power FET for W-CDMA Base Stations**
K. Inoue

TH4B-4: **High Power Modular S-band Solid State Transmitters Family for ATC and Naval Applications Radars**
M. Cicolani

TH4B-5: **Modeling Single- and Multi-carrier Performance of a Helix TWTA with the 1-D Parametric Code, CHRISTINE**
D.K. Abe, B. Levush, M.T. Ngo

TH4B-6: **Multi-megawatt X-band Semiconductor Microwave Switches**
F. Tamura, S.G. Tantawi

TH4C Photonic Synthesis of Microwave Signals
Special Session

Chair: P.D. Bieracki · Co-Chair: A.J. Seeds

This special session reports very good progress generating millimeter-wave-modulated light. Advantages of photonic techniques include remoting, immunity to EMI, new system concepts, etc. Photonic heterodyning improved by injection locking slave lasers generates low phase noise signals from 1 to 94 GHz (Logan, JDS Uniphase; and Johansson and Seeds, UC London). Monolithic integration of a photonic add/drop multiplexer of 60 GHz mm-waves for fiber-radio WOM ring networks is reported by Kitayama (Osaka U.) et al. Berceli (Techn. Univ. Budapest) et al. extend the frequency of photonically distributed subharmonically-locked oscillators to 94 GHz. And Wang et al. (Univ. Kent) report on the indirect injection locking and generation of a 30 GHz HEMT oscillator using a 1550 nm optical signal. The general trend in photonic synthesis of high speed signals is toward higher quality (low phase noise) and toward even higher frequencies in W band.

TH4C-1: **Fibre-integrated Heterodyne Optical Injection Phase-lock Loop for Optical Generation of Millimetre-wave Carriers**
L.A. Johansson, A.J. Seeds

TH4C-2: **(Invited) All-optical Heterodyne RF Signal Generation Using a Mode-locked-laser Frequency Comb: Theory and Experiments**
R.T. Logan Jr.

TH4C-3: **(Invited) A Good Prospect for Broadband Millimeter-wave Fiber-radio Access System — An Approach to Single Optical Component at Antenna Base Station**
T. Kuri, R. Heinzelmann, A. Stuhr

TH4C-4: **Optical Millimeter Wave Generation Utilizing a Subharmonic Reference**
T. Berceli, G. Jr., S. Kudszus

TH4C-5: **30 GHz Microstrip HEMT Oscillator Using Indirect Optical Injection Locking**
X. Wang, N.J. Gomes, L. Gomez-Rojas

TH4D Filters/Multiplexers (4)

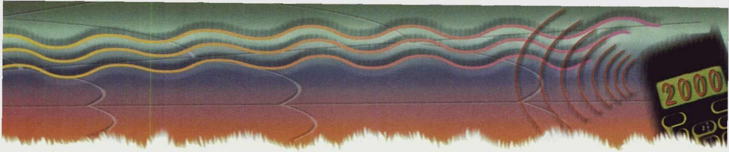
Chair: C. Wang · Co-Chair: R. Snyder

This session reports progress in the waveguide filter and multiplexer synthesis theory, multimode approach, power handling analysis, and wide tenability and novel structures. The major direction includes accurate modeling, compact filter design and wide tenability. Fast, accurate, compact and low cost design for new filter and multiplexer will be the research interest of this area.

TH4D-1: **A Wide-band Tunable Filter Technique Based on Double-diplexing and Low-Q Elements**
R.V. Snyder

TH4D-2: **Triple Mode Filters with Coaxial Excitation**
G. Gerini, F. Diaz Bustamante, M. Guglielmi

TH4D-3: **Accurate Modeling of Narrow-band Filters for Satellite Communications**
W. Hauth, M. Guglielmi, D. Schmitt



TH4D-4: **A Simplified Analysis for High Power Microwave Bandpass Filter Structures**
A. Sivadas, M. Yu, R. Cameron

TH4D-5: **Six-pole Triple Mode Filters in Rectangular Waveguide**
M. Mattes, J. Mosig, M. Guglielmi

TH4D-6: **Transversal Filter Using Whispering Gallery Quarter Cut Resonators**
V. Pommier, D. Cros, P. Guillon, A. Carlier, E. Rogeaux

FRIDAY, JUNE 16, 2000

8:00 AM–12:00 PM

WFC: MICROWAVE OSCILLATORS – LOOKING BACK AND LOOKING FORWARD (OVERVIEW AND STATE OF THE ART OF OSCILLATOR THEORY AND DESIGN)

This workshop will provide an overview of oscillator design together with the new developments that include nonlinear simulation and measurements. It is our belief that the design practice, measurements, simulation and nonlinear theory of oscillations should be brought together so that the growing complexity of circuit and systems design can be successfully addressed. Communication systems in particular are in need of trade-offs between bandwidth, linearity and power consumption (to mention just a few), which require careful nonlinear analysis.

The year 2000 has many anniversaries related to oscillators: Basic structures will be 80 years old; van der Pol theory will be 70 years old; justification of van der Pol theory will be 60 years old; and applications to microwaves by Kurokawa will be 30 years old. Ironically, during all those years, the oscillator theory and design practice developed on diverging paths. One of the very few exceptions to that rule is Kurokawa's work at Bell Labs. Our goal is to diminish the gap between the design practice, which still remains chiefly linear, and the new design methods, which are powerful but little known.

The workshop will consist of invited papers that outline oscillator design and provide an overview of best design practices and the newest developments in the field. Strengths and limits of specific applications will be presented and followed by a general discussion. Workshop participants are invited to present specific results of their work. Short presentations with the use of view graphs are particularly encouraged.

WFH: PRINTED ANTENNA TECHNOLOGY FOR WIRELESS AND SATELLITE COMMUNICATIONS

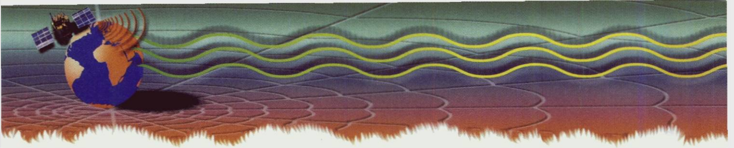
This half-day workshop will provide participants with a good understanding of the miniaturization concepts for printed antenna technology for wireless connectivity and satellite communications covering the frequency range of 450 MHz to millimeter waves. The workshop will commence with an overview of miniaturization concepts for printed antennas. The second speaker will address the miniaturization applicable to space shuttle borne and deployed micro-satellite antennas. This technology would address inflatable and membrane supported antennas at L-, X- and Ka-band frequencies. The third speaker will address the development of a low cost L-band planar multilayer circular phased array for potential mobile satellite communications. The design and modeling of planar antennas using software tools also will be included. This workshop would be beneficial to RF and microwave engineers involved in antenna design for Bluetooth-enabled wireless products; software-defined, radio-based devices; portable phones; satellite-borne antennas; and fixed or mobile antennas for direct reception from satellites. The miniaturization concepts also would benefit persons working in the area of sensor telemetry.

8:00 AM–5:00 PM

WFA: INTEGRATED TRANSCEIVER DESIGN USING SILICON-BASED SEMICONDUCTORS

RF transceivers are key elements in the expanding communications area. Instant communications without interconnecting wires has been a major factor in the explosive growth of communications. Efforts are being directed toward making the transceiver smaller, lighter and less expensive while using less power. One way to achieve these goals is to incorporate both analog and digital circuits in a low-cost, silicon-based semiconductor. A critical need exists to provide the RF engineer with the design tools and performance information necessary to incorporate the integrated design in this low-cost medium.

This workshop will focus on silicon-based RF integrated design techniques. Both CMOS and BiCMOS process characteristics and RF performance will be presented for active (diodes, BJTs and MOSFETs) as well as passive components (resistors, capacitors and inductors). The advantages and disadvantages of each process will be enumerated. Key characteristics such as gain, match, noise figure, efficiency and 1/f noise will be explored. The ad-



vantages of balanced over single-ended circuits will be presented. A clear objective will be to introduce design techniques in this medium to the RF design engineer. RF circuit techniques to incorporate critical circuit functions such as the oscillator, LNA, power amplifier, switches, filtering and mixing into the integrated medium (including typical performance) also will be presented. Transceiver analog and digital mixed-signal circuitry, including analog as well as A/D, D/A, synthesizer, modulation, filtering and processing, is critical in today's transceiver. A summary of these techniques from an RF design prospective will be presented. Finally, transceiver design examples that highlight the design techniques and performance achieved will be presented.

WFB: High Power Transmitter Systems and Related Subsystems for Wireless Base Stations

Together with switches, base stations constitute some of the costliest investments a wireless operator needs to make in order to establish wireless service in a given geography. There are numerous architectures and philosophies that guide the design and performance of a base station. It is an area of engineering that brings a large number of disciplines together and, consequently, a large number of parameters, including electrical, mechanical, reliability and economic (and even legal and regulatory), that need to be traded off against each other. It is also an application ground for some of the most rapidly changing and evolving technologies such as DSP, linearization, digital radios, high power devices and components, software, power supplies and cooling.

This workshop will bring together numerous experts representing the cross section of industries that design and manufacture components and assemblies for base stations as well as organizations involved in designing and deploying base stations. This is a very wide topic but, by focusing it on the transmission side, it is expected that an area of intense activity will be recognized in its own right that will provide a forum for much needed technical exchange.

WFD: Microwave and Photonic Applications of MEMS

The field of microelectromechanical systems (MEMS) has seen tremendous growth recently and is generally considered a revolutionary, enabling technology. Some accounts have estimated MEMS as a $10 B market today (and a $34 B market by 2002). MEMS techniques have evolved from the fabrication technologies used in microelectronics to a much more varied and powerful set of tools, techniques and materials. As such, MEMS technology can be used to provide robust and inexpensive miniaturization and integration of simple elements into more complex systems, allowing significant advantages and increased functionality in many RF and photonic applications. Current MEMS applications include accelerometers; pressure, chemical and flow sensors; micro-optics; optical scanners; and fluid pumps.

The aims of this workshop are to disseminate, update and discuss ongoing research in the MEMS field relating to both device development and systems applications and to stimulate new developments at several levels. The intent is to cover the following topics: an overview/history of MEMS techniques, RF MEMS device development, RF applications of MEMS, and micro-optoelectromechanical systems (MOEMS) efforts and applications as well as other related RF and photonic MEMS topics. In addition, by gathering the various MEMS communities, we hope to promote and stimulate new MEMS applications. The session will consist of tutorial presentations highlighting the various MEMS fabrication technologies such as silicon micromachining and deep etch x-ray lithography. These presentations will serve to educate people not associated with the field and portray the current state of the art in MEMS techniques. Presentations on MEMS devices will follow, demonstrating the broad capabilities and vast potential of MEMS technology. These will be complemented by presentations that focus on the wide variety of RF and photonic applications incorporating MEMS technology, including sensors, phased array antennas, software radio and optical communications. Attendees are also encouraged to bring questions or a few view graphs to describe their problem or approach.

WFE: Ferroelectric Materials and Microwave Applications

Advances in several areas of materials science have led to a variety of new materials with strong potential applications to microwave and millimeter-wave components. Many of these materials are now available in a thin film that can be integrated into existing MMIC processes. For example, new ferroelectric materials such as barium strontium titanate (BaxSr1-xTiO3) have been developed with low loss and field-dependent permittivity that can be varied by a factor of 4, suitable for a number of tunable circuits as a low-cost varactor replacement technology. High-permittivity materials are also available in thin films for small-area bypass capacitors and for integration with MEMS devices. Ferroelectric materials such as PZT have been refined for use in static memories and may be useful in microwave control applications. New thin-film ferrite and permanent magnet materials such as lanthanum cobalt magenate (LaxCo1-xMnO3) have been developed that show which have field-dependent permeabilities and low loss. A large number of other electroceramics, piezoelectrics, liquid crystals and polymers are also under development with applications at RF and microwave frequencies.

WFF: Automated Circuit Optimization Using Electromagnetic Simulators

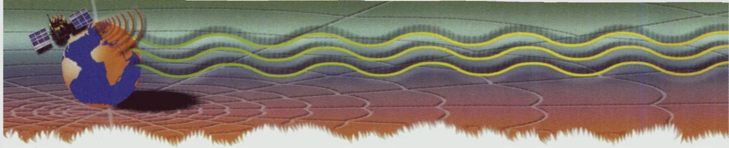
Microwave engineers have been using optimization techniques in CAE for decades. Most, if not all, commercial CAE systems for RF, wireless and microwaves have automatic optimization capabilities. The role of optimization in modeling, simulation and design is taken for granted by microwave circuit designers. It is now also emerging as a significant component of electromagnetics (EM) based circuit design. With the increasing availability of fast, robust, commercial EM simulators (both special purpose and general purpose), it is also possible to include their results both in performance-driven and yield-driven circuit optimization to combine the advantages of yield-driven design with the accuracy of EM simulation for first-pass success. The push continues to go beyond traditional uses of EM simulators for validation, generation of equivalent circuits or look-up tables and to integrate EM simulations directly into the linear/nonlinear circuit design process in a manner transparent to the designer. EM simulators will not realize their full potential as design tools unless they are driven by optimization routines to automatically adjust some designable parameters.

This workshop will address the state of the art. Expectations for using EM simulators as effective tools in an automated design environment continue to be raised based on the considerable and excellent work currently in progress. This workshop will emphasize optimization methodologies as a cornerstone in simulation, modeling, design and manufacturing. The workshop will draw upon the popularity and success of previous related workshops at MTT-S symposiums. A balance between theory, implementation and practical discussions of computational issues will be struck so that the workshop will appeal to a wide range of engineers.

WFG: Biological Effects of EM Fields

Owing to the broad usage of electricity and related systems by people in the course of their daily life, questions have been raised regarding their safety. Public concerns amount from hazards of non-ionizing EM fields and radiation, including electric and magnetic fields and radiation, which arise from sources like power lines, distribution lines, substations, computers, radio transmitters, mobile phones, cellular stations and other electrical devices. This short course will review the long history of this issue, the controversy concerning possible biological effects and expected health hazards. It will provide details of the engineering research and scientific data that result in the setting of health safety standards. The discussion also will highlight the simulation approaches and experimental investigations that lead to the development of the health protection guidelines and examine various risks of exposure to various fields and radiation for humans. The presentation is descriptive with minimal use of mathematics. Examples of actual field surveys will be discussed extensively.

[Continued on page 246]



2000 RFIC SYMPOSIUM TECHNICAL PROGRAM

MONDAY, JUNE 12, 2000

8:00 AM

MON1A Exciting Applications of RFICs
Plenary Session

Chair: F. Ali · Co-chair: D. Lovelace

Expansive growth in the wireless communication area has ushered in new and exciting applications of RFICs. This Plenary Session of invited papers will introduce us to this brave new world of RF gadgets and applications.

MON1A-1: ***(Invited)*** **Communication ICs for the Next Millennium**
Dwight Decker

MON1A-2: ***(Invited)*** **Bluetooth Radio Architectures**
J. Gilb

MON1A-3: ***(Invited)*** **RF and System Requirements for Cable Modem Applications**
D. McMullin

MON1A-4: ***(Invited)*** **High Data Rate Wireless LANs**
Steve Saliga

10:30 AM

MON2A Cutting Edge RFICs

Chair: D. Lovelace · Co-chair: F. Ali

"Cutting Edge RFICs" is a special session of invited papers that highlights new RFICs that have achieved exceptional levels of integration and performance. A fully integrated television receiver will be presented. Other papers include breakthroughs in direct conversion receivers for GSM and an advanced sigma-delta fractional-n synthesizer.

MON2A-1: ***(Invited)*** **Broadband Tuner on a Chip for Cable Modem, HDTV and Legacy Analog Standards**
B. Taddiken, W. Ezell, E. Mumper, K. Clayton, J. Douglass, V. Birleson, J. Esquivel, O. Werther, G. Dawe

MON2A-2: ***(Invited)*** **Symphony – A Sigma Delta Synthesizer**
M. Mulbrook

MON2A-3: ***(Invited)*** **A Direct Conversion Transceiver for Multi-band GSM Application**
J. Strange

MON2B Millimeter-wave Components and Subsystems

Chair: L. Liu · Co-chair: J.P. Mondal

This session discusses state-of-the art performance on millimeter-wave active and passive components in the frequency range of 60 GHz and above. It also describes for the first time the application of virtual modeling in developing millimeter-wave subsystems. SiGe is gradually maturing and its application at frequencies above 30 GHz is growing. The session will present progress in millimeter-wave components using SiGe and other III-V material. With these enhanced components and subsystems we can expect that more higher level integrated and higher performance systems will become available.

MON2B-1: **67-GHz Static Frequency Divider Using 0.2-mm Self-aligned SiGe HBTs**
K. Washio, R. Mayami, E. Ohue, K. Ohue, M. Tanabe

MON2B-2: **Monolithic Resistive Mixers for 60 GHz Direct Conversion Receivers**
K.S. Ang, M. Chongcheawchamnan, I.D. Robertson

MON2B-3: **Monolithic Power Amplifiers Covering 70–113 GHz**
H. Wang, L. Samoska, T. Gaier, A. Peralta

MON2B-4: **A High-performance 85–119 GHz GCPW MMIC Low Noise Amplifier**
V. Radisic, C.W. Probanz, M. Hu, M. Micovic, M. Wetzel

MON2B-5: **Applications of Virtual Modeling to the Development of a 39 GHz MMIC Transceiver on Multilayer Multichip Assembly (MCA) Substrate**
J. Mondal, E. Bogus, S. Ahmed, G. Dietz, P. Sahm, T. Nguyen, M. Yusim, S. Consolazio

1:30 PM

MON3A Integrated VCOs

Chair: T. Tewksbury · Co-chair: J. Moniz

VCOs are a fundamental building block of all communications transceivers but have resisted integration due to their stringent phase noise and performance requirements. This session focuses on new process techniques and design techniques that enable integrated radios with on-chip VCOs. The session begins with an invited paper describing a novel feedback technique for reducing oscillator phase noise. The next three papers present fully integrated, low phase noise VCOs operating at 5.0, 2.4 and 1.0 GHz. The final paper presents a fully integrated 5.35 GHz VCO and prescalar in 0.25 µm CMOS.

MON3A-1: ***(Invited)*** **A Novel RF IC for UHF Oscillators**
U. Rohde

MON3A-2: **A Fully-monolithic SiGe Differential Voltage-controlled Oscillator for 5 GHz Wireless Applications**
H. Ainspan, M. Soyuer, A. Ruehli

MON3A-3: **A Fully Integrated SiGe Bipolar 2.4 GHz Bluetooth Voltage-controlled Oscillator**
B.U.H. Klepser, J. Kucera

MON3A-4: **A Low Phase Noise Monolithic VCO in SiGe BiCMOS**
J.M. Mourant, J. Imbornone, J. Tewksbury

MON3A-5: **A Fully Integrated 5.35-GHz CMOS VCO and a Prescaler**
C.M. Hung, B.A. Floyd, K.K. O

MON3B Integrated Receivers

Chair: S. Lloyd · Co-chair: K. Ashby

There is a continual push for highly integrated receivers. This is driven by the goals of lower overall system cost and reduced size. This session focuses on several novel receiver designs as well as demonstration of very high levels of integration for major wireless standards.

MON3B-1: ***(Invited)*** **A Highly Integrated Commercial GPS Receiver**
M. Mulbrook

MON3B-2: **Analog Baseband IC for Use in Direct Conversion W-CDMA Receivers**
M. Goldfarb, W. Palmer, T. Murphy, R. Clarke, B. Gilbert, K. Itoh, T. Katsura, R. Hayashi, H. Nagano

MON3B-3: **A Low-IF, Polyphase Receiver for GSM Using Log-domain Signal Processing**
B.J. Minnis, P.A. Moore, A.W. Payne, A.C. Caswell, M.E. Barnard

MON3B-4: **Low Cost 900 MHz Single-chip Cordless Telephone Receiver**
D. Lovelace, S. Bader, D. Coffing, J. Durec, R. Hester, K. Huehne, E. Main, P. Ovalle, R. Tang, D. We

MON3C RF Power Amplifiers — Watt's Up

Chair: M. Kumar · Co-chair: F. Ali

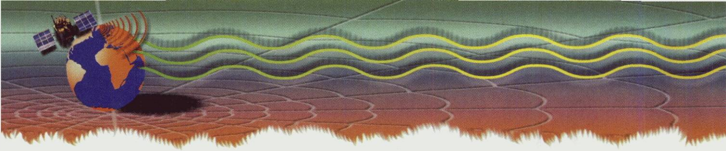
This session describes design techniques and performance improvements in RF power amplifiers for wireless communications applications. Power device technologies such as pHEMT, MESFET and HBT have been utilized to address various applications.

MON3C-1: **A 3.2 V, 45% Efficient, Novel Class AB+C CDMA MMIC Power Amplifier Using Quasi Enhancement Mode pHEMTs**
J. Cao, R. Singh, X.W. Wang, C.K. Queck, H. Nakamura

MON3C-2: **An Ultra Low Current Consumption Two Step Power Control Driver MMIC with Self Current Control for Wideband-CDMA Handsets**
M. Nakayama, K. Motoyoshi, T. Katazawa, K. Tara, M. Hagio

MON3C-3: ***(Student Paper)*** **A Single Supply Very High Power and Efficiency Integrated pHEMT Amplifier for GSM Applications**
F. Huin, C. Duvanaud, V. Serru, F.F. Robin, E. Leclerc

[Continued on page 248]



MON3C-4: **A 3.0–4.0 GHz Fully Matched High Linearity GaAs MMIC Power Amplifier for Wireless Communications**
E.Y. Chang, C.Y. Chang, A. Ezzeddin, H.C. Huang, T.L. Lee, J.W. Wu

MON3C-5: **Effect of Bias Scheme on Intermodulation Distortion and Its Use for the Design of PCS TX Driver**
J.S. Ko, H.S. Kim, B.K. Ko, B.H. Park

3:30 PM

MON4A Transmit ICs

Chair: J. Moniz · Co-chair: T. Tewksbury

The push for improved linearity, efficiency and lower cost for PA and transmit ICs is the focus of this session. The invited paper on PA linearity is followed by two Si (BTT & CMOS) PAs and two fully integrated transmit ICs in BiCMOS for cordless and CDMA, respectively.

MON4A-1: *(Invited)* **The Current Status of Microwave Amplifier Linearity and Intermodulation Improvement Techniques**
C.S. Aitchison

MON4A-2: **A Monolithic 2.8 V, 3.2 W Silicon Bipolar Power Amplifier with 54% PAE at 900 MHz**
A. Heinz, W. Simbuerger, H.D. Wohlmuth, P. Weger, W. Wilhelm

MON4A-3: **A 1.9 GHz Low Voltage CMOS Power Amplifier for Medium Power RF Applications**
A. Giry, J.M. Fournier, M. Pons

MON4A-4: **A Low Power 900 MHz Transmitter IC with Audio Baseband for ISM Applications Using 0.25 mm BiCMOS**
K. Huehne, S. Bader, D. Coffing, J. Durec, R. Hester, D. Lovelace, E. Main, P. Ovalle, R. Tang, D. W

MON4A-5: **A Base-band to RF BiCMOS Transmitter RFIC for Dual-band CDMA/AMPS Wireless Handsets**
K. Sahota, K. Gzrd, B. Walker, S. Szabo, W. Su

MON4B Receiver Front Ends

Chair: S. Heinen · Co-chair: K. Brenndoerfer

The session will show the progress in RX front-end design. As shown in the first paper silicon bipolar technologies can be used to integrate LNAs up to 10 GHz. New techniques for switching the LNA's gain while maintaining the performance will be presented.

The second part of the session will focus on image rejection mixers by first showing a design achieving 65 dB of image rejection. The second paper dealing with that topic reports on the first SiGe BiCMOS dual-band image reject mixer.

MON4B-1: **Monolithic LNAs up to 10 GHz in Production-near 65 GHz f_{max} Silicon Bipolar Technology**
D. Zöschg, W. Wilhelm, J. Bock, H. Knapp, M. Wenzer

MON4B-2: **A New Design Approach for Variable-gain Low Noise Amplifiers**
S. Pennisi, S. Scaccianoce, G. Palmisano

MON4B-3: **A Completely Integrated 1.9 GHz Receiver Front-end with Monolithic Image Reject Filter and VCO**
J.W.M. Rogers, C. Plett, J.A. Macedo

MON4B-4: **Fully Differential Dual-band Image Reject Receiver in SiGe BiCMOS**
J.F. Imbornone, J.M. Mourant, J.L. Tewksbury

MON4B-5: *(Student Paper)* **The Performance Limiting Factors as RF MOSFETs Scaling Down**
Y.H. Wu, A. Chin, C.S. Lang, C.C. Wu

MON4C Broadband Amplifiers and VCOs

Chair: V. Nair · Co-chair: M. Kumar

This session describes high frequency performance of broadband amplifiers and VCOs. High data rate fiber optic applications using broadband ICs are presented.

MON4C-1: *(Student Paper)* **Ultra Low Power GaAs MMIC Low Noise Amplifier for Smart Antenna Combining at 5.2 GHz**
F. Ellinger, U. Lott, W. Baechtold

MON4C-2: **0.4–8 GHz Broadband MMICs in Novel RF Chip Size Package for Optical Video Distribution System**
K. Fujimoto, K. Kawashima, M. Nishitsuji, K. Nobori, H. Nagqata

MON4C-3: **A Capacitively Coupled HBT Distributed Amplifier for 10 Gb/s Optical Modulator Driver Applications**
K.W. Kobayashi, M. Lammert, A. Gutierrez-Aitken, E. Kaneshiro, P.C. Grossman

MON4C-4: **A Low Noise 2–20 GHz Feedback MMIC Amplifier**
H. Zirath, P. Sakalas, J.M. Miranda

MON4C-5: **A Family of Monolithic Inductor-varactor SiGe-HBT VCOs for 20 GHz to 30 GHz LMDS and Fiber-optic Receiver Applications**
S.P. Voinigescu, D. Marchesan, M.C. Copeland

MON4D Microwave and Millimeter-wave Control Circuits

Chair: T. Tokumitsu · Co-chair: R. Kagiwada

This session presents state-of-the-art results for various systems applications. These include: HBT vector modulator for millimeter-wave wireless applications, MMIC vector modulation for Ka-band satellite communication, InO DHBT linear amplifier for communication systems, Si and GaAs chip set for millimeter-wave automotive radars and Ka-band RF MEMs phase shifters for phased array applications.

MON4D-1: **An 18–21 GHz InP DHBT Linear Microwave Doherty Amplifier**
K.W. Kobayashi, L. Yang, A. Gutierrez-Aitken, E. Kaneshiro, P.C. Grossman

MON4D-2: **A Subharmonically Pumped I/Q Vector Modulator MMIC for Ka-band Satellite Communication**
W. Philibert, R. Verbiest

MON4D-3: **Monolithic GaAs/InGaP HBT Balanced Vector Modulators for Millimeter-wave Wireless Systems**
A.E. Ashtiani, A. Vilches, T. Gokdemir, Z. Hu, I.D. Robertson, S.P. Marsh

MON4D-4: **A Mixed Si and GaAs Chip Set for Millimeter-wave Automotive Radar Front Ends**
H.J. Siweris, A. Werthof, H. Tischer, T. Grave, H. Werthmann, R.H. Rasshofer, W. Kellner

MON4D-5: **Ka-band RF MEMS Phase Shifters for Phased Array Applications**
B. Pillans, S. Eshelman, A. Malczewski, J. Ehmke, C. Goldsmith

TUESDAY, June 13, 2000

TUE2A Low Noise Technology
Joint IMS-RFIC Session

Refer to IMS Session TU2A.

TUE3A Wireless Circuit Techniques
Joint IMS-RFIC Session

Refer to IMS Session TU3A.

TUE4A Integrated Transceivers
Joint IMS-RFIC Session

Refer to IMS Session TU4A.

ARFTG Technical Program: Going Beyond S-Parameters

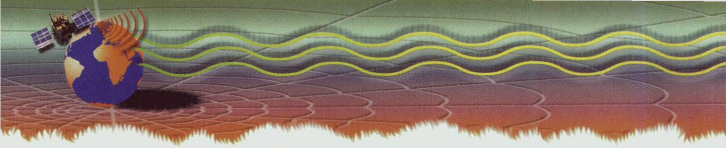
FRIDAY, June 16, 2000

8:30 AM **Why are Non-linear Microwave Systems Measurements so Involved?**
Y. Rolain, W. Van Moer, G. Vandersteen, J. Schoukens

8:50 AM **Extraction of Transistor Large Signal Models from Vector Non-linear Network Analysers**
M.C. Curras-Francos, P.J. Tasker, M. Fernandez-Barciela, Y. Campos-Roca, E. Sanchez

9:10 AM **Waveform Measurements – The Load-pull Aspect**
F. Van Raay, G. Kompa

[Continued on page 250]



9:30 AM **A Novel Experimental Noise Power Ratio Characterization Method for Multi-carrier Microwave Power Amplifiers**
T. Reveyrand, D. Barataud, J. Lajoinie, M. Campovecchio, J.M. Nebus, E. Ngoya, J. Sombrin, D. Rogues

9:50 AM **Measurement Driven Models of Non-linear Electronic Components**
N. Tuffilaro, D. Usikov, L. Barford

10:10 AM **Introduction of Six Interactive Forum Contributions**

10:50 AM **Estimating the Magnitude and Phase Response of a 50 GHz Sampling Oscilloscope Using the "Nose-to-Nose" Method**
P.D. Hale, T.S. Clement, K.J. Coakley, C.M. Wang, D.C. DeGroot, A.P. Verdoni

11:10 AM **Ka-band Quasi-optical Measurements Using Focused Gaussian Beams**
B. Deckman, J.J. Rosenberg, D. Rutledge

11:30 AM **Broadband Determination of Two-port Transmission of pHEMTs Embedded in Transmission Lines**
J.A. Reynoso-Hernandez, C.F. Estrada-Maldonado

11:50 AM **Accuracy Evaluation of On-wafer Load-pull Measurements**
A. Ferrero, V. Teppati

12:10 PM **Verification of Non-linear MOSFET Models by Intermodulation Measurements under Loadpull Conditions**
D. Schreurs, E. Vandamme, S. Vandenberghe, G. Carchon, B. Nauwelaers, K.U. Leuven

2:00 PM **Methodology for Large Signal Behavioral Modeling of Non Linear RF Circuit Easily Affordable for Industrials**
F. Graux, F. Dhondt, C. Tolant, P. Eudeline, B. Bonte, Y. Crosnier

2:20 PM **Automated Macromodelling of Time-varying Systems with RF Applications**
J. Roychowdhury

2:40 PM **A Systematic Simulation of Large Signal on Chip Amplifier Modules Excited by WCDMA Signals**
R. Mahmoudi, J.L. Tauritz

3:00 PM **Bit-error-rate Estimation for OFDM Based Telecommunication Systems Schemes in the Presence of Non-linear Distortions**
G. Vandersteen, Y. Rolain, W. Van Moer, J. Verbeeck, J. Schoukens

3:20 PM **Introduction of Six Interactive Forum Contributions**

4:00 PM **A New Six-port Based Time Domain Load-pull Measurement Technique**
P. Poire, F.M. Ghannouchi, G. Brassard,

4:20 PM **Accuracy of Extremely High SWR Prematching Tuners**
D. Dubouil, C. Tsironis

4:40 PM **Non-linear Noise Measurement on a High Power Amplifier**
M.S. Muha, A.A. Moulthrop, C.P. Silva

5:00 PM **Multi-port Noise Characterization and Differential Amplifiers**
J. Randa

MICROWAVE APPLICATION & PRODUCT SEMINARS (μAPS) TECHNICAL PROGRAM

TUESDAY, JUNE 13, 2000

EM SIMULATION
10:10–11:50 AM

A Tutorial on Using the Free Sonnet Lite 3-D Planar Electromagnetic Analysis Software, *James Rautio*; IE3D Planar and 3D Electromagnetic Simulation and Optimization Package, *Jian-X Zheng*; FIDELITY Time-Domain Full 3D Electromagnetic Simulator,*Jian-X Zheng*; PiCASSO: Printed Circuit Antenna System Simulator and Optimizer, *Kazem Sabet*; Advanced 3D Simulation of Passive Structures with FDTD, *Andreas Wien*; (EM Design SW), *Malgorzata Celuch*

NONLINEAR, CIRCUIT AND SYSTEM SIMULATION AND MEASURAEMENTS
1:10–5:00 PM

Coplanar Circuit Design with COPLAN for ADS, *Mohsen Naghed*; (CST Microwave Studio), *Peter Thoma*; MDSPICE Mixed Frequency and Time-domain SPICE Simulator, Jian-X Zheng; Topas: Advanced Nonlinear Modeling Software for FETs and BJTs, *R. Follmann*; Narrowband Ultra-low VSWR Coaxial Cable, *Bruce Bullard*; Using Circuit-level Simulation of RF Components in Combination with System Simulation in APLAC, *Arvi Karhumäki*; Applying Neural Networks to RF and Microwave System Modeling, *Vladimir Veremey*; Neuro Network-based Microwave Modeling and Design, *Q.J. Zhang*; Device Characterization with the Automated Tuner System, *Gary Simpson*; Calibration Kits and Components for the Wireles Century, *Bela Szendrenyi*; Minimum Loss Transistor Test Fixture for Sub 1 W Load Pull Testing, *Christos Tsironis*

WEDNESDAY, JUNE 14, 2000

MILLIMETER WAVES AND FERRITES
9:30–11:50 AM

A Family of User-friendly Self-biased Millimetre-wave LNAs, *Pierre Quentin*; Passive Components: Microstrip Isolators and Circulators, *James Kingston*; The "Alpha Two" Millimeter-wave Package, *John Kennedy*; Surface-mount Connectors for Applications up to Millimeter Waves, *Bernhard Rosenberger*; 4 mm Square Isolator for 2 GHz Band, *Hideto Mikami*; Coaxial Cable Assembly with a Discontinuous Outer Jacket, *Vahid Badii*; Hairpin Filter Design Using Ansoft Design Tools, *Luigi Greco*

FILTERS, LTCC AND PAs
1:00–5:00 PM

High Volume Filter and Diplexer Production by Investment Casting, *Chris Shaw*; Advanced Technology for Passive Microwave Components, *A.M.K. Saad*; New Multi-planar Ceramic Band Pass Filter for 2.4 GHz Applications, *Clive Hendricks*; Maximizing RF Performance by Integrating Multiple Dielectric Constants and Embedding Passive Components in Ceramic Modules, *Paul Danner*; CAD Techniques Applied to LTCC Technology, *Randall Rhea*; Green Tape/LTCC Materials Systems for Wireless/RF Applications, *Daniel Amey*; Power Amplifiers on LTCC, *D. Koether*; Linearizers for LMDS and Millimeter-wave Applications, *James Dragone*; A High Power X-band GaInP/GaAs HBT MMIC Process, *Hervé Blanck*; High Power VSWR Detector Using a Passive Power Sensor, *Joseph Mazzochette*; History of Broadband Power Amplification, *S.K. Leong*

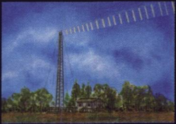
THURSDAY, JUNE 15, 2000

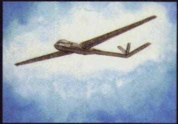
FAB, AMPLIFIERS, MIXERS AND OSCILLATORS
9:30–11:50 AM

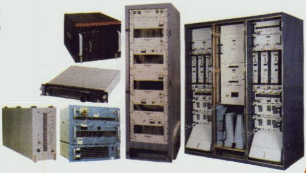
Micro-contamination Control in VLSI Processing, *Izzy Bansal*; Direct Wafer Bonding of Silicon Wafers, *Izzy Bansal*; Laser Structuring of Fine Lines, *Dieter Meier*; An Octave Bandwidth, 60 dB Dynamic Range, Microwave Successive Detection Logarithmic Video Amplifier, *Douglas Bajgot*; Cost Improvements through Insertion of Surface-mount Technology in a Logarithmic Power Detector Redesign, *Douglas Bajgot*; First-Pass Design of a Low-cost GaAs MMIC Amplifier, *Douglas Bajgot*; 8 GHz Image Reject Subharmonic Mixer, *Tony Donisi*; Ultra-broadband Single Balance Subharmonic Mixer, *Tony Donisi*; Next Generation of Near Atomic Clock Quartz Oscillators, *Manish Vaish*; A High Reliability Surface Mount Oscillator for Advanced Telecom Applications, *Byran Milliren*; Sapphire Resonator Oscillators with Ultra Low Phase Noise, *J.H. Searls*

SYSTEMS AND SUBSYSTEMS
1:00–2:20 PM

Wideband Photonic Links, *David Krautheimer*; A High Resolution Radar for Short Range Automotive Applications, *Dirk Steinbuch*; A Telemetry Transmitter Chip Set for Ballistic Applications, *John Lachapelle*; Commercial mm-wave Chip Sets Comprising LNA, Driver, MPA and HPA Developed on a Single pHEMT Process, *G.D. Edwards*







NEWS FROM WASHINGTON

F/A-18 Radar Production Contracts Awarded

Raytheon Co. has received two contract awards for the production of the AN/APG-73 radar for installation in US Navy, US Marine Corps and Royal Australian Air Force (RAAF) F/A-18 aircraft. An award from the Boeing Co. totals approximagely $467.2 M and will support F/A-18 E/F Super Hornet aircraft production in FY 2000 through 2004. The second award, from the US Navy's Naval Air Systems Command, has a total value of approximately $200.2 M and covers the production of radar and retrofit kits to upgrade existing US Navy, US Marine Corps and RAAF F/A-18 aircraft.

The APG-73 radar is the newest all-weather, multimode search-and-track sensor for the F/A-18. The system is an upgrade of the combat-proven APG-65 system and handles both air-to-air and air-to-surface missions while providing higher throughputs, greater memory capacity, improved reliability and easier maintenance with no increase in size or weight compared to its predecessor. The APG-73 also produces high resolution radar ground maps and performs precision strike missions with improved weapon designation accuracy.

Approximately 222 systems will be built for Boeing over a five-year period starting with an FY 2000 purchase totaling $72.9 M. Seventy-one complete radars will be built for the RAAF to replace APG-65 systems onboard F/A-18 A/B aircraft and 40 APG-73 radar retrofit kits consisting of complete radars less the antenna and transmitter will be built to upgrade older US Navy and US Marine Corps F/A-18 aircraft systems. Work on the contracts will be performed at Raytheon's facilities in El Segundo, CA; Forest, MS; and Andover, MA.

Air Navigation Augmentation Service Company to be Organized

Lockheed Martin has announced its intent to form Synchronetics,™ a new company that will provide worldwide navigation services in support of air traffic management modernization. The announcement follows earlier information that Lockheed Martin had applied to the Federal Communications Commission (FCC) for authority to launch and operate the Regional Positioning System, (RPS), a global system of geostationary satellites. Using that system, Synchronetics will offer a full range of navigation services that provide assured broadcast of Global Positioning System (GPS) augmentation integrity and accurate data messages generated from existing and future ground networks. Local and wide area GPS augmentation will be offered to civil aviation authorities worldwide, including the FAA.

Synchronetics is intended to provide the structure for international partners to participate in the ownership and development of regional business. Lockheed Martin believes that international participation is a key ingredient in the development of a seamless, global air traffic navigation service. It has also noted the requirement for commitment of anchor tenants to the program before financial investments are made. In addition, formation of three regional subsidiaries in the Americas, Asia-Pacific and Europe-Middle East-Africa to provide the global coverage has been contemplated. Each subsidiary will secure its own financing and regional partners to develop its portion of the system. In all regions, the service will be compatible with other satellite-based navigation systems being implemented globally, including the US Wide Area Augmentation System (WAAS) and Local Area Augmentation System (LAAS), the Japanese Multifunction Transportation System Augmentation System and the European Geostationary Navigation Overlay System. In regions currently without augmentation system ground networks, Synchronetics and its partners will assist in providing the necessary infrastructure for an integrated system solution.

Synchronetics service will comply with FAA and ICAO requirements for the safe, dependable use of satellite-based navigation. LAASs are scheduled for service beginning in 2001. Pending regulatory approval and commitment from anchor tenants, wide area augmentation with RPS broadcast services will be made available in 2003.

WAAS Demonstrated Successfully

As reported in *Government Computing News*, recent use of the WAAS in a series of demonstration flights along the East Coast successfully indicated the Raytheon-developed navigation system's capability to augment GPS data to help pilots keep their aircraft on track. WAAS is an important component in the FAA's modernization plans because it eventually will let pilots choose more direct routes and make landings safer. The FAA requirement that the system keep the aircraft on course within a 7.6 meter margin of error was more than satisfied. During the test, the plane remained within three to four meters of the plotted course. Even though the approach was complicated by turbulence, the system appeared able to keep the aircraft on the proper path. The only troubling FAA requirement remaining prior to certification of the WAAS is the demand that the navigation system provide no more than one second of errant GPS data during a 47.5-year period, a statistic that is obviously difficult to prove. Earlier this year, the FAA asked Raytheon to refine WAAS' algorithms to ensure system dependability and meet the agency's safety requirements. The FAA is now deciding whether to deploy an early version of WAAS or wait until Raytheon resolves the certification issues and implement the final version.

NEWS FROM WASHINGTON

10-Year Worldwide Fighter/Attack Aircraft Production Forecast

In its latest forecast, The Teal Group estimates that 2932 combat aircraft with a total value of $136.1 B (in 2000 US dollars) will be built worldwide during the 2000–2009 period. The forecast covers all combat aircraft over 20,000 pounds maximum take-off weight, including all supersonic planes as well as the AMX and Harrier. Russian aircraft are included, but Chinese planes are not. The report cites the decline in production following the end of the Cold War as a reason for the the industry's struggle to regain growth. By comparison, the 1990–1999 period witnessed a total production of 4445 fighters with an aggregate value of $152.5 B (also in 2000 US dollars). In addition, the report expects that Boeing's share of the market during the next 10 years will decline from 40 percent in 1999 to 16 percent in 2009 as its programs related to McDonnell's legacies are completed. However, if South Korea selects the F-15 for its F-X program, Boeing's future market position could be significantly improved. The Eurofighter is expected to carry the highest program value during the next 10 years with cumulative estimated deliveries worth just over $30 B. If this program proceeds as forecast it is also expected to double the European share of the total market from 20 percent in 1999 to 40 percent in 2009. Beyond 2009, the report expects that the market will be dominated by the Joint Strike Fighter. If that program proceeds as planned, the US is expected to regain its leadership position in the market by 2015. For additional information, contact Richard Aboulafia, The Teal Group Corp. (703) 385-1992, ext. 103.

TRW Delivers Next-generation Tactical Reconnaissance Systems

TRW Inc., Sunnyvale, CA, has delivered the Guardrail 2000, the latest equipment in the US Army's airborne tactical reconnaissance arsenal. The Guardrail Common Sensor System 2 (Guardrail 2000) will be a key component of the Army's next-generation Aerial Common Sensor system that is expected to provide battlefield commanders with advanced tactical surveillance data. The system comprises a twin-engine Beechcraft airplane and a ground station that remotely controls the flow of intelligence data. Earlier versions of the system were used during Desert Storm and to support the Bosnia peacekeeping effort. ■

INTERNATIONAL REPORT

Martin Streetly, International Correspondent

Thomson-CSF Wins BIFF Contract

French contractor Thomson-CSF Comsys has been awarded a Euro 38 million contract covering the production of 1500 Battlefield Identification Friend-or-Foe (BIFF) systems for France's armed forces. As currently structured, the French BIFF effort anticipates acquisition of 5400 units in three production lots. The equipment being supplied is compliant with a BIFF standard that has been jointly established by France, Germany, the UK and the US and operates in the 33 to 40 GHz frequency band. The Thomson-CSF BIFF is a question-and-answer system designed for installation on battlefield vehicles with weapon firing capability. It interrogates detected targets as to their identity (categorising them as friendly or unknown) while at the same time allowing potential targets to inform shooters that they are friendly. Thomson-CSF notes that the equipment it is supplying will be interoperable with the identification systems being fielded by the armies of the US, Britain and Germany. This capability has been achieved via the use of the 33 to 40 GHz range as a common operating band and the development of a common Franco-American waveform. Thomson further notes that its BIFF makes use of a modular design that allows it to be configured as a combined interrogator-transponder, fixed transponder or portable strap-on transponder that can be transferred between vehicles on an as and when needed basis. The first French BIFF systems are scheduled for delivery in 2002.

Matra Marconi Delivers HIRDLS

Franco-British space contractor Matra Marconi Space (MMS) has supplied the Rutherford Appleton Laboratory (RAL) with the main flight structure and mechanisms for the High Resolution Dynamic Limb Sounder (HIRDLS) earth observation instrument. To be flown on the US National Aeronautics and Space Administration's (NASA) Earth Observing System Chemistry satellite during 2002, the HIRDLS is intended to scan a designated section of the earth's atmosphere for specified chemical compounds (including ozone) once every orbit. The sensor will be flown at an altitude of 705 km from where it will sample the earth's atmosphere within the eight to 120 km height band. Designed for an operational life of six years, HIRDLS's primary task will be to assess whether or not worldwide pollution controls are effective and contributing to a slowing down of global warming and/or annual ozone loss. HIRDLS has been funded by NASA and the UK's Natural Environment Research Council and has involved development work by MMS, the RAL, and Reading and Oxford Universities. For its part, MMS has delivered both an HIRDLS engineering model for launch environment testing and the already noted flight structure and mechanisms that are now to be mated with a range of UK- and US-sourced electronics and optics.

We Are Not Amused!

In a lighter than normal vein, *Microwave Journal*'s "International Report" understands that Her Majesty, Queen Elizabeth II has objected to the erection of a 20 m mobile telephone transmission mast disguised as a tree near Windsor Castle, Berkshire, England. In a letter of objection to the local planning authority, a royal aide is reported to have described the proposed "fir tree" mast that service provider Vodaphone would like to "plant" near the Long Walk in Windsor Great Park as "ridiculous." "International Report" will of course bring you further developments in this saga as they occur.

NATAR Woos Turkey

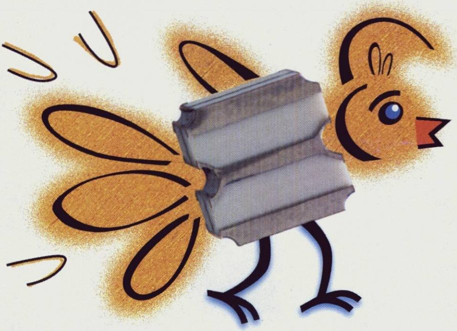
Representatives of the five-nation Brussels, Belgium-based NATO Advanced Technology Radar (NATAR) consortium have met with representatives of Turkish industry to discuss the possibility of Turkey's participation in the programme. Officially designated a NATO project earlier this year, NATAR (comprising representatives from Belgium, Canada, Denmark, Norway and the US) has been tasked with presenting a proposal for a six-aircraft, NATO-owned-and-operated radar ground surveillance capability that would function as both a crisis management and peace-keeping support tool. Likely to be structured along the lines of the Alliance's existing multinational Airborne Early Warning Force, a NATO airborne radar ground surveillance capability is considered an urgent requirement. NATAR's project definition phase is expected to take two years, with the first operational system delivered during 2008. The competitiion is expected to be fierce with contenders likely to include a variant of the UK's Airborne Stand-Off Radar (ASTOR) system, NATAR's Airbus A320-mounted Northrop Grumman AN/APY-XX radar and an outgrowth of the Franco-German, Dutch and Italian SOSTAR radar technology demonstrator. The APY-XX radar is an active array upgrade that Northrop Grumman is developing for the US Air Force's E-8 Joint Surveillance Target Attack Radar System (Joint STARS) aircraft under the Joint STARS Radar Technology Insertion Programme.

Racal Launches World's Smallest TETRA Radio

UK contractor Racal Defence Electronics claims to have created the world's smallest secure Trans European Trunked Radio (TETRA) standard surveillance radio. The new 380 to 430 MHz band Vector radio is designed specifically for use by police, customs, military and governmental agencies, and offers standard and end-to-end encrypted TETRA direct and trunked-mode operation as well as a software-programmable digital architecture that is configured for future enhancements. System operation is initiated via a covert palm-sized radio control unit or an overt, clip-on intelligent microphone/loudspeaker unit. System encryption is by means of a removable encryption module and facilities are available for over-the-air encryption key filling and/or remote operation of features such as stun and live microphone. The stun function is intended to kill the radio should it fall into the wrong hands while the live microphone mode allows a remote operator to activate it. The ruggedised Vector package is sealed against water ingress and includes a vehicle adapter, a secure peripherals interface, linear modulation technology and a FLASH-loaded, digital signal processing architecture that supports UK-enhanced grade encryption.

Roke Manor Makes First UMTS Call over a TD-CDMA (TDD) Interface

Roke Manor Research Ltd. claims to have made the world's first Universal Mobile Telecommunications System (UMTS) standard telephone call over a time division CDMA (TD-CDMA) air interface. Forming part of an experimental time division duplex (TDD) network, the significance of this event is its demonstration of the validity of the air interface provision that is incorporated in Europe's third-generation mobile communications UMTS standard and the International Mobile Telecommunications 2000 (IMT-2000) standard's Universal Terrestrial Radio Access (UTRA) specification. Both UMTS and UTRA include provisions for the interconnection of mobile handsets and base stations using TD-CDMA and frequency division duplex wideband CDMA interface modes. Such an approach offers the possibility of constructing highly flexible networks capable of providing enhanced voice and data services in high subscriber, high usage density hot spots, together with movement towards an ultimate goal of seamless global radio coverage. The first examples of UMTS technology are scheduled to enter commercial service in 2001. ■



Hong Kong Telecommunications Market Opens Up

The Hong Kong government has opened up its telecommunications market by granting fixed network licenses to five companies and the right to operate international satellite services to 12 other applicants. PSINet HK Ltd., HKNet-Teligent Company Ltd., HK Broadband Network Ltd., Eastar Technology Ltd. and SmarTone Telecommunications Holdings Ltd. will operate wireless networks and deliver telecommunictions services to homes and businesses. The five companies are expected to invest 2.8 billion Hong Kong dollars (US$358 M) over the next three years. Companies with international communications licenses include the Hong Kong-based subsidiary of Teleglobe, the only North American data and voice carrier licensed for that service. The 12 licensees for international services have pledged to invest a total of 770 million Hong Kong dollars (US$98.7 M) during the next three years. They will also be the first competition in the area for Cable and Wireless HKT Ltd., the previous holder of the monopoly for international telecommunications services in Hong Kong.

Cellular Telephone RF Semiconductor Market to Approach $8 B in 2004

A recent report from Strategies Unlimited, "RF Semiconductors for Cellular/PCS Handsets, Market Review and Forecast 2000," forecasts that the worldwide market for RF semiconductor devices in cellular telephones will grow from $3.9 B in 1999 to $7.7 B in 2004. The report bases the prediction on its examination of the semiconductor technology and trends behind the evolution toward third-generation (3G) cellular chipsets as well as its projections of the worldwide demand for handsets through 2004.

A strong global demand for mobile communications is expected to lead to a subscriber base of 1.3 billion by 2004, and annual handset demand is projected to grow from 240 million in 1999 to 600 million in 2004. New services such as instant messaging, wireless data and Internet access are also expected to contribute to strong growth over the next five years. GSM handsets are the largest market for RF semiconductors and accounted for $2 B of device shipments in 1999. CDMA, IS-136 TDMA, PDC and analog chipsets together accounted for the balance of $1.9 B in 1999. According to the report, silicon bipolar technology devices account for the majority of RF chips in the handset market. Gallium arsenide (GaAs) chips composed 33 percent of the 1999 market and heterojunction bipolar transistor chip sales showed strong growth during the same year. Increased integration of RF and IF circuits during the next five years is expected to significantly reduce the number of chips per handset, and CMOS, BiCMOS and silicon germanium will play major roles in that transition. GaAs ICs are forecast to continue their lead in power amplifier and switch sockets. Beginning in 2000, Bluetooth data links and GPS receivers for location-based services are expected to create a chip market that will reach $500 M in 2004. For additional information, contact Strategies Unlimited (650) 941-3438, fax (650) 941-5120 or e-mail: info@strategies-u.com.

Partnership to Concentrate on Wireless Communications Interfaces

Tokyo-based Taiyo Yuden Co. Ltd. and SyberSay Communications Corp. of Sunnyvale, CA have announced a strategic partnership to capitalize on the commercial development of next-generation wireless communications interfaces that will allow users to perform comfortable, hands-free operation of cell phones, PDAs, PCs and other products using proprietary voice-recognition software. The first product of the partnership, a miniature wireless transceiver using Bluetooth short-range radio transmission technology, will be marketed this year under the SkyPod™ brand name. The arrangement includes joint marketing and distribution channels for SyberSay products in Japan, and Taiyo Yuden will allocate resources for the design and development of miniaturized high performance electronic hardware modules incorporating Bluetooth technology for SyberSay's new line of wireless personal interfaces.

SyberPod will initially consist of a small combination earpiece/microphone that can transmit and receive voice instructions from a pager-sized belt-clip control unit for hands-free operation of any compatible voice-enabled device within 40 feet. A second-generation SyberPod, due in 2001, will eliminate the belt-clip base unit by incorporating a miniaturized control unit in the earpiece itself.

Hughes ICO Global Communications Satellites Employ Active Phased-array Antennas

A series of modified Hughes Space and Communications Co. HS 601 spacecraft incorporating active phased-array antennas will form the 12-satellite medium earth orbit ICO Global Communications constellation. The spacecraft are approximately 25 percent taller than earlier HS 601s to accommodate innovative transmit and receive antennas. The multiple beams from the multiple S-band arrays in space will provide full earth coverage. The active arrays, controlled by digital beamforming processors, match beam configurations to fluctuating usage patterns and make the most efficient use of available bandwidth. Each of the processors has the computing power of more than 600 Pentium III-based computers. In addition to accommodating the antenna array, the modified spacecraft have extended thermal heat radiators to handle the high power electronics and two dual-junction GaAs solar cell wings that provide nearly 9 kW of end-of-life power. The satellites have an expected life span of 12 years.

Fiber-optic Isolator Market to Exceed $850 M in 2009

A recent report from ElectroniCast Corp., "Fiber-optic Isolator Global Market Forecast," predicts a growth in the worldwide demand for fiber-optic isolators from $274.5 M in 1999 to $869.5 M in 2009. North America, which accounted for 45 percent of consumption in 1999, is expected to see its share rise to 53 percent by 2009. Telecommunications applications are forecast to account for a rather constant share of the worldwide total during the 10-year period with their 60 percent in 1999 dropping slightly to 58 percent in 2009. The Specialty application share is forecast to increase to 16 percent in 2009 from its 12 percent 1999 share. Other Market Segments, Military/Aerospace, Cable TV and Premises Data Networks are expected to account for approximately the same portion of the overall market in 2009 as they do currently. For additional information, contact ElectroniCast (650) 343-1398, fax (650) 343-1698 or e-mail: electronicast@msn.com.

Radar-based Adaptive Automotive Cruise Control Demonstrated

TRW recently demonstrated an adaptive automotive cruise control system employing a 77 GHz forward-looking radar. The radar is the product of Autocruise, a TRW and Thomson-CSF joint venture formed to develop, manufacture and sell the system for adaptive cruise control systems. Production is expected to begin later this year. The new radar may be located behind the front grille or bumper and has a forward-looking range of up to 150 meters. The system operates at speeds from 30 to 180 kph and uses the standard cruise control switches and an enhanced display to show the vehicle ahead. The system will maintain an appropriate headway between vehicles; maximum brake force, when needed, is 30 percent and, when the road ahead is clear, the vehicle is accelerated to the original set speed. ■

AROUND THE CIRCUIT

INDUSTRY NEWS

■ Advanced technology product and service provider **TRW Inc.** and first-mile broadband engine supplier for e-business gateways **Endgate Corp.** have signed a definitive agreement to merge Endgate and **TRW Milliwave Inc.**, a wholly owned TRW subsidiary, to create **Endwave Corp**. The new company will supply broadband access equipment, including specialized antennas, transceivers and outdoor units. The transaction includes a supply agreement ensuring Endwave's access to TRW's advanced GaAs MMIC foundry, and the closing of the merger is subject to regulatory approval. Endwave will be owned approximately 50 percent by TRW and 50 percent by Endgate's current shareholders. Both TRW and current Endgate shareholders will contribute cash to Endwave to support the new company's growth. Endwave will be located in Sunnyvale, CA and maintain design and manufacturing facilities in Sunnyvale, Santa Clara and Diamond Springs, CA.

■ The assets of the legacy business of **Millitech Corp.** have been purchased by **MMW Acquisition LLC** from **Telaxis Communications Corp.** Businesses being transferred include the millimeter-wave components and assemblies and the SATCOM divisions. The new company, **Millitech LLC**, will retain all of the former employees of both businesses and is currently adding resources to revitalize its engineering bench strength and improve customer service.

■ **ADC**, a supplier of network equipment, software and integration services for broadband, multiservice networks located in Minneapolis, MN, will acquire Tustin, CA-based **PairGain Technologies Inc.**, a designer of digital subscriber line networking systems. Under the terms of the agreement, each share of PairGain Technologies' common stock will be converted into 0.43 share of ADC common stock with a fixed exchange ratio. Based on the closing share price of $46.81 for ADC's stock on February 22, the transaction is valued at approximately $1.6 B. The proposed transaction is expected to be completed during ADC's third fiscal quarter, which ends on July 31, and is intended to be accounted for as a pooling of interests and treated as a tax-free reorganization for US federal income tax purposes. Closing of the proposed transaction is subject to the approval of PairGain Technologies' stockholders, receipt of required regulatory approvals and other customary conditions.

■ Highly integrated microwave component, assembly and subsystem developer **Anaren Microwave Inc.**, Syracuse, NY, has acquired all of the outstanding capital stock of **RF Power Components Inc.**, a privately held manufacturer of coaxial and surface-mount RF power resistors and attenuators based in Long Island, NY. According to Anaren, the acquisition strengthens and expands its microwave power product line, enabling the company to better serve its wireless original equipment manufacturer (OEM) customers.

■ Privately held defense electronics firm **Condor Systems Inc.**, San Jose, CA, has completed the acquisition of the business and certain assets of **Andrew SciComm Inc.**, a worldwide supplier of electronic products and systems for signal intelligence and electronic warfare applications located in Garland, TX, from its parent company, **Andrew Corp.** The purchase includes the sale of the trade name SciComm. Terms of the transaction were not disclosed.

■ Electrical test product and service manufacturer **Everett Charles Technologies (ECT)**, a subsidiary of **Dover Corp.** located in Pomona, CA, has acquired **PrimeYield Systems Inc.**, a manufacturer of test contactors and the North American distributor of **Micronics Japan Co.** probe cards for semiconductor testing. Under the terms of the transaction, PrimeYield Systems will become a part of ECT's semiconductor test group. According to ECT, the PrimeYield acquisition represents one of a series of steps the company plans to make in the semiconductor test business. Financial details of the transaction were not disclosed.

■ **M/A-COM Inc.**, Lowell, MA, has completed the acquisition of **ITT GaAsTEK**, the GaAsTEK business unit of **ITT Industries Inc.** The GaAsTEK unit, a provider of GaAs MMIC processes located in Roanoke, VA, will operate as a part of M/A-COM. The acquisition will enhance M/A-COM's capabilities in several areas, including providing the capacity of a third GaAs fabrication facility to the company and strengthening its product capabilities and market position in both the wireless and aerospace and defense markets. In related news, M/A-COM has introduced a GaAs-based enhancement/depletion (E/D)-mode semiconductor IC process that has been installed at both its Colorado Springs, CO fabrication facility and the newly acquired Roanoke, VA operation. M/A-COM developed the E/D process to meet the stringent linearity and single-supply voltage requirements of second-generation (2G) and third-generation (3G) wireless handsets, infrastructure and wireless local area network products.

■ Satellite wireless communications product designer **Norsat International Inc. (NII)**, Burnaby, British Columbia, Canada, has signed an agreement to acquire (subject to regulatory approval) privately held **SpectraWorks Inc.**, a developer of systems and software for broadcasting multimedia broadband content across satellite, terrestrial wireless and digital cable networks. According to NII, the acquisition significantly broadens the range of solutions the company can provide for multimedia Internet and private Internet-based data networks. The acquisition will allow NII to add uplink broadcast transport products to its terminal access products, which include Ka-band outdoor units being developed for the new ASTRA-NET and KoreaSAT satellite broadband multimedia networks.

[Continued on page 266]

■ Plated copper thick-film metallized ceramic substrate, chip carrier and package producer **Remtec Inc.**, Norwood, MA, has acquired **Tecmark Plating Services** and equipped the 13,000-square-foot facility with state-of-the-art electrolytic and autocatalytic plating lines. The expanded facility is also supported by an on-site analytic laboratory and x-ray system for advanced quality control and research and development activity. Designed specifically for plating ceramic boards and crystals, the enhanced facility now offers improved product cycle times and a production capability of 50,000 metallized ceramic panels per month.

■ **Signal Technology Corp.**, Danvers, MA, and **LogiMetrics Inc.**, Bohemia, NY, have entered into a nonbinding letter of intent pursuant to which Signal Technology will acquire LogiMetrics through the merger of a wholly owned Signal Technology subsidiary. In connection with the proposed merger, Signal Technology intends to contribute the assets of LogiMetrics' **mmTech Inc.** subsidiary to its recently formed **Signal Wireless Group (SWG)**. Under the terms of the merger, holders of LogiMetrics common stock will receive a certain percentage of a tracking security that will reflect the performance of SWG, which will be distributed upon completion of a public offering of SWG equity and Signal Technology common stock. In addition, upon execution of the letter of intent, Signal Technology has assumed the management and operation of the New York business through its **Keltec** division and has assumed all current liabilities of the business.

■ **Ericsson Components AB**, a supplier of microelectronic components for wireless applications, broadband communications, fixed access and communication via fiber optics, has changed its name to **Ericsson Microelectronics AB**. In related news, the company has announced that the worldwide operations for its DC/DC power modules have become an integral part of Ericsson Microelectronics.

■ **Micro Communications Executive Search (Micro Comm)** is celebrating 20 years in business by expanding its operation into a 10,000-square-foot facility located at 35 New England Business and Research Center, Andover, MA. In addition, the copany intends to introduce a new company, **MicroRF Wireless.com**, which will offer cutting-edge consulting services to the microwave/RF wireless communication industry.

■ Subminiature RF connector manufacturer **Connector Concepts Inc.** has opened a new administrative and sales office located at 2301 NW 33rd Court, Unit 104, Pompano Beach, FL 33069 (800) 801-4569, (954) 971-4569, fax (954) 971-5117. The company currently manufactures a line of connectors, adapters and special design connectors in its facility on the West Coast.

■ **Sikama International Inc.** has doubled the size of its manufacturing plant in Santa Barbara, CA and relocated its corporate offices, including sales, marketing and accounting, to an adjacent building to allow for more space in the production facility. The new state-of-the-art facility features a demonstration showroom, including a number of fully operational machines.

■ **EMS Wireless**, a division of **EMS Technologies Inc.**, has opened an enhanced production facility located in Norcross, GA. As a result of the new facility, the company is now one of the largest base station panel antenna manufacturers in the US market and expects to support a 400 percent increase in unit production capabilities. The new facility will also enable the company to significantly decrease order delivery lead times.

■ Microwave and RF product designer **Alpha Industries Inc.**, Woburn, MA, has received design wins and initial production orders for RF semiconductors to be used by three PC manufacturers in high speed wireless data modules. The company's semiconductors perform RF switching in Windows™ and Macintosh computers and other mobile computing devices, providing wireless access to local area networks and wireless synchronization with personal digital assistants and cellular handsets.

■ **ANADIGICS Inc.**, Warren, NJ, has received an order for more than 10 million RF switches and has begun production shipments to a large US-based manufacturer of wireless handsets. The models AWS5504S14 and AWS5506S14 single-supply 3 V switches will be used in an 800 MHz digital CDMA/AMPS dual-mode telephone. In related news, the company has shipped samples of dual-band heterojunction bipolar transistor power amplifiers for use in GSM/digital communication system (DCS) wireless handsets.

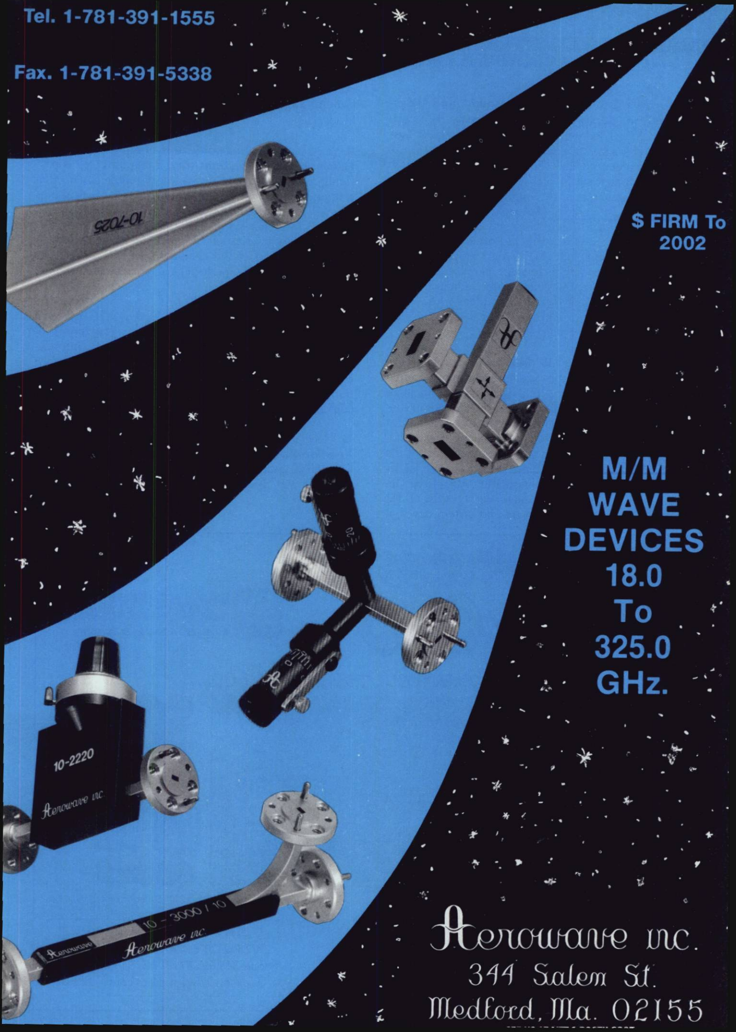
■ **Ansoft Corp.**, Pittsburgh, PA, has signed a software licensing agreement with **Thomson-CSF**, appointing Ansoft Thomson-CSF's approved worldwide supplier of electromagnetic analysis software. Under the terms of the agreement, Ansoft HSFF, a high frequency structure simulator that enables engineers to design three-dimensional (3D) structures, has been selected as the approved electromagnetic 3D solution for Thomson Atelier de Developpement Materiel (ATDM). The two parties will work together to provide Thomson-CSF with the tools and support necessary to optimize ATDM.

■ **First Source Inc.** has signed a national distribution agreement with **RF Industries** of San Diego, CA to distribute its full line of coaxial products.

■ Signal processing component and subsystem manufacturer **IF Engineering**, Dudley, MA, has appointed **Dage Corp.** as its export management company for overseas marketing and sales. This appointment provides IF Engineering with access to more than 30 countries around the world.

■ **Lucent Technologies USA** and **KMW Korea** have reached a general-purpose agreement under which Lucent has named KMW its worldwide supplier of high technology components for IMT-2000. Lucent Technologies' audit team reviewed KMW and its facilities for a six-month period before granting KMW this status.

[Continued on page 268]



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■ **Motorola's Commercial Government and Industrial Solutions Sector** has agreed to license its SmartNet™ and SmartZone™ trunking protocol to **IFR Systems Inc.** The agreement enables IFR Systems to provide test equipment for this wide range of systems and to develop and implement SmartNet and SmartZone protocols in its next-generation test solutions for digital Project 25 systems. In related news, **Motorola Labs** has finalized an agreement with Munich, Germany-based **Karl Suss** that permits Karl Suss to offer Motorola's proprietary mask protection technology (MPT) to its worldwide client base. This patent-pending technology allows a large number of contacts between mask and wafer without the normal mask wear or damage. Karl Suss plans to integrate MPT into its existing product line and license the new process to customers immediately.

■ **QUALCOMM Inc.** and **RF Micro Devices Inc.** have announced an alliance to provide advanced power amplifiers for the CDMA market. Initially, the two companies will cooperate on the development of CDMA power amplifiers for inclusion in present and future QUALCOMM CDMA chipsets. Future development may include other RFICs for CDMA applications. Under the terms of the agreement, QUALCOMM will market and sell the jointly developed CDMA power amplifiers using RF Micro Devices' wafer foundry for manufacturing. QUALCOMM will provide the necessary software and system development tools to enable faster development cycles for manufacturers using the QUALCOMM power amplifiers. In related news, RF Micro Devices has received production orders for GSM and DCS/PCS power amplifiers from **Groupe Sagem**, a French manufacturer of GSM mobile handsets.

■ Wireless communications test equipment provider **Telecom Analysis Systems Inc.**, Eatontown, NJ, is providing its WCDMA-LAB series test system in conjunction with equipment from **Agilent Technologies Inc.** to provide a wideband CDMA RF performance test system. The automated test system facilitates precise receiver performance characterization by providing accurate and repeatable air interface test conditions, and will be used by vendors to qualify the performance of candidate handsets for the Japanese market.

■ **W.L. Gore & Associates Inc.**, Newark, DE, has been named **Eastern Communications Co.'s (Eastcom)** local supplier for surface-mount electromagnetic interference gaskets. A telecom equipment manufacturer for **Motorola** for more than 10 years, Eastcom recently introduced originally designed telephones bearing the Eastcom logo to local retailers.

■ Electronic design automation (EDA) solution provider **Xpedion Design Systems Inc.** has integrated its GoldenGate™ series RF simulation and behavioral modeling products with **Synopsys**' COSSAP® system-level design

[Continued on page 270]

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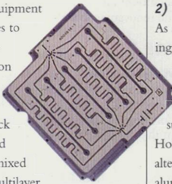

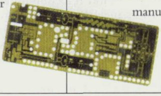

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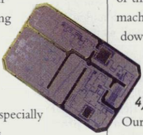

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3) Accurate, On-site Machining Capabilities

Filtran maintains complete on-site manual and computer-aided machining facilities to accurately punch, rout or mill thin substrates or thick metal backings with machining tolerances: ±.005", down to ±.001". We also have a close association with a local laser machining facility.

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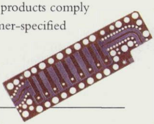
Our Sodium Etchant formulation for PTH and edge plating gives us tight control of processing, resulting in reliable, high-performance circuits and excellent adhesion of copper to PTFE.

5) Strict Quality Assurance

Our stringent program of in-process inspection results in high yields on the most complex circuits. We strictly monitor all production processes, and our upfront engineering, SPC and final inspection all help to ensure that products comply with customer-specified standards.



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series. By coupling these products (performed under the Synopsys in-Synch EDA interoperability program), time to market is improved as well as designer productivity for RF and wireless communication designs. The new GoldenGate-COSSAP interface unifies bottom-up and top-down design methodologies for existing 2G and evolving 3G and Bluetooth communication standards.

■ In response to industry demand for power supply products, **Astec Semiconductor**, Milpitas, CA, has increased production capacity by 400 percent across its voltage reference IC product offering. The increase in production capacity is designed to ensure that customers do not experience increased lead times for control components. Accordingly, the company has expanded its wafer, packaging and test capabilities as well as its engineering and production staff.

■ The **Thick Film Division** of **Mini-Systems Inc.**, North Attleboro, MA, which is certified to the Life Failure Rate S for MIL-PRF-55342 Fixed-film, Resistor Chip Performance Specification, has established a new program to provide customers with real-time data on similar products. The Mini-Systems Inc. Reliability Program (MSIRP) allows these products to be tested on a continuous basis and produces a certificate of conformance to accompany the data. The MSIRP displays the data in a graphical representation plotted against military standard criteria. Inspectors on the production line select samples at random and send them to quality assurance for testing. The data are also published on the company's Web site and updated periodically.

■ Hybrid and semiconductor equipment manufacturer **Palomar Technologies**, Vista, CA, has shipped its 12th model 3500-II die bonder to Philippines-based **Philips Laguna Cabuyao** to manufacture RF transistors. The 11 Palomar Technologies bonders currently in operation at the Philips facility are used in the manufacture of both RF transistors and community antenna televisions.

■ In response to rapid growth in high density flexible interconnect opportunities, **Rogers Corp.**, Rogers, CT, is manufacturing its R/flex® 8080 line of liquid photoimageable overcoat (LPI) materials in the US to serve both US and European customers. Since 1997, Rogers has maintained a distribution agreement with Japan-based **Nippon Polytech Corp.** to supply Nippon Polytech's LPI covercoats to Rogers customers. A new agreement between Rogers and Nippon allows Rogers to broaden the range of products it will offer and to manufacture the covercoat products in the US. Rogers expects to begin manufacturing the product line this year at its **Circuit Materials Division** in Chandler, AZ.

■ Measurement solution provider **Tektronix Inc.**, Beaverton, OR, has developed a new business strategy to focus on the global telecommunications industry and computer and Internet infrastructure. Practicing this strategy, the company hopes to leverage its competencies, extend its market share and realize double-digit growth goals. Using a market description known as "The Zone," Tektronix is aiming at the targeted computer and telecommunication industries, including their semiconductor requirements. The company also plans to develop closer customer relationships to accelerate design cycles.

■ A research team at the Department of Energy's **Los Alamos National Laboratory**, Los Alamos, NM, has devised a new, more accurate blood test to identify workers who are sensitized to beryllium. The team, led by Babetta Morrone of the Laboratory's **Bioscience Division**, has also pinpointed genetic markers that indicate increased risk for a small number of workers who are more likely to develop chronic beryllium disease, a disabling and sometimes fatal lung condition.

■ **The Phoenix Company of Chicago Inc.**, Wood Dale, IL, and its affiliated companies, **Palco Connector**, **Mil-Con Inc.** and **Custom Assembly LLC**, have been certified to the ISO 9001 quality system standard. The companies design and manufacture combination D-subminiature, filtered, and military audio and multipin connectors; RF/microwave cable, PCB and electromechanical assemblies; and delay lines.

■ **Raytheon Microsystems**, Buena Park, CA, has presented Trenton, NJ-based **Stealth Microwave** with an award in recognition and appreciation of superior value and service and innovative power amplifier design.

FINANCIAL NEWS

■ **Anaren Microwave Inc.**'s board of directors has authorized a three-for-two stock split in the form of a 50 percent stock dividend payable to shareholders of record on May 12. Certificates representing the additional shares resulting from the dividend are expected to be mailed on June 9.

■ Erlangen, Germany-based **Palomar Technologies GmbH** has announced that it has exceeded 1999 sales expectations by more than 10 percent and is forecasting a strong 2000. Demand for the company's wire and die bonders has been particularly strong for wireless, microwave and telecommunications applications. Strong sellers include the company's upgraded model 3500-II component assembly cell, a new line of CBT™ 6000 high speed automatic ball bonders and the models 2460-V and 2470-V wire bonders.

■ Embedded antenna technology producer **RangeStar Wireless**, Aptos, CA, has announced that it is in the final stages of its mezzanine round of financing. This private placement of funds will allow the company to finalize its planned objectives and fully capitalize on immediate market opportunities. The investment is expected to accelerate the scheduled initial public offering date for RangeStar to early fall.

■ **REMEC Inc.**, San Diego, CA, has completed a follow-on public offering of common stock. The company realized net proceeds of $133.2 M for the 3.5 million shares issued.

[Continued on page 272]

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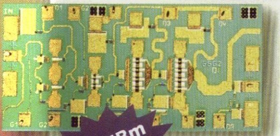


+21 dBm PSAT

HMC283

MEDIUM PA 17 - 40 GHz

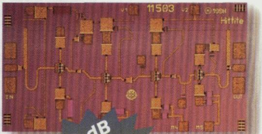
- 21 dB GAIN
- +26 dBm OIP3
- 1.62 mm^2
- REPLACEMENT FOR HMMC5040 MPA

LOW NOISE

HMC263

LNA 24 - 36 GHz

- 23 dB GAIN
- ADJUSTABLE NF & P1dB OUT
- 3.29 mm^2
- SINGLE +V BIAS



2.3 dB NOISE FIGURE

A SELECTION OF OUR MILLIMETER WAVE AMPLIFIERS

PART NUMBER	FREQUENCY (GHz)	FUNCTION	GAIN (dB)	NF (dB)	P1dB OUT (dBm)
HMC283	17 - 40	Med. PA	21	10	+18
HMC261	20 - 40	Driver AMP	13	7	+12
HMC262	15 - 24	LNA	25	2.0	+5
HMC281	18 - 32	LNA	22	2.5	+10
HMC263	24 - 36	LNA	25	2.3	+6
HMC282	36 - 40	LNA	27	3.5	+9

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CONTRACTS

■ **IFR Systems Inc.** Wichita, KS, has been awarded a three-year, $8.1 M contract from British Telecommunications (BT) to supply calibration and maintenance services for BT's electronic test equipment used in field and laboratory applications throughout the UK. As BT's primary service vendor, IFR Systems will be responsible for calibration and maintenance of telecommunications test equipment manufactured by IFR as well as third parties.

■ **REMEC Inc.** has received several new contracts, including an additional $6.2 M fiber-optic component order representing a share of the OC-192 modulator driver business from Nortel Optoelectronics. In addition, REMEC is nearing completion of an initial $19 M order from Motorola (previously General Instrument) for GaAs amplifiers and received a follow-on order valued at $4 M. The company's **Broadband Wireless Group** has also received several contracts, including one valued at approximately $2 M from an international fixed wireless access service provider for mm-wave fixed wireless access equipment. In addition, the division received a contract from Ensemble Communications that will result in sales of $1 M of mm-wave fixed wireless access equipment over the next several months. Finally, the Broadband Wireless Group has received two pilot productions awards for the point-to-multipoint broadband wireless market and a production award for modules that interface microwave and fiber-optic technology.

■ **Andrew Corp.** has been awarded a $6 M contract to provide broadband wireless system supplier Newbridge Networks Corp. with broadband wireless hub antennas. Andrew will provide its BCA series high gain hub antennas for the Newbridge Networks local multipoint distribution system broadband wireless solution, which enables service providers to enter the telecommunications market quickly with a broad portfolio of quality services for business customers. This antenna contract is the first order placed under a master purchase agreement between Andrew and Newbridge Networks. In addition to the BCA series antennas, the agreement also covers HELIAX® coaxial cable, RingFlare™ connectors, SureGround™ RF grounding kits and Andrew Arrestor Plus® surge arrestors, which protect installed radio equipment from lightning damage.

■ **SSPA Microwave Corp.** has entered into agreement with the Ministry of Railways, People's Republic of China to supply 12 sets of 40 W and 33 sets of 25 W high performance, Ku-band radio frequency units. The contract is valued at $1.8 M with delivery expected to be completed by mid-October.

■ **EMS Technologies Inc.** has been awarded two separate contracts from TRW to supply radio frequency switching systems and electronic power conditioners for the satellite payloads of the Astrolink global broadband communications system. TRW will build the digital, pack-

[Continued on page 274]

et-switched payloads for Astrolink International LLC satellites, which will provide the world's first global broadband communications system. Financial terms of either contract were not disclosed.

PERSONNEL

■ **Roger R. Hemminghaus** has been elected to the CTS Corp. board of directors. Currently, Hemminghaus is chairman emeritus of Ultramar Diamond Shamrock Corp. and chairman of the Federal Reserve Bank of Dallas, TX. In related news, CTS has named **Roger E. Rickey** VP and GM of its frequency products business. Rickey brings to the company more than 38 years of broad-based engineering, manufacturing, quality and management experience.

■ **Jeffery Wheeler** has been appointed CFO at Test-Mart. Prior to joining the company, Wheeler held senior finance and management positions with several firms, including Sierra Financial Group, Wells Fargo, Logistics Management Inc. and Zacson Corp.

■ M-tron Industries Inc. has appointed **Robert R. Zylstra** president and CEO. Prior to joining the company, Zylstra served as GM of new business ventures within the data storage and information management business of Imation Corp.

▲ Alan Haase

■ Andrew Corp. has promoted **Alan Haase** to group president, communication products. Haase joined Andrew in 1998 as VP, terrestrial microwave products from Ericsson where he was employed for 11 years in several capacities, including VP, wireless professional services; GM, cellular systems/PCS–Canada; and director, GSM strategic sales and marketing.

■ Taconic has promoted **Jim O'Keefe** to president. Most recently, O'Keefe served as VP and general manager of Taconic's Industrial Products Business.

■ **David W. Wightman** has joined Dow-Key Microwave Corp. as president. Most recently, Wightman was president of Sunbank.

■ AMT has made two new personnel appointments, including **Randy Jenkins** as VP, corporate sales and **Scott Rumery** as director of engineering. Jenkins, who joined AMT in 1999 as director, new business development has more than 15 years of related experience in product sales and marketing, including positions at Filtronic Comtek, M/A-COM and Avantek-HP. Rumery joined the company in 1998 with more than 14 years of development experience, including work at Hewlett-Packard and Avantek.

■ IFR Systems Inc. has named **Mitch Stone** VP of sales, Americas region. Stone joins IFR Systems from Datum Inc., where he served as VP, sales and marketing since 1995. He succeeds **Sam Strang**, who will continue to serve as VP, corporate accounts. In related news, IFR Systems has appointed **José Delgado** director, sales and marketing for Latin America. Prior to joining the company, Delgado was the Eastern US and Latin American business development manager for AIL Systems Inc.'s Antenna Products Division.

■ Tropian Inc. has appointed **Michael A. Kinser** VP, sales and marketing with responsibility for the company's worldwide sales and marketing activities. Prior to joining Tropian, Kinser served as senior VP of marketing at Telular Corp.

■ Aeroflex Lintek Corp. has promoted **Stephen A. Brumley** to VP, operations responsible for production and program execution. Brumley's past experiences include engineering management; program management; and indoor/outdoor antenna and radar cross-section test range design, verification, utilization and management.

■ Norsat International Inc. (NII) has named **Lindsay E. Ryerson** VP, Norsat Narrowband Networks. Most recently, Ryerson was with Aurora Distributing, an operating unit divested by NII in 1998, to oversee Aurora's transition to its new ownership.

■ Varian Inc. has promoted **Sergio Piras** and **Wilson Rudd** to corporate VPs. Previously, Piras was GM of Varian Vacuum Technologies in Torino, Italy; Rudd's most recent position was GM of the $96 M Varian Electronics Manufacturing business.

■ Sanders, a Lockheed Martin company, has named **Glenn Thoren** director, intellectual property exploitation. Most recently, Thoren was director of technology licensing at the company.

▲ Peter Beaulieu

■ **Peter Beaulieu** and **Raul Diaz** have joined Continental Microwave and Tool Company Inc. (CMT) as engineering manager and senior design engineer, respectively. Both Beaulieu and Diaz are formerly of M/A-COM and have filter, ferrite and microwave component experience.

▲ Raul Diaz

■ As part of its celebration of the Third Millennium, the IEEE plans to award 3000 IEEE Millennium Medals and certificates to individuals who have been selected by IEEE societies, sections and major boards for outstanding contributions in their respective areas of activity. These medals will be distributed throughout the year. MTT members chosen to receive Third Millennium Medals include **Stephen F. Adam**, **Les Besser**, **Eliot D. Cohen**, **Seymour B. Cohn**, **E. James Crescenzi Jr.**, **Robert L. Eisenhart**, **Vladimir G. Gelnovatch**, **Al Gross**, **K.C. Gupta**, **George I. Haddad**, **Peter R. Herczfeld**, **John B. Horton**, **Harlan Howe Jr.**, **Tatsuo Itoh**, **Rolf H.**

[Continued on page 276]


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REP APPOINTMENT

■ High performance laterally diffused metal oxide RF power semiconductor manufacturer **UltraRF**, Sunnyale, CA, has appointed **Sangus** to represent its cost-effective RF power semiconductors in Sweden, Norway, Denmark and Finland.

NEW MARKET ENTRY

■ **Sebago Molders LLC** is a new company formed to offer waveguide covers for the microwave industry, including a new line of plastic waveguide covers that solve the problems of poor fit and twisted covers. The company is located at 525 John Dietsch Blvd., N. Attleboro Ind. Park, Attleboro Falls, MA 02763 (508) 643-4600, fax (508) 699-7774. The Web site is www.sebagomolders.com.

WEB SITES

■ **Paratek Microwave Inc.** has launched a new Web site at www.paratek.com that features the company's line of Parascan™ voltage-tunable dielectric materials used to develop, manufacture and commercialize electronically tunable RF components and electronically steerable antennas for the broadband wireless telecommunications industry.

■ **Polyflon Co.** has launched a newly designed Web site at www.polyflon.com. The site contains descriptions of current and new products, including microwave laminates and circuits, HV/RF capacitors and engineering-grade plastics, as well as processing information.

■ The **Olektron Operation** of **Signal Technology Corp.** has updated its Web site to include more than 12 new products and a complete list of available product data sheets in PDF format. The site, located at www.sigtech.com/olektron, also features new lines of switch combiners and multifunction logarithmic amplifiers.

■ High density modular test solution provider **VXI Technology Inc.** has launched a new Web site that provides test engineers involved in automated testing with a resource to help specify and document a customized test station. The site, www.TestDesignOnline.com, can be utilized for internal development and budgeting or for requesting a quote for the development of a complete system by any independent integrator. Links are provided to several Web sites to enhance product selection.

DC, Linear AC and Nonlinear AC Stability Analysis Using Bifurcation and Nyquist Theory

Designing power and low noise amplifiers, gain blocks, multipliers and oscillators for modern communication systems requires delicate trade-offs between various design specifications including linearity, power efficiency, crosstalk between channels and stable operation over a wide range of input power and impedance. Most of the techniques used in amplifier designs, whether for power amplifier linearization or to minimize crosstalk between channels or noise figure, result in complex architectures with several nonlinear or active devices in the circuit. One of the primary criteria for any successful amplifier, multiplier or oscillator design is the assurance of its stable operation at DC and power on and at various input and output signal levels and terminating impedances.

Classical Stability Analysis and Its Limitations

The stability analysis of any RF and microwave circuit is the figure of merit for its consistent operation behavior (for example, no oscillations for an amplifier, or unconditionally sustainable oscillations for an oscillator). Circuit stability can be determined from the S parameters of the active device, input and output matching circuits, and terminations. A two-port network is said to be unconditionally stable at a given frequency if it is stable against oscillation for all passive source and load impedances. If a two-port network is not unconditionally stable, it is potentially unstable and is said to be conditionally stable. In the second case, some passive source and load impedance combinations can cause the two-port network to oscillate.

For a two-port network, necessary and sufficient conditions for unconditional stability are that the stability factor K (Rollet's factor) is greater than one and the real part of the input immitance parameter (γ_{11} and γ_{22}) is greater than zero, with an overriding condition that the poles of the two-port network under investigation with ideal terminations (open and short circuit) must lie in the left half plane. These criteria are expressed in terms of K and Δ (scattering matrix determinant), and zeros of the characteristic frequencies of the network. In particular, the network is unconditionally stable if $K > 1$ and $|\Delta| < 1$, and the zeros of the characteristic frequencies lie in the left half plane.

[Continued on page 280]

Jake Goldstein and Mehdi Soltan
Xpedion Design Systems Inc.
Santa Clara, CA

In terms of reflection coefficients and S parameters of the two-port network, the conditions for unconditional stability at a given frequency are

$$|\Gamma_s| < 1,\ |\Gamma_l| < 1 \text{ and } |\Gamma_{out}| < 1$$

where

$$\Gamma_{in} = S_{11} + \frac{S_{12}S_{21}\Gamma_l}{1 - S_{22}\Gamma_l}$$

$$\Gamma_{out} = S_{22} + \frac{S_{12}S_{21}\Gamma_s}{1 - S_{11}\Gamma_s}$$

For, $|\Gamma_s| < 1$ and $|\Gamma_l| < 1$, the necessary and sufficient conditions for unconditional stability are

$$K = \frac{1 - |S_{11}||S_{11}| - |S_{22}||S_{22}| + |\Delta||\Delta|}{2|S_{12}S_{21}|} > 1$$

$$|\Delta| = |S_{11}S_{22} - S_{12}S_{21}| < 1$$

In the conditionally stable case (K < 1), the loci of Γ_s and Γ_l in the Smith chart, shown in **Figure 1** where values of Γ_s and Γ_l produce $|\Gamma_{out}| = 1$ and $|\Gamma_{in}| = 1$, are called the input and output stability circles, respectively. The radii r and centers c of the stability circles in the Γ_s and Γ_l planes, respectively, are given as

input stability circle:

$$r_s = \left| \frac{|S_{12}S_{21}|}{|S_{11}||S_{11}| - |\Delta||\Delta|} \right|$$

$$c_s = \frac{\left(S_{11} - \Delta S_{22}^*\right)^*}{|S_{11}||S_{11}| - |\Delta||\Delta|}$$

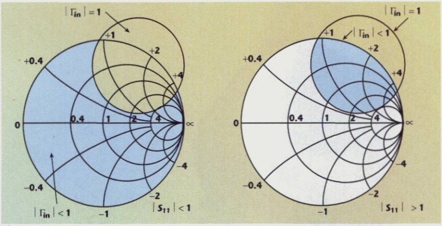
output stability circle:

$$r_L = \left| \frac{|S_{12}S_{21}|}{|S_{22}||S_{22}| - |\Delta||\Delta|} \right|$$

$$c_L = \frac{\left(S_{22} - \Delta S_{11}^*\right)}{|S_{22}||S_{22}| - |\Delta||\Delta|}$$

If $|S_{11}| < 1$, the inner area of the Smith chart, which is outside the out-

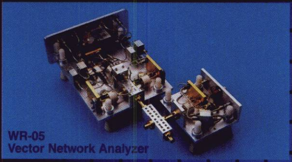
[Continued on page 282]



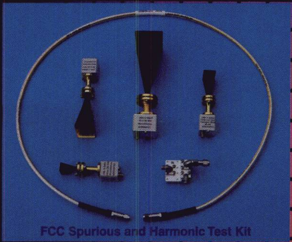
▲ *Fig. 1 The output stability circle in the Γ_l plane.*

mmW Test Equipment

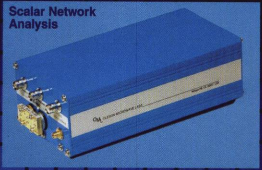
Vector Network Analysis Systems Use with popular microwave VNA equipment to achieve millimeter wave vector/amplitude measurement capability. Can be used in either the forward direction only (S11 & S21) with one T/R module and one T module *or* in the forward and reverse direction (S11, S21, S22, S12) with two T/R modules. Systems are available for all waveguide bands from WR-22 to WR-05.



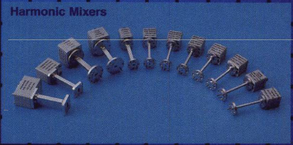
Waveguide VNA Calibration Kits for calibration of the above Vector Network Analysis Systems. Contains all of the components necessary to achieve any of the popular calibration methodologies.



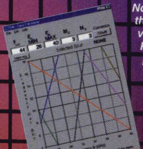
FCC Spurious and Harmonic Test Kit for use with popular Spectrum Analyzers. Each kit contains four mixers providing continuous coverage from 40 to 220 GHz. Each mixer is equipped with an appropriate horn antenna for accomplishing the FCC desired radiated spurious level measurement. Shown with optional diplexer and cable.



Scalar Network Analysis (SNA) Systems and Multiplier Sources Complete SNA systems containing filtered multipliers with –50 dBc spurs and harmonics. Included are a dual directional coupler and detectors for reference, reflection and transmission. Available for WR-22 through WR-10. Filtered Multiplier Sources are also available without the coupler or detectors. Multiplier Sources are available without filtering for the WR-08 through WR-05 waveguide bands. All of these products are engineered to extend the user's 8 to 20 GHz equipment.



Harmonic Mixers Use with popular Spectrum Analyzers to achieve millimeter wave spectrum analysis. Mixers are available for all waveguide bands from 18 to 325 GHz. LO/IF diplexers are available for most modern spectrum analyzers. Measured conversion loss data supplied with emulation of most modern spectrum analyzers for WR-42 through WR-10.



Now available free at the OML Web Site is the Windows™ compatible, block converter "Spurious Product Prediction Program" illustrated to the left. With this program, engineers can examine their block converter designs for harmful spurious responses.

Also contained on the Web Site are complete specifications for all of the above millimeter wave frequency extension products as well as technical papers addressing many of the more common millimeter wave testing problems.

Contained in these papers are many useful millimeter wave charts and graphs not found elsewhere.

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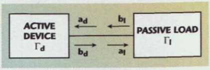
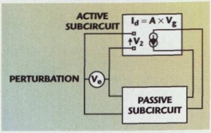


▲ *Fig. 2 An active RF/microwave network representation.*

Fig. 3 The circuit representation in active and passive segments. ▼



put stability circle, represents the stable region. On the other hand, if $|S_{11}| > 0$, the intersection of the inner areas of the Smith chart and the output stability circle represents the stable region. The shaded area represents the stable regions in the Γ_l plane.

However, there are serious limitations in this widely used process. The flaw is that stability conditions based on the K factor are strictly valid only for a single-transistor amplifier. When the amplifier contains more than one active device, the K factor test may lead to incorrect conclusions. This scenario is commonly encountered by designers. The method described previously is also insufficient and inaccurate to apply to the stability analysis of nonlinear RF and microwave circuits. The unconditional stability analysis of two-port RF and microwave circuits that is generally performed by designers and proposed in many textbooks and commercial design software packages utilizes only K and Δ parameters. This approach fails in many cases, such as in the analysis of multistage amplifiers or complex networks. Moreover, in practical cases, the S parameters of the active devices do not satisfy the unconditional stability criterion related to K and Δ for all frequencies. In this situation the designer must verify the conditional stability of the network.

In some cases, it is better to perform an analysis for instability, that is, assume the circuit to be an oscillator. The oscillation condition states that the product of the reflection coefficients of the active device and passive load must be equal to 0 ($\phi_d + \phi_l = 0$). It is intuitively clear that in this situation a signal incidentally present on the system is amplified until oscillations are established. Nevertheless, this approach is not always correct because to check the conditional stability it is necessary to know the behavior of the circuit (not only at the resonant frequency, but also for any frequency). Moreover, the result of this method depends on the choice of the normalizing impedance of the reflection coefficient.

An accurate method for checking the stability of a circuit is to consider the Nyquist criterion, which overcomes the limitations of the traditional methods described previously. The Nyquist criterion is a graphical method that allows determination of the stability of a closed-loop system, starting from the system's open-loop transfer function. However, applying the Nyquist criterion requires complex circuit analysis and exact knowledge of the open-loop transfer function of the system under investigation.

STABILITY ANALYSIS USING NYQUIST AND BIFURCATION ANALYSIS

The Nyquist theory method is applicable to small-signal circuits. In the presence of large-signal RF drive (such as in a power amplifier or oscillator), the device nonlinearities can considerably modify the stability pattern, for example, by causing spurious oscillations or generating subharmonics. This behavior cannot be detected by the Nyquist approach since it requires more sophisticated techniques based on bifurcation theory.

By applying the Nyquist criterion to active RF and microwave circuits as shown in ***Figure 2***, if Γ_d is the reflection coefficient seen looking into the active device and $\Gamma_l(f)$ is the reflection coefficient seen looking into the passive circuit, it is possible to define a transfer function similar to that of a closed-loop system. In fact, it is possible to evaluate the ratio of $a_l(f)$ and $a_d(f)$, resulting in

$$\frac{a_l(f)}{a_d(f)} = \frac{\Gamma_d(f)}{1 - \Gamma_d(f)\Gamma_l(f)}$$

The Nyquist criterion is a graphical method that allows determination of the stability of a closed-loop system from the open-loop transfer function with the frequency varying from zero to infinity. If P_{cl} (greater than or equal to zero) is the number of right half-plane poles of the closed-loop transfer function, P_{op} (greater than or equal to zero) is the number of right half-plane poles of the open-loop transfer function and N_i is the number of clockwise encirclements of the critical point (1, j0) (negative if counterclockwise), the closed-loop system is stable if and only if

$$P_{cl} = P_{op} + N_t = 0$$

and if the open-loop transfer function does not cross the critical point. If the open-loop system is stable ($P_{op} = 0$), it is sufficient that $N_t = 0$ (reduced criterion).

Linear Stability Analysis

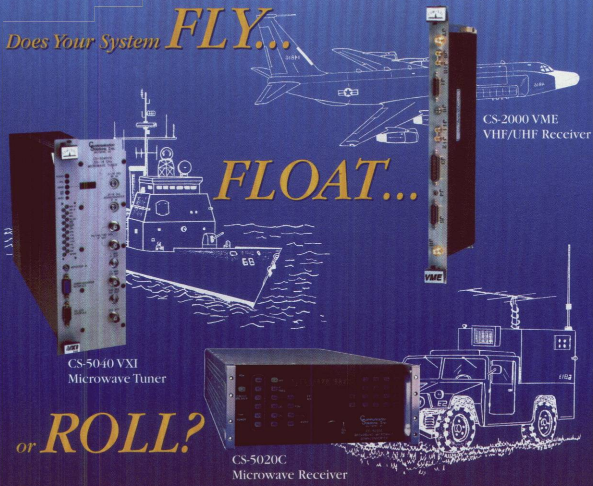
To illustrate generalized Nyquist stability analysis, the circuit schematic is represented in the classical form of an amplifier with feedback, as shown in ***Figure 3***. For this analysis, the circuit elements are separated into two blocks: all active elements in the equivalent amplifier block and all passive elements in the feedback block. It is well known that the circuit is unstable if the feedback is additive. More precisely, the circuit is unstable if the determinant of the equilibrium equation has a zero with a positive real part.

$$V_g = \beta(\rho + j\omega)\, I_d + \alpha(\rho + j\omega)\, V_g$$
$$I_d = A\, V_g [1 - \beta(\rho + j\omega)A]\, V_g = \alpha(\rho + j\omega)V_g$$
$$\delta(\omega) = \det\,[1 - \beta(j\omega)A]$$

In practice, it is not possible to compute zeros of the determinant. For diagnosis of the stability, the GoldenGate™ simulator employed for analyses in this article uses Nyquist criteria, that is, the locus of the determinant with varying frequency is plotted in the complex plane. The circuit is unstable if the determinant locus encircles the origin clockwise. The amount of encircling gives the number of instability frequencies. Intersections of the locus with the negative real axis provide a good estimate of instability frequency (starting oscillation frequencies).

To further simplify interpretation of the Nyquist stability plot, the simulator provides a projection of the nat-

[Continued on page 284]



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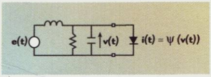

▲ *Fig. 4 A nonlinear circuit.*

ural locus into the phase plane (called unwrapped locus), where the user can easily check the encircling of the origin. The frequency step along the locus is also automatically monitored by the simulator to adapt to the fast or slow variation of the locus. This analysis is extremely important for high Q circuits.

Nonlinear AC Stability Analysis

The principle of stability analysis using harmonic balance is a generalization of the Nyquist principle already seen in the linear analyzer (DC bias stability). It requires introducing a small evanescent perturbation $\rho + j(\omega_k + \omega)$ on all active nodes of the circuit and observing if the resulting circuit output disappears with time. The perturbation equation is obtained by linearizing the harmonic balance equation around the steady-state equilibrium condition.

The resulting equations may be put in the form of amplifier gain with feedback. The open-loop gain of the amplifier is represented by derivatives of the nonlinear sources and the feedback gain is represented by the immittance of the passive subcircuit, as shown in ***Figure 4***. The perturbation equilibrium equations are

$$I[\omega_k + (\omega - j\rho)] = Y1[\omega_k + (\omega - j\rho)]V[\omega_k + (\omega - j\rho)] + Y2[\omega_k + (\omega - j\rho)]E[\omega_k + (\omega - j\rho)]$$

where

$$\omega_k = \sum_i k_i\, \Omega I \ (k = 1, \ldots, NH)$$

$$I\left[\omega_k + \left(\omega - j\rho\right)\right] = \left[\frac{\delta I}{\delta V}\right] V\left[\omega k + \left(\omega - j\rho\right)\right]$$

$$\delta\left(\omega\right) = \det\left[1 - \beta\left(j\omega\right)A\right]$$

Following the Nyquist criterion, the circuit is considered unstable if the locus of the determinant of the characteristic equation encircles the origin clockwise when the perturbation frequency is swept from zero to infinity. In practice it is only necessary to sweep the frequency from zero to the maximum oscillation frequency of the active devices. While using the simulator, the user need not determine the frequency step and maximum frequency (except for DC); these parameters are automatically monitored by the simulator. The simulator also detects the encircling or not of the origin. A stability flag, set to one if the circuit is stable and zero if not, is given as an output. The simulator also provides the instability frequencies when the circuit is unstable.

The weakest point of the stability analysis using Nyquist criterion is that it can be computationally intensive, especially when computation of stability margins relating to design parameters is desired. However, when it has already been verified that the bias point is stable, the main risk of instability in large-signal drive conditions

[Continued on page 286]

is frequency division by two and hysterisis. These two types of instability may be detected with a reasonable computation cost during steady-state simulation. Bifurcation analysis is very useful for computing the locking range of analog frequency dividers and locked oscillators, as shown below.

STEP-BY-STEP DC, LINEAR AC AND NONLINEAR AC STABILITY ANALYSIS

DC Operating Point Stability

DC stability analysis is performed to check if the biasing point of the circuit under test is stable or not. For nonautonomous circuits (such as an amplifier, mixer or active filter), DC stability analysis determines that the circuit does not turn into an oscillator as the power supply is turned on. The DC operating point must be stable. Similarly, for autonomous circuits (such as in an oscillator design) DC stability analysis verifies that the circuit actually oscillates when the power supply is turned on. Hence, the DC operating point must be unstable in this case.

DC Stability Analysis

For nonautonomous circuits (amplifiers), DC analysis is performed to locate the biasing point and DC stability analysis is used to determine if the biasing point is stable. If the biasing point is stable, the analysis determines the resonant frequency characteristics of the circuit (stopband or passband frequencies); if the biasing point is unstable, it determines the potential oscillation frequencies.

For autonomous circuits (oscillators), a DC analysis is similarly performed to locate the biasing point. A DC stability analysis is then performed to determine if the biasing point is actually unstable so that oscillations will build up. If the biasing point is unstable, the simulator provides the potential oscillation frequencies; if the biasing point is stable, it provides the resonant frequency characteristics of the circuit for information (stopband or passband frequencies).

Note that in the case of high Q circuits, if the Nyquist plot definition is set up with too small a number, the stability analysis may lead to incorrect conclusions. The simulation results must be carefully analyzed. For example, the simulation results may indicate that the biasing point is stable when it is not. In case of any doubts, it is safe to set the Nyquist plot definition to the highest level. In addition, the only reliable way to determine the startup of oscillation frequency is through DC stability analysis. Nonlinear AC stability analysis should not be used for this purpose.

Harmonic Balance Analysis

In the case of nonautonomous circuits (such as amplifiers), if the DC bias point is stable, AC analysis of the amplifier should be performed (that is, linear AC, S parameter or harmonic balance). Note that if the DC bias is unstable and an AC analysis is performed, misleading results may occur and most often the harmonic balance analysis is terminated with a message of harmonic balance overflow. In the case of autonomous circuits (such as oscillators), if the DC bias point is unstable, AC analysis (that is, harmonic balance analysis) of the oscillator is performed. The stability analysis provides an accurate estimation of the oscillation frequency.

If the circuit is unstable and the DC stability indicates that the bias point is unstable, even when using the highest Nyquist plot definition, harmonic balance oscillator analysis still can be performed with one of the resonant frequencies provided by the stability analysis. If sustainable and stable oscillations are found, the stability of oscillation still needs to be checked to determine if the oscillator is not going to start from DC but will require a starting RF pulse. This requirement may be confirmed by performing a nonlinear stability analysis by analyzing the oscillator as an amplifier.

Large-signal Stability Analysis

Large-signal operating point stability analysis is performed to check if the steady state obtained for an amplifier, mixer or oscillator is maintained long enough to be physically sustained. For nonautonomous circuits, nonlinear stability analysis indicates whether the amplifier continues to be an amplifier for the given input drive and frequency. Sometimes for certain drive levels and input frequencies the amplifier may turn into an oscillator (self-oscillating mixer) or, more often, a frequency divider. For autonomous circuits, nonlinear stability analysis indicates whether oscillations are sustained at this frequency and power. If the stability test indicates an unstable condition, it means that the circuit is actually oscillating at some other frequency, or possibly it has more than one simultaneous oscillation frequency. The actual frequency of oscillation is usually listed in the DC stability analysis results.

Note that during large-signal operating point stability analysis the maximum perturbation frequency must be set to the fundamental frequency tone (in the case of one-tone analysis). The Nyquist plot is nearly periodic with a period equal to the fundamental tone. The instability frequency provided by the analysis corresponds to an offset frequency from one of the harmonics (DC, $\pm f_o$, $\pm 2f_o$, ..., $\pm Nf_o$), so that the true frequency of instability is actually $|kf_o \pm f_{ins}|$.

A STEP-BY-STEP AMPLIFIER AND MULTIPLIER STABILITY ANALYSIS EXAMPLE

A step-by-step process for stability analysis of an amplifier, using the simulator, begins by performing a DC stability analysis to determine if the circuit is stable at the bias point. While setting up this analysis, the stability analysis must be run while the maximum perturbation frequency is set large enough to cover the maximum frequency of oscillation of the device. The maximum frequency may depend on the device and substrate technology or the cutoff frequency of the transistors used in the circuit design.

In the first case, if the DC stability analysis indicates that the circuit is unstable, it also provides the instability frequency or frequencies. The next step is to reconsider the circuit topology or change the active device or devices used in the circuit design until the stability analysis indicates stable DC performance. When the circuit is composed of several active devices, it is interesting to know which devices are contributing to the instability. In the simulator, this detection is simple and very user friendly. The simulator allows the designer to individually turn the target device(s) to a passive state simply by setting the TURNOF flag to 1 and watching if the instability vanishes. If turning a device to the off state produces stable operation, it indicates that this particular device is contributing to unstable DC operation.

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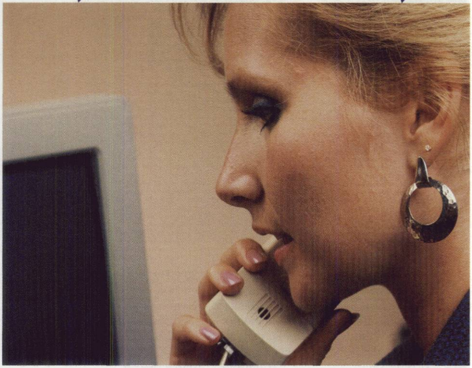

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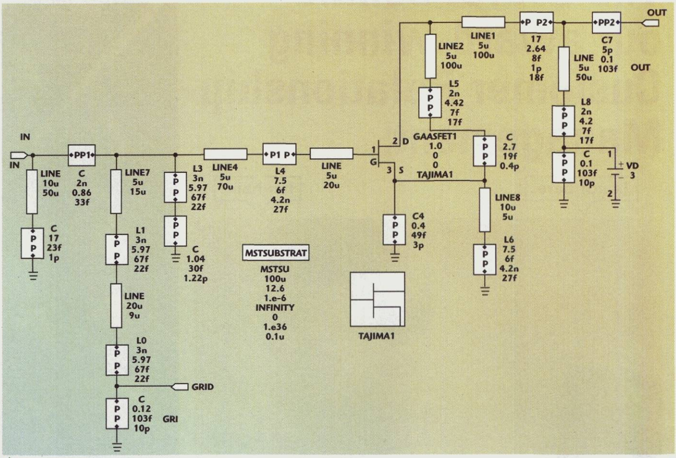


▲ *Fig. 5 A 6 GHz amplifier design.*

In the second case, if the DC stability analysis indicates that the circuit is stable, the next step is to perform nonlinear harmonic balance analysis to compute the nonlinear steady-state condition of the circuit and perform nonlinear stability analysis to check if the steady-state condition is physically sustained/stable or just an artifact of the mathematical solution of the circuit equations. This step is one of the most important and critical aspects of any circuit design and is ignored by most other commercial RF and microwave simulation tools.

If none of the nonlinear regions of operation is sustainable (that is, unstable), the simulator provides the instability frequency (offset frequency). If f_{inst} is the simulated offset instability frequency, the real frequency of instability is one of the frequencies $f_k \pm f_{inst}$, where f_k is the DC and harmonic (or intermodulation) products of the steady-state region of operation. Usually, it is DC $\pm f_{inst}$ or fundamental tone $\pm f_{inst}$.

The critical information from the nonlinear stability analysis is to determine if the circuit is stable or not (for a given biasing and input drive) or, in other words, if the waveform and power given by the harmonic balance simulator are a real representation of a physical situation. The actual value(s) of the instability frequency(ies) is only secondary information and mostly for informational purposes.

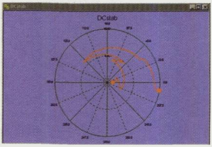
A 6 GHz, GaAs MESFET-based MMIC amplifier design, shown in ***Figure 5***, is designed to operate as a frequency divide by two. When biased at –1.8 V gate voltage, this circuit behaves as a times-two frequency multiplier at low and medium input levels. However, when biased at –1.8 V gate voltage and the input signal is driven higher than 10 dBm, the amplifier becomes unstable and starts to function as a frequency divide-by-two circuit. This particular behavior can be predicted by nonlinear stability analysis.

DC Stability Analysis

As shown in ***Figure 6***, the DC stability analysis is performed with a maximum frequency of 20 GHz (since the circuit is using a GaAs MESFET with a cutoff frequency of 20 GHz), step size of 100 and accuracy level of 3. ***Figure 7*** shows a Nyquist plot from the DC stability analysis of the amplifier using the simulator. The analysis indicates that the DC bias point of this circuit is stable, which means that this circuit

▲ *Fig. 6 The DC stability analysis setup.*

Fig. 7 Nyquist plots from the DC stability analysis results. ▼



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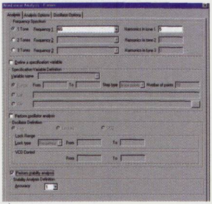


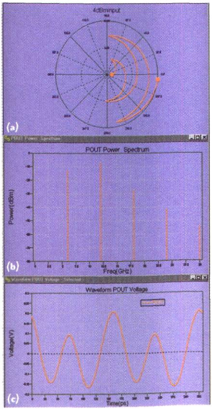
▲ *Fig. 8 The nonlinear stability analysis setup.*

will behave as well as an amplifier under small-signal operation.

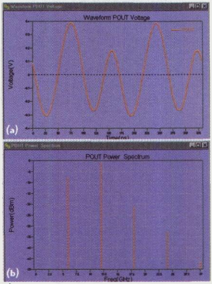
Nonlinear Stability Analysis

Nonlinear stability analysis using the simulator's nonlinear harmonic balance is set up as shown in ***Figure 8***. The analysis is performed using a single-tone input frequency with input power levels of 4 and 8 dBm, and considering five harmonics.

As shown in ***Figure 9***, the nonlinear stability analysis indicates that the circuit is stable at a 4 dBm input drive, and the waveform and power output indicate that the circuit performs as a multiplier at this input drive level. ***Figure 10*** shows the harmonic balance re-



◀ *Fig. 9 Nonlinear analysis results with 4 dBm input drive; the (a) Nyquist plot, (b) output power spectrum and (c) output voltage waveform.*



▲ *Fig. 10 Nonlinear analysis results with 8 dBm input drive; the (a) output voltage waveform and (b) output power spectrum.*

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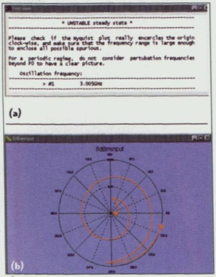
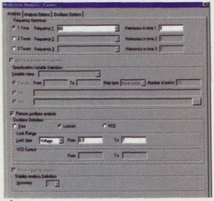
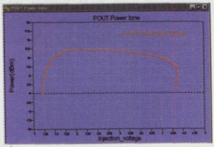


▲ *Fig. 11 The nonlinear stability analysis (a) report and (b) Nyquist plot for 8 dBm input drive.*

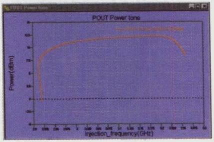


▲ *Fig. 12 The nonlinear stability analysis setup.*



▲ *Fig. 13 A locked oscillator power output plot formed by sweeping the input voltage.*

Fig. 14 A locked oscillator power output plot formed by sweeping frequency with a fixed input voltage. ▼



sults obtained when the nonlinear stability analysis is performed with 8 dBm input drive. The waveform and output power results indicate that the circuit still works as a 2× multiplier with 8 dBm input power. However, when a nonlinear stability analysis of this circuit is performed at 8 dBm input power level, as shown in ***Figure 11***, the analysis indicates that the circuit is unstable. Thus, the results from harmonic balance simulation indicate a steady-state region of nonlinear circuit operation that is not physically sustained; that is, the circuit is nonlinear unstable. ***Figure 12*** shows the simulator setup screen for nonlinear stability analysis.

The results produced by harmonic balance analysis are only a mathematical solution (or artifact) and not physically realizable. The nonlinear stability analysis shows an instability offset frequency of 3 GHz. As explained previously, the actual instability frequency is $f_o \pm 3$ GHz, or DC ±3 GHz, which means it is 3 GHz in this case. Thus, at this input drive level the circuit is operating as a frequency divide-by-two circuit.

It is important to note that the waveform and spectrum produced by harmonic balance analysis at an input drive level of 8 dBm look normal for multiplier operation just as for the 4 dBm input. Hence, only looking simply at the output waveform or output power spectrum is quite misleading. It may be impossible to determine, without accurate and extensive nonlinear stability analysis, whether the nonlinear harmonic balance results are just a mathematical artifact of analysis or a physically realizable effect. Accurate nonlinear stability analysis is the only way to determine this fact.

As determined from the above analysis, when the circuit is operating as an oscillator, frequency divide by two, the accurate simulation method is to analyze the circuit in an oscillator mode using nonlinear harmonic balance analysis (since the circuit is unstable, as shown from nonlinear stability analysis). ***Figure 13*** shows the simulation output plot, which displays the frequency division that starts at approximately 5 dBm (1.2 V) and vanishes at approximately 17 dBm (4.4 V) input power level for a 6 GHz input frequency. A similar analysis is performed, except in this case the input power is fixed at 15 dBm (3.5 V) and the input frequency is swept from 5 to 8 GHz. The results, shown in ***Figure 14***, indicate that at a fixed input power of 15 dBm (3.5 V) the circuit performs as a frequency divider starting at 2 × 2.91 = 5.82 GHz and ending at 2 × 3.259 = 6.518 GHz.

A STEP-BY-STEP OSCILLATOR STABILITY ANALYSIS EXAMPLE

A step-by-step process for stability analysis of an oscillator using the simulator begins by performing a DC stability analysis to determine the starting frequency(ies) of oscillation(s), if any. These are called instability frequencies (or also, mistakenly, oscillation frequencies). The stability analysis must be run while the maximum perturbation frequency is set large enough to cover the maximum frequency of oscillation of the device. The maximum frequency may depend on the device and substrate technology or the cutoff frequency of the transistors used in the circuit design.

Next, an oscillator analysis is performed to compute the real oscillation frequency and power. This analysis is required only if the DC stability analysis indicates that the circuit is unstable. If the stability analysis results in more than one frequency of instability, an oscillator analysis must be performed for each instability frequency. Therefore, an oscillator analysis with an estimated oscillation frequency equal to every frequency of instability must be run. Only one of these oscillation regimes will be physically sustained.

A nonlinear stability analysis is then performed for each oscillation regime to check if the oscillation regime is physically sustained. If none of the regime is sustained (that is, stable), this means that there is another regime to be found, probably a two-tone or chaotic regime, in which case the harmonic balance method cannot determine the proper solution. In practice, this condition means that the designer must modify the circuit to have proper oscillation(s). A 0.87 GHz, GaAs MESFET-based

[Continued on page 294]

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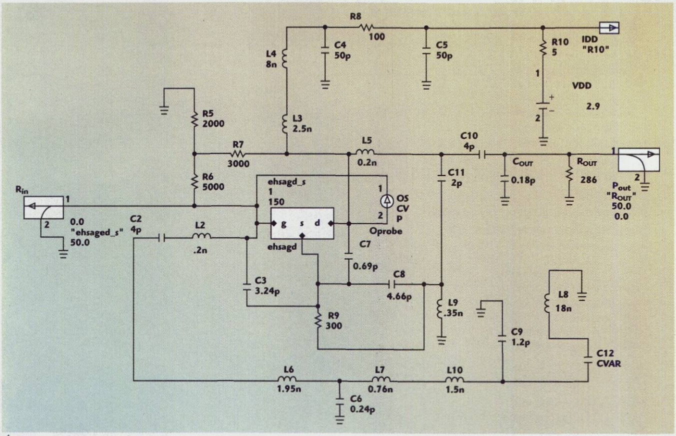
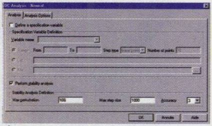


▲ *Fig. 15 A 0.87 GHz oscillator design.*

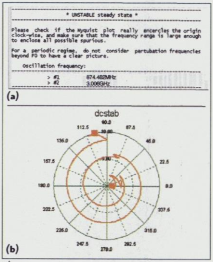


▲ *Fig. 16 The DC stability analysis setup.*

MMIC oscillator design example is shown in ***Figure 15***.

DC Stability Analysis

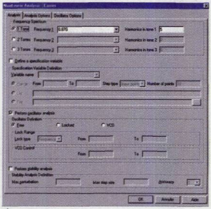
The DC stability analysis is performed with the maximum frequency of 10 GHz, step size of 1000 Hz and accuracy level of 3, as shown in ***Figure 16***. (Since the circuit is using a GaAs MESFET it was not expected to be unstable at any frequency greater than 10 GHz.) The stability analysis indicates that the DC state of this circuit is unstable, which is acceptable for a circuit designed to be an oscillator. The analysis provides two frequencies of instability (0.87 and 3 GHz), as shown in ***Figure 17***. In addition, it can be seen that the Nyquist plot encircles the origin twice. An examination of the Nyquist plot is necessary to verify whether the definition of the diagram is good enough. Good definition means a regular plot with no large discontinuities of phase. If the definition is not good, the setup must be changed to increase the accuracy parameter and the analysis rerun.



▲ *Fig. 17 DC stability analysis (a) report and (b) Nyquist plot.*

Nominal Oscillator Analysis

The stability analysis indicates that the DC state is unstable (which is expected from this circuit) with two frequencies of instability (possible starting frequencies of oscillation). Therefore, two different oscillator analyses are required to be run, one for each instability frequency. For this analysis the estimated oscillation frequency is set equal to the instability frequency.



▲ *Fig. 18 The nonlinear analysis setup at 0.87 GHz.*

First, the oscillation frequency is set equal to the 0.87 GHz instability frequency and five harmonics are considered to account for the nonlinearity of the oscillator, as shown in ***Figure 18***. The simulator computes a real oscillation frequency of 881 MHz with the output waveform and power

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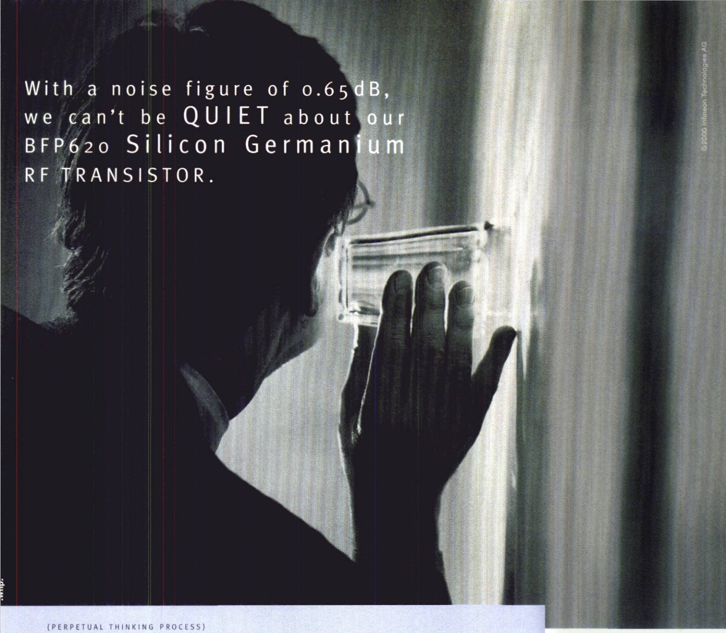

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Ic max	80 mA
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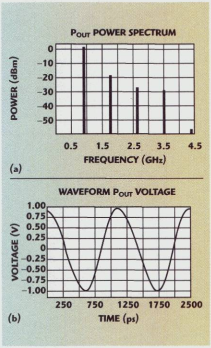
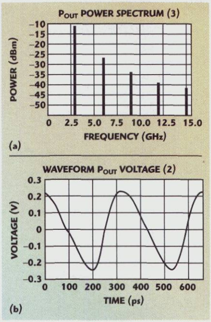
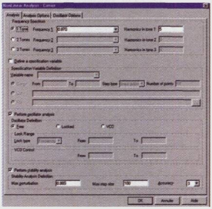


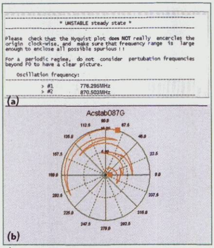
▲ *Fig. 19 Nonlinear analysis (a) output power spectrum and (b) output voltage waveform at 0.87 GHz.*



▲ *Fig. 20 Nonlinear analysis (a) output power spectrum and (b) output voltage waveform at 3 GHz.*

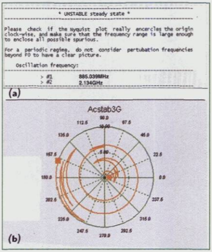
▲ *Fig. 21 Nonlinear stability analysis setup for 0.88 GHz oscillation.*





▲ *Fig. 22 Nonlinear stability analysis (a) results report and (b) Nyquist plot for 0.88 GHz oscillation.*

Fig. 23 Nonlinear stability analysis (a) results report and (b) Nyquist plot for 3 GHz maximum perturbation. ▼



spectrum shown in ***Figure 19***. Next, the oscillation frequency is set equal to the 3 GHz instability frequency and five harmonics are considered. The simulator computes a real oscillation frequency of 3 GHz with the output waveform and power spectrum shown in ***Figure 20***. The output power is approximately 13 dB lower than for the previous oscillation frequency.

Nonlinear Stability Analysis

Two oscillation frequencies (mathematical solutions) have been identified, one at 0.88 GHz and the other at 3 GHz. It now must be determined which of the two is really physically sustained, if either. It should be noted that even if only a single mathematical oscillation regime is determined, its stability must be checked to determine if it is really sustained. This is a specific limiting feature of all numerical simulators. The output of a numerical simulator is always a mathematical solution, the physical existence of which must be confirmed by a stability analysis. In contrast to time domain simulators, harmonic balance, DC and linear frequency domain simulators produce nonphysical solutions because, in the analysis setup, a fixed fundamental frequency basis must be selected. This characteristic is why stability analysis is a very important feature for RF and microwave designs.

For stability analysis of a periodic signal, such as from the oscillator regime, a maximum perturbation frequency equal to the fundamental frequency of the regime must be set. ***Figure 21*** shows the setup for 0.88 GHz maximum perturbation, which is the oscillation frequency. The simulator's stability analysis indicates that this oscillation regime will be sustained, as shown in ***Figure 22***. Similarly, the maximum perturbation frequency is set equal to the fundamental frequency of 3 GHz. The resulting stability analysis indicates that this regime is unstable, thus it cannot be physically sustained. The analysis also provides the frequencies of instability, as shown in ***Figure 23***.

Note that in the case of nonlinear stability, instability frequencies given by the simulator are offset frequencies. If f_{inst} is the offset instability frequency given by the simulator, the real frequency of instability is one of the frequencies $f_k \pm f_{inst}$, where f_k stands for DC and harmonic (or intermodulation) products of the steady-state regime. The simulator cannot solve the indetermination. Usually the determined frequency is DC $+f_{inst}$ or the fundamental tone, $-f_{inst}$, and design knowledge of the circuit leads easily to the proper value.

The main information required for nonlinear stability analysis is whether or not the circuit is stable (for the given biasing and input drive) or, in other words, if the waveform and power provided by the harmonic balance simulator are really physical. The actu-

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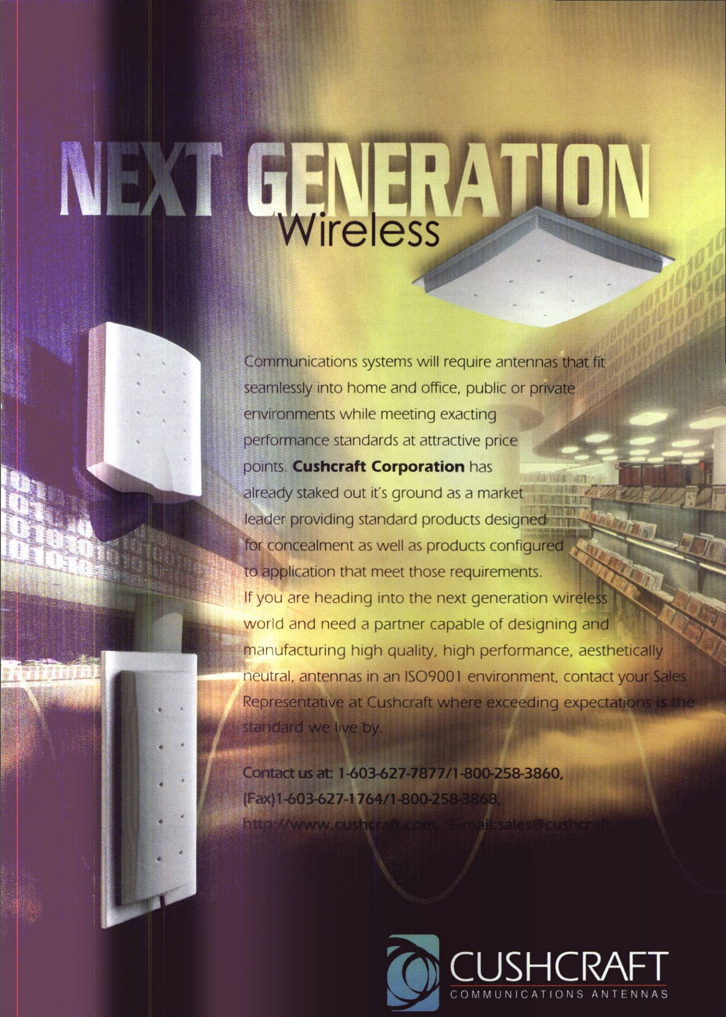
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al value(s) of instability frequency(ies) is only secondary information. The simulator provides this information with some indetermination to be resolved if necessary by the designer. In this example, the instability frequencies (offset) given by the simulator are 0.887 and 2.13 GHz, which, in turn, correspond to the physical oscillation frequencies previously determined (that is, 0.881 GHz ≅ DC + 0.887 GHz, 0.881 GHz ≅ 3 – 2.13 GHz).

CONCLUSION

Traditionally used stability parameters (K and Δ) most often are not sufficient to determine the stability or instability of a two-port active microwave network, especially for nonlinear circuits, and even linear circuits with a feedback loop. Requiring all active devices to be individually unconditionally stable is most often too stringent a demand and generally does not permit the designer to achieve optimum performance from a design. Stability analysis using Nyquist and bifurcation criteria avoids such limitations and enables designers to achieve better performance from their circuit with an added level of confidence that their circuits will be stable as an amplifier or an oscillator.

ACKNOWLEDGMENT

The simulations in this article were performed using the GoldenGate suite of simulators, products of Xpedion Design Systems Inc., Santa Clara, CA. Additional information may be obtained from the company's Web site at www.xpedion.com. ■

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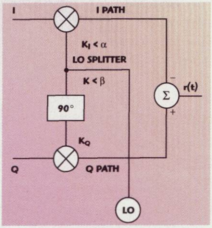
Modulation Imperfections in IS54/136 Dual-mode Cellular Radio

Nonideal in-phase and quadrature (IQ) calibration circuits on one hand, and the synthesizer's phase noise spurious response and carrier leakage on the other, affect modulation quality by degrading modulation parameters such as error vector magnitude (EVM), spectral mask and residual AM. The transmitter's gain chain and its output power amplifier linearity and synthesizer phase noise degrade the spectral purity of the transmitter and its spectral mask even further, consequently degrading the system's bit error rate (BER) performance. This article identifies typical modulation errors related to the RF and digital sections of a dual-mode[12,13] (TDMA/AMPS) cellular phone front end, and develops calibration methods that will effectively minimize the internal modulator errors by analyzing the output signal.

Quadrature modulators have been used for single-sideband (SSB) transmission and, in recent years, for quadrature AM (QAM) and other digital modulation schemes in digital radios. In dual-mode cellular phone radios, the modem is designed to use one modulator for both digital- and analog-mode transmissions. This single modulator simplifies the design and calibration of the RF section of the mobile unit.

Fig. 1 A quadrature modulator.



The block diagram of a quadrature modulator, shown in ***Figure 1***, comprises two mixers and a summation circuit to combine the mixer outputs. The inputs to the mixers are the information-bearing baseband (lowpass) i(t) and q(t) signals and a carrier of the local oscillator signal $\cos(\omega_c t)$ mixed with the I input, and $\sin(\omega_c t)$ mixed with the Q input. Thus, the transmitted signal is expressed as[17]

$$r(t) = \sqrt{i^2(t) + q^2(t)}\cos\left(\omega_c t + \tan^{-1}\left(\frac{q(t)}{j(t)}\right)\right)$$

$$= A(t)\cos(\omega_c t + \theta(t)) \qquad (1)$$

or

$$A(t)e^{j\theta(t)} = i(t) + jq(t) \qquad (2)$$

[Continued on page 302]

Avi Brillant
Optomic Microwaves Ltd.
Migdal Ha'Emek, Israel
David Pezo
Celletra Ltd.
Yoqne'am Elit, Israel

The later presentation of the quadrature phase-shift keying (QPSK) modulator output signal implies that any complex modulation can be generated using properly chosen amplitudes and phases of the I and Q signals. Moreover, since the I and Q signals have lowpass characteristics, the low frequency modulation circuitry is usually easier to implement at the required accuracy. This ease of implementation is a major reason for the popularity of quadrature modulators.

ANALOG FM MODULATION IMPAIRMENTS

Generating FM Using QPSK Modulators

To establish an FM signal, the carrier's amplitude is held constant and the phase is varied. Thus, the FM transmitted signal is represented by[17]

$$r(t) = A\cos\left(\omega_c t + \Delta\omega \int_{-\infty}^{t} m(\tau)d\tau\right) \quad (3)$$

where $\Delta\omega$ is the peak radian deviation and the peak magnitude of m(t) is 1. m(t) is the information-bearing signal and the phase $\theta(t)$ is given by the integral of $\Delta\omega m(t)$. From Equation 3 it can be concluded that the required baseband I and Q signals needed to generate an FM transmitted signal using a QPSK modulator are given by[17]

$$\begin{aligned} i(t) + jq(t) &= A(t)e^{j\theta(t)} \\ &= A(t)\exp\left(j\Delta\omega \int_{-\infty}^{t} m(\tau)d\tau\right) \\ &= A(t)\left\{\cos\left(\Delta\omega \int_{-\infty}^{t} m(\tau)d\tau\right)\right. \\ &\quad \left. + j\sin\left(\Delta\omega \int_{-\infty}^{t} m(\tau)d\tau\right)\right\} \end{aligned} \quad (4)$$

Residual AM of an FM Modulated Signal

In the case of ideal modulation, A(t) = A. However, in reality, there are several parameters that affect the amplitude A vs. time such as amplitude and phase imbalances between I and Q baseband inputs. These imbalances cause fluctuations in the magnitude A known as residual AM. Residual AM of an FM signal is defined as the amount of AM fluctuation on the FM signal amplitude. Residual AM is measured by the AM modulation index mi% as

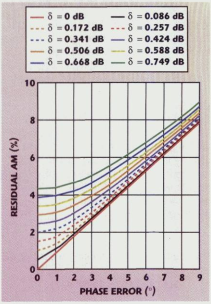
$$mi\% = \frac{m1 - m2}{m1 + m2} \times 100 \quad (5)$$

where

$$m1 = \max|A(t)|$$
$$m2 = \min|A(t)|$$

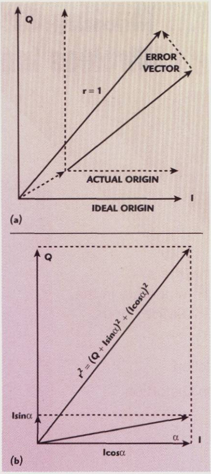
Figure 2 shows the residual AM plotted as a function of phase balance between I and Q, while the amplitude balance is a parameter.

It can be seen that the residual AM is more sensitive to the phase balance α than to the amplitude imbalance δ for high phase imbalance. However, amplitude imbalance correction is crucial for small phase errors because, in the ideal case, the I and Q trajectory is a circle with a radius equal to $A_I = A_Q = A$. However, in the nonideal case there is an amplitude imbalance between I and Q, phase imbalance α and DC offsets. The phase imbalance causes the projection of I onto Q where I is decreased by $\cos\alpha$ while Q is increased by $1 + \sin\alpha$. Hence, the circle turns into an ellipse with the offset axis due to the DC offsets caused by the carrier leakage.



▲ *Fig. 2 Residual AM vs. phase balance of a 1.004 kHz FM-modulated signal with 8 kHz peak deviation.*

[Continued on page 304]

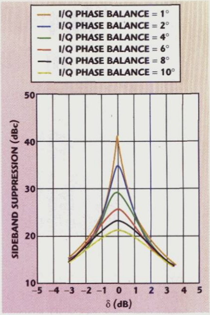


▲ *Fig. 3 The (a) origin offset and EVM errors and (b) I/Q phase error.*

DIGITAL π/4 DQPSK SIGNAL IMPAIRMENTS AND EFFECTS

Signal impairment types can be divided into two groups: linear impairments (such as I and Q amplitude imbalance, phase imbalance, and I and Q DC offset[14–16] causing the carrier leakage) and nonlinear impairments (such as AM to PM generally caused by the transmitter power chain, and LO phase noise affecting the phase imbalance by adding the LO's $\pm\Delta\theta$ RMS phase shift to the phase error between I and Q). The focus here is on the effects of linear impairments.

The transmitter's modulation impairments affect the constellation diagram of the transmitted signal, as shown in ***Figure 3***, and thus degrade the EVM and channel performance. I and Q amplitude imbalance affects the constellation symmetry and causes an ellipse-shaped constellation diagram, depending on which I or Q input is larger. The I and Q paths' phase mismatch causes constellation distortion in both the x and y directions because the orthogonal projection of one component on the other is not zero. The phase error rotates the constellation points from their original location. Because of DC offset of the I/Q inputs, the leakage of the carrier to modulator output affects the constellation origin offset. Since carrier leakage consists of two perpendicular components related to the I path and the Q path of the QPSK modulator, the constellation origin is shifted both in the x- and y-axis directions, respectively. By applying sine and cosine functions to the I and Q inputs, the resultant modulated signal becomes an SSB RF signal. Using these input signals, the modulator can be easily calibrated and checked for any malfunctioning and, thus, any constellation distortion and BER degradation can be eliminated.



▲ *Fig. 4 Sideband suppression vs. amplitude balance factor δ for various I/Q phase balance parameters.*

I and Q Amplitude Imbalance

The sideband suppression of an SSB signal is defined by[14–16]

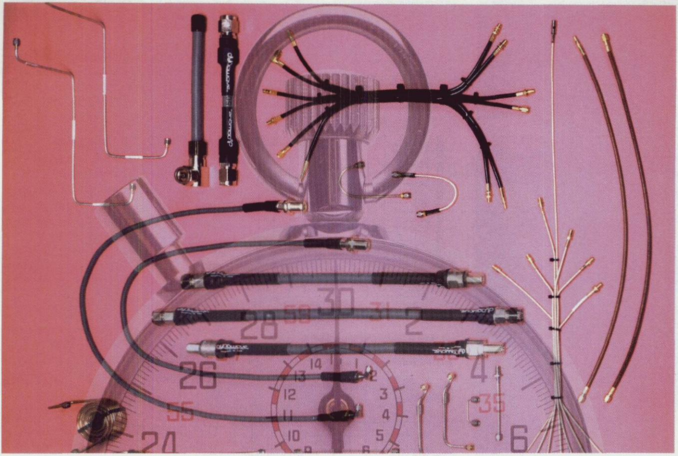
$$S[\text{dBc}] = 10\log\left[\frac{\delta^2 + 2\delta\cos\alpha + 1}{\delta^2 - 2\delta\cos\alpha + 1}\right] \quad (6)$$

where

α = phase imbalance between the I path and the Q path
δ = amplitude imbalance (in decibels or as a relative value)

Figure 4 shows the sideband suppression as a function of amplitude

[Continued on page 306]



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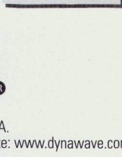

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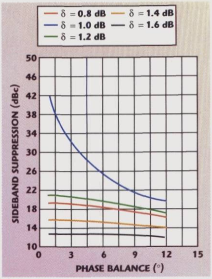
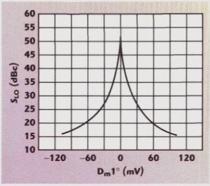


▲ *Fig. 5 Sideband suppression vs. phase balance for various I/Q relative balance factors.*

Fig. 6 Carrier suppression as a function of DC offset. ▼



balance between I and Q while the phase balance between I and Q is a parameter. It can be seen that phase imbalance α and amplitude imbalance δ limit sideband suppression so that, for 30 dB of suppression, α should be below 3° and δ below 0.3 dB.

I and Q Relative Phase Imbalance

The same reasoning for an SSB signal sideband suppression (when I and Q transmission phases are not in perfect match) can be used by setting Equation 6 for constant amplitude error. ***Figure 5*** shows the sideband suppression as a function of phase balance between I and Q while the amplitude balance between I and Q is a parameter. It can be seen that I and Q relative phase imbalance affects the sideband suppression for up to 10 percent amplitude imbalance. Phase errors over 3° limit the ability to calibrate the sideband suppression and require a phase-calibrating circuit. Hence, for low phase errors, only a simple amplitude matching circuit is required. For a 3° phase error and 0.3 dB amplitude error the sideband suppression is 30 dBc and thus the measured EVM is 4.5 percent.

I and Q DC Offset Calibration

The second calibration required is the DC offset between I and Q. This parameter affects the carrier leakage from the modulator. A carrier signal leaking to the antenna affects the origin offset of the constellation at the base station's receiver. The result may cause poor BER performance. The carrier suppression is given by[14,15]

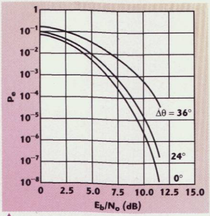
$$S_{LO}\left[dBc\right] = 10\log\left[\frac{\frac{1}{4}\left[1+2K\delta\cos\left(\beta-\alpha\right)+\left[K\delta\right]^2\right]}{D_{m1}^2+2K\delta D_{m1}D_{m2}\sin\beta+\left[K\delta D_{m1}\right]^2}\right] \tag{7}$$

The potential impairments of the modulator (shown previously) and input baseband signals (I vs. Q) are defined using

- D_{c1} = DC offset error of the LO at the I input
- D_{c2} = DC offset error of the LO at the Q input
- D_{m1} = DC offset error at the I input
- D_{m2} = DC offset error at the Q input
- α = phase error between I and Q inputs
- β = phase balance of the LO splitter within the modulator to quadrature
- δ = amplitude balance between I and Q inputs
- $K_I < \alpha$ = I path mixer transfer function, including the phase error α between I and Q inputs
- K_Q = Q path mixer transfer function, with zero phase
- K = amplitude balance of the LO splitter within the modulator

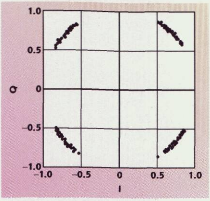
Figure 6 shows the carrier suppression as a function of DC offset voltage where the phase quadrature error β of the LO divider is a parameter between 1° and 10°, and α = 1°, δ = 1 dB and K = 1. It can be seen that the carrier leakage is highly sensitive

[Continued on page 308]



▲ *Fig. 7 Bit error probability for coherently detected BPSK with constant phase errors.*[5]

Fig. 8 A constellation diagram for QPSK with phase noise of $\Delta\theta_{RMS} = 5.75°$. ▼

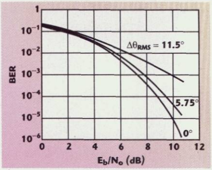


to DC offset errors of the I and Q inputs and thus offsets of less than 20 mV are essential for a carrier reduction of 30 dB and higher. By analyzing Equation 6 for constant α and DC offset, it can be shown that the carrier suppression is only slightly affected by errors in LO quadrature β or LO amplitude imbalance factor K.

NONLINEAR ANALYSIS

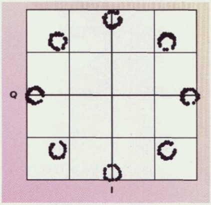
Frequency Accuracy of the Carrier

Frequency error causes a constant phase error offset ±Δθ from the required phase of the symbol point. The result can be seen as a constant rotation of Δθ radians of the constellation diagram around its center. A binary phase-shift keying (BPSK) modulated signal is a simple example to describe the frequency error effect.[9] The error probability ratio E_b/N_o of the modulated signal is reduced by $\cos^2\Delta\theta$; thus, it results in degradation of bit error probability of the system, so a higher energy per bit to noise ratio is required to achieve the same E_b/N_o. **Figure 7** shows bit error probability for various phase errors values.



▲ *Fig. 9 Bit error probability for coherently detected QPSK with phase noise.*[5]

Fig. 10 A constellation diagram for π/4 DQPSK with a spurious of −20 dBc within the channel band. ▼



Phase Noise

A practical synthesizer displays random frequency fluctuations around its center frequency known as phase noise. There are several ways to define the LO's phase noise. The common definition is SSB phase noise $\mathscr{L}(f)$[dBc/Hz]. However, with phase-modulated signals, the LO's phase stability $\Delta\theta_{RMS}$ as incidental phase modulation is used to describe the LO phase noise. An indication of the total phase stability of the LO within the information bandwidth is given with this last definition. For a stable oscillator used for communication radios the phase noise follows the relationship[17]

$$\text{if}\quad 2\int_{fa}^{\infty}\mathscr{L}(f)df << 1\text{rad}^2,$$

$$\text{then}\ \Delta\theta_{RMS} = \pm\sqrt{2\int_{fa}^{fb}\mathscr{L}(f)df} \qquad (8)$$

This phase error is a stochastic value that exists in both the I and Q vectors. As a result, both the I and Q signals would have the same phase error due to phase noise and the phase relationship between I and Q components is preserved when phase noise exists. Hence, r(t) becomes[17]

$$r(t) = \sqrt{i^2(t) + q^2(t)}\ \bullet$$
$$\cos\left[\omega_c t + \tan^{-1}\left(\frac{q(t)}{i(t)}\right) \pm \Delta\theta_{RMS}\right]$$
$$= A(t)\cos\left(\omega_c t + \beta(t) \pm \Delta\theta_{RMS}\right) \quad (9)$$

The bit error probability vs. E_b/N_o can be calculated analytically using

$$P_e\left(\frac{E_b}{N_o}, \theta\right) = \int_{-\infty}^{\infty} F_e\left(\frac{E_b}{N_o}, \theta\right) f(\theta)d\theta \qquad (10)$$

where

$F_e(E_b/N_o, \theta)$ = bit error probability for the given modulation technique as a function of E_b/N_o and a random phase error θ

$f(\theta)$ = distribution function of the phase noise θ

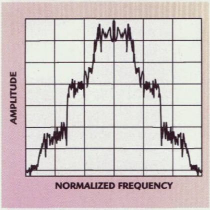
A Gausian distribution of mean zero and variance $\Delta\theta_{RMS}$ is assumed.

The phase noise results in random rotations of the constellation diagram around the center point. **Figure 8** shows a constellation diagram of a QPSK-modulated signal when the RMS phase error is 5.75°. **Figure 9** shows bit error probability of a QPSK-modulated signal for three $\Delta\theta_{RMS}$ phase error values. Phase noise results in a degradation in bit error probability. In an ideal communication system, BER goes to zero as E_b/N_o goes to infinity. In the presence of phase noise, the error probability goes to a nonzero value. As the phase noise power increases, the bit error increases, thus improvement of the bit error probability performance by increasing the E_b/N_o is limited.

Spurious Response

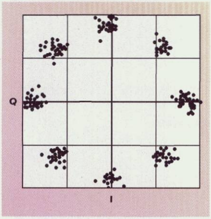
The effect of spurious outputs from the synthesizer on modulated signal quality depends on the frequency offset of the spurious signal from the synthesizer's desired frequency. Spurious signals within the channel band shift the symbols' position around their constellation target point and cause BER degradation. The shift radius of the symbols depends on the spurious-to-carrier power ratio. **Figure 10** shows the con-

[Continued on page 310]



▲ *Fig. 11 Out-of-band emission for a π/4 DQPSK-modulated signal.*

Fig. 12 A constellation diagram of a 20 dB signal-to-noise ratio π/4 DQPSK-modulated signal. ▼

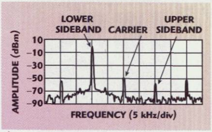


stellation diagram of a QPSK-modulated signal in the presence of a –20 dBc spurious signal. Out-of-channel band spurious signals contribute to the increment of the out-of-band emission.

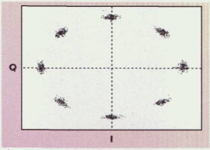
Power Amplifier Nonlinearities

In cellular portables, which are battery fed, it is important to design the transceiver for minimum power consumption. A lower power consumption power amplifier (PA) is more efficient but less linear. Nonlinearity of the PA results in AM-to-AM and AM-to-PM conversions. These conversions cause degradation in modulation quality and produce poor bit error probability and increased out-of-band emissions that reduce spectral efficiency. The nonlinear characteristics of the PA are represented by

$$s(t) = A(|g(t)|)e^{j\Phi(|g(t)|)}$$
$$= A(|g(t)|)e^{j[\phi(t)+\Phi(|g(t)|)]} \quad (11)$$

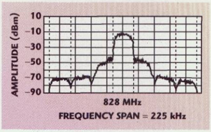


▲ *Fig. 13 Sideband suppression and carrier leakage calibration.*



▲ *Fig. 14 π/4 DQPSK constellation response at 36 dBm and EVM = 6.1 percent. (IS136 specification is 12 percent.)*

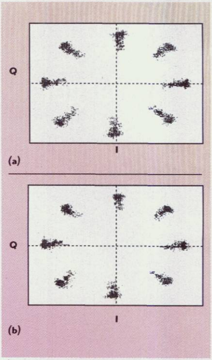
Fig. 15 The π/4 DQPSK spectral mask at 32.7 dBm at TDMA operation. ▼



where

$|g(t)|$ = magnitude of the input signal to the PA
$A(|g(t)|)$ = AM-to-AM conversion
$\Phi(|g(t)|)$ = AM-to-PM conversion
$\phi(t)$ = phase of the input signal r(t)

The effect of the AM-to-AM and AM-to-PM conversion of a PA results in out-of-band power emission known as spectral mask. The out-of-band power emission can be modeled by measuring $A(|g(t)|)$ and $\Phi(|g(t)|)$ functions, and analyzing the power spectrum of the output signal when a baseband signal waveform function is applied to $A(|g(t)|)$ and $\Phi(|g(t)|)$. An alternative way is to approximate $A(|g(t)|)$ and $\Phi(|g(t)|)$ by a power series and then applying a power spectrum analysis[6,10,11] efficiency. ***Figure 11*** shows the power spectrum of a π/4 differential QPSK (DQPSK) modulated signal shaped by a square root raised cosine filter with α = 0.35 that feeds the approximated PA.



▲ *Fig. 16 Temperature effects on a QPSK modulator while switched between Rx and Tx phase; (a) Tx (0°C) and (b) Tx (4°C) operation.*

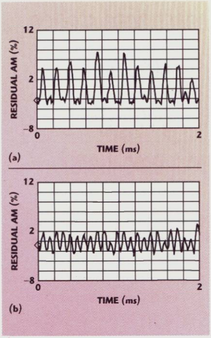
Thermal Noise

The transmitted symbols represented by the constellation diagram points take the form of a cloud of points around each ideal target of the constellation, as shown in ***Figure 12***. Thermal noise results in a modulation error that degrades the bit error probability of the system. Another effect of the transmitted noise is desensitization of the receiver. Generally, the transmit and receive channels within a transceiver are connected to the antenna through a duplexer. A wideband PA injects high level broadband noise into the receiver and, thus, reduces its sensitivity. The thermal noise effect on receiver sensitivity can be minimized by proper design of the out-of-band transmitter's noise rejection.

MEASURED RESULTS

A dual-mode subscriber unit containing a radio card with 440 to 450 MHz transmit and 485 to 495 MHz receive channels and 825 to 850 MHz transmit and 870 to 895 MHz receive channels was tested. The measured results are shown in ***Figures 13***, ***14***, ***15*** and ***16***. Calibration methods and optimization based on the aforementioned analysis were used in the dual-

[Continued on page 312]



▲ *Fig. 17 Residual AM (a) before and (b) after calibration.*

mode radio card, achieving good agreement between the measured and calculated results. ***Figure 17*** shows the measured residual AM before and after calibration.

CONCLUSION

When designing digital radio modulator and demodulator circuits, it is important to consider the effects of a nonideal modulator and the limited accuracy of its baseband interface network. The analytical approach to modulation impairments presented in this article can help in dealing with practical nonideal modulation effects, which are common to digital communication radios.

Special attention should be given to I and Q signal amplitude and phase balancing if a QPSK modulator is used to generate an analog FM signal. Special care also must be given to the modulator's I and Q input DC offset balancing to optimize carrier leakage (origin offset) problems. Optimizing the transmitter's power amplifier to an optimal biasing point and designing the synthesizers to exhibit low phase noise and spurious improves the spectral mask and constellation performance of the radio's transmitter.

Residual AM tested in an FM mode must be measured at a low power transmit level to ensure that the transmitter chain is operating in a linear region and there is no clipping or limiting mechanism that will improve the result and give a wrong impression. Some of the modulators are very sensitive to temperature changes while being switched on and off during Rx/Tx phases. This characteristic is due to the GaAs MESFET channel warm-up phenomena. It is recommended that the modulator be kept on at all times rather than using the power save option.

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Avi Brillant *received his BSc degree in electrical engineering from the Technion Israel Institute of Technology, Haifa in 1986. From September 1986 to July 1993, he was with MicroKim Ltd. (formerly a subsidiary of M/A-COM) in Haifa as a design engineer in the Amplifiers and Sources Group. In 1993, Brillant joined MTI Technology and Engineering Ltd. in Tel-Aviv as a system engineer. At the same time he also was a consulting engineer for BreezeCom (LanAir) and designed MTI's first WLL product for the Tadiran Wireless Group. In July 1995, Brillant joined Optomic Microwaves Ltd. in Migdal-Ha'Emek as a system design engineer and, later, was named program leader of the IS54/IS55 Dual-mode WLL IUSATEL Cellular Radio for Mexico with the Telrad Telephony Division. Currently, Brillant is an Optomic board member and senior engineer in charge of communications products for VSAT, LMDS, microwave and mm-wave links, and cellular applications. He is also a member of the Israeli MMIC Consortium. He can be reached via e-mail at optomic@optomic.co.il or by phone 972-6-6545440 or fax 972-6-6545382.*

David Pezo *received his BSc degree in electrical engineering from the Technion — the Israeli Institute of Technology — in 1988. He worked as a system engineer at MTI Technologies and Engineering in Tel-Aviv before joining Telrad Telephony in Lod as a project manager and system engineer of the IS54 WLL in 1995. Currently, he is a program manager at Celletra, Yoqne'am-Elit, Israel. Pezo is also completing his MSc degree in the field of communications in the engineering department of Tel-Aviv University. He can reached via e-mail at dpezo@celletra.com or by phone 972-4-9592522 or fax 972-4-9592523.*

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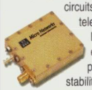

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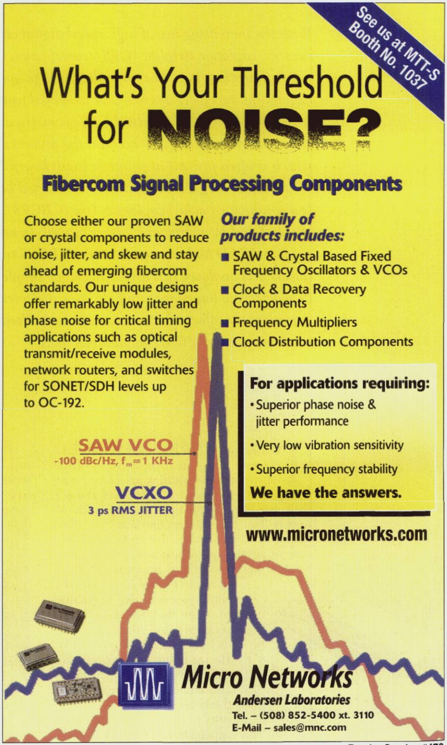


Reader Service #470

An Analysis of Enclosed Coplanar Strips

With the increasing use of high speed digital circuits in modern electronic devices, coplanar stripline (CPS) transmission lines are of major importance as interconnecting lines. For example, the high speed digital circuits used in differential receivers operate best when fed using CPS balanced transmission lines. However, the theoretical CPS geometry and associated current design equations do not take into account the presence of a bottom ground conductor, which is often present in printed circuit board MIC or MMIC configurations. When a bottom ground conductor is inserted below a CPS, the resulting structure is a conductor-backed coplanar strip (CBCPS). Such a configuration is often encountered in microwave mixers as well. In addition, until today no simulation model in CAD tools existed for these CBCPS transmission lines. Using current quasistatic analysis, this article develops simple closed-form equations for characteristic impedance and effective dielectric constant for CBCPSs and

made by J.B. Knorr and K.D. Kuchler[2] with a full-wave analysis, and then by others with quasistatic[3,4] or full-wave methods.[5] Assuming that complementary lines give equal phase speed for a signal, I.J. Bahl et al.[6] have developed expressions for CPS characteristic impedance and effective dielectric constant that consider the finite h value.

The second difference is the inevitable conductor thickness t. The resulting effect was originally evaluated by H.A. Wheeler[7] for the microstrip case and subsequently applied to CPS by K.C. Gupta et al. In detail, an extra width dw function of t is added to each strip width, and a new CPS with zero-thickness conductors is evaluated. The dimensions of the CPS are

$$\begin{aligned} w_t &= w + dw \\ s_t &= s - dw \end{aligned} \qquad (1)$$

where

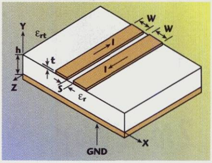
$$dw = \frac{1.25t}{\pi}\left[1 + \ln\left(\frac{4\pi w}{t}\right)\right]$$

Unequal-width CPS configurations have been studied by I. Kneppo and J. Gotzman[8] and losses have been examined by K.C. Gupta[6] et al. High speed pulse propagation in CPSs has also been investigated,[9,10] verifying the good capability of this transmission line for that purpose.

CBCPS ANALYSIS

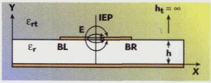
The CBCPS geometrical structure to be analyzed is shown in ***Figure 3***. It is assumed that a pure TEM mode propagates in this transmission line. (This assumption is true only if a homogeneous dielectric media surrounds the strips.) The conductor thickness t is assumed to be infinitesimal. The specialized theoretical analysis of this structure is performed once for the top-side half-space and once for the bottom dielectric space. This method of proceeding is suitable when a conformal transformation method[11] is employed for the analysis, as in this case.

Observing the electric field strength lines shown in ***Figure 4***, an ideal electric plane (IEP) can be placed at the middle of the spacing s and orthogonal to the ground plane to simplify the analysis. According to the TEM propagation mode this assumption is believed to be true. Due to this symmetry, only one-half of the bottom side, indicated with BL and



▲ *Fig. 3 The CBCPS's geometrical structure.*

▼ *Fig. 4 Electric field strength.*



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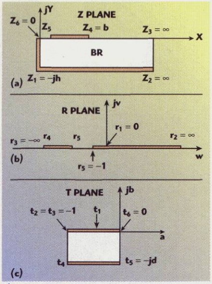
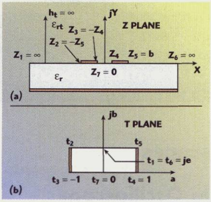


▲ *Fig. 5 Analysis of one-half of the structure.*

▼ *Fig. 6 C_t evaluation.*



BR, is analyzed, as shown in ***Figure 5***. This geometry will be transformed into the T-plane structure displayed in the figure. However, note that the capacitance evaluated in the T-plane structure is two times that for the complete CBCPS structure since one-half of the distance s is being considered in the T plane.

The transformation between the Z and R planes is performed using the equation $z = AI_1 + B$ where A and B are constants. I_1 is expressed as

$$I_1 = \int (r+1)^{-1/2} r^{-1/2} dr \qquad (3)$$

This transformation maps the BR region of the Z plane into the upper plane of the R plane. Solving the previous simple integral and applying the $t_6 = 0 \leftrightarrow r_6 = -1$ and $z_1 = -jh \leftrightarrow r_1 = 0$ relationships, the desired transformation is

$$z = \frac{2h}{\pi} \ln\left(\sqrt{r} + \sqrt{r+1}\right) - jh \qquad (4)$$

and

$$r_4 = -\cosh^2\left(\frac{\pi z_4}{2h}\right)$$

and

$$r_5 = -\cosh^2\left(\frac{\pi z_5}{2h}\right) \qquad (5)$$

The geometry in the R plane is then mapped to the T plane through another Schwarz-Christoffel[12] transformation $t = CI_2 + D$. The integral involved in such a transformation is expressed as

$$I_2 = \int (r+1)^{-1/2} \left(r + |r_4|\right)^{-1/2} \left(r + |r_5|\right)^{-1/2} dr \qquad (6)$$

that with the variable substitution

$$r = \left(1 - |r_5|\right) v^2 - 1 \qquad (7)$$

can be transformed in the elliptic integral of first kind $F(v, p_b)$,[13] with parameter p_b given by

$$p_b = \frac{\operatorname{senh}\left(\frac{\pi z_5}{2h}\right)}{\operatorname{senh}\left(\frac{\pi z_4}{2h}\right)} \equiv \frac{\operatorname{senh}\left(\frac{\pi s}{4h}\right)}{\operatorname{senh}\left[\left(\frac{\pi}{2h}\right)\left(\frac{w+s}{2}\right)\right]} \qquad (8)$$

Thus, the final transforming equation can be written as

$$t = QF(v, p_b) + E \qquad (9)$$

where Q and E are constants.

Applying the relationships $t_6 = 0 \leftrightarrow r_6 = -1$, $t_4 = -1 - jd \leftrightarrow r = r_4$ and $t_5 = -jd \leftrightarrow r = r_5$, the desired value of d is $K(p_b)/K(p_b')$, where K() is the complete elliptic integral of the first kind.[13] The primed parameters are the so-called complementary parameters and are evaluated as $p' = (1 - p^2)^{0.5}$. Therefore, the resulting capacitance per unit length of the T-plane structure is $C_{bs} = \varepsilon_0 \varepsilon_r K(p_b')/K(p_b)$ and, consequently, the bottom capacitance of the Z plane is

$$C_b = \frac{0.5\varepsilon_0 \varepsilon_r K(p_b')}{K(p_b)} \qquad (10)$$

The ratio of the elliptic integral was evaluated by W. Hilberg,[14] and is given by

$$\frac{K(p')}{K(p)} = \frac{1}{\pi} \ln\left[2\frac{1+(p')^{0.5}}{1-(p')^{0.5}}\right] \quad \text{for } 0 \le p \le \frac{1}{\sqrt{2}}$$

$$\frac{K(p')}{K(p)} = \pi\left\{\ln\left[2\frac{1+p^{0.5}}{1-p^{0.5}}\right]\right\}^{-1} \quad \text{for } \frac{1}{\sqrt{2}} \le p \le 1 \qquad (11)$$

To evaluate the total capacitance C per unit length of the CBCPS structure the top capacitance C_t of the unlimited top side of the CPS must be evaluated, as shown in ***Figure 6***. The Schwarz-Christoffel transformation $t = GI_3 + H$ involves the integral I_3, which is given by

$$I_3 = \int \left(z^2 - z_4^2\right)^{-1/2} \left(z^2 - z_5^2\right)^{-1/2} dz \qquad (12)$$

that with the variable substitution

$$z = z_4 q$$

can be rewritten as

$$I_3 = -\left(\frac{1}{z_5}\right) F(q, p) \qquad (13)$$

where

$$p = \frac{z_4}{z_5} \equiv \frac{s}{(s+2w)}$$

The final transforming equation is

$$t = LF(z, p) + M \qquad (14)$$

where L and M are constants.

Such a transformation maps the $y > 0$ half plane of the Z plane into the internal region of the rectangle in the T plane. Then, applying the relationships $t_2 = -1 + je \leftrightarrow z = z_2$, $t_3 = -1 \leftrightarrow z = z_3$ and $t_7 = 0 \leftrightarrow z = z_7$, the desired value of e is $K(p')/K(p)$, and the resulting capacitance per unit length C_t

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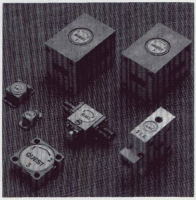


for the top side of the Z plane is

$$C_t = \frac{0.5\varepsilon_0\varepsilon_{rt}K(p')}{K(p)} \qquad (15)$$

where ε_{rt} is the relative dielectric constant of the dielectric above the substrate. $\varepsilon_{rt} = 1$ is assumed in every function unless otherwise stated. Therefore, the resulting total capacitance per unit length C of the CBCPS is

$$C = 0.5\varepsilon_0\left[\frac{\varepsilon_{rt}K(p')}{K(p)} + \frac{\varepsilon_r K(P_b')}{K(p_b)}\right] \qquad (16)$$

Then, using the previous equation in the general definition of the effective relative dielectric constant for the quasistatic case yields

$$\varepsilon_{reh} = \frac{C(\varepsilon_r)}{C(\varepsilon_r = 1)} = \frac{\dfrac{\varepsilon_{rt}K(p')}{K(p)} + \dfrac{\varepsilon_r K(p_b')}{K(p_b)}}{\dfrac{K(p')}{K(p)} + \dfrac{K(p_b')}{K(p_b)}} \qquad (17)$$

Evaluating the effective relative dielectric constant for the original CPS produces

$$\varepsilon_{re\infty} = \frac{(\varepsilon_r + \varepsilon_{rt})}{2} \qquad (18)$$

The characteristic impedance ζ can be obtained by the well-known equation for TEM transmission lines. $\zeta = 1/Cv$, where v is the light propagation in the medium. The final expression is

$$\zeta(p, h/b, \varepsilon_r, \varepsilon_{rt}) = \frac{240\pi}{\sqrt{\varepsilon_{reh}}}\left[\frac{K(p')}{K(p)} + \frac{K(p_b')}{K(p_b)}\right]^{-1} \qquad (19)$$

Since, after a simple De l'Hopital application,

$$\lim_{h\to\infty} p_b = p \qquad (20)$$

the elliptic integrals evaluated with p_b or p have the same value for $h\to\infty$ and, consequently,

$$\lim_{h\to\infty} \varepsilon_{reh} = \varepsilon_{re\infty} \qquad (21)$$

In addition, it is simple to demonstrate that

$$\lim_{h\to 0} p_b = 0 \qquad (22)$$

and, consequently, using Hilberg's equation,

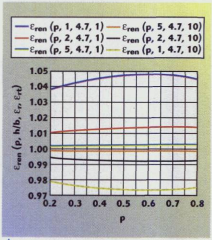
$$\lim_{h\to 0} \zeta = 0 \qquad (23)$$

and

$$\lim_{h\to 0} \varepsilon_{reh} = \varepsilon_r \qquad (24)$$

Equation 23 is physical since when h = 0 the two conductors are short circuited and the charactersitic impedance of the line is, of course, zero while Equation 24 is nonphysical. In fact, if h = 0, no substrate with a ε_r value exists, and the solution to Equation 24 is only analytical, showing that when h = 0 the electromagnetic field tends to be completely concentrated in the substrate. However, it has no physical result since for h = 0 no transmission line exists and $\zeta = 0$.

The value ε_{ren} (p, h/b, ε_r, ε_{rt}) of ε_{reh} normalized to $\varepsilon_{re\infty}$ is shown in ***Figure 7*** as a function of p for ε_r = 4.7. Two sets of three curves each are displayed: one set is for ε_{rt} = 1; the other has ε_{rt} = 10. Three curves are plotted for each set in accordance with values of h/b = 1, 2, 5. Note that when h increases, the value of ε_{ren} decreases toward 1 if $\varepsilon_r > \varepsilon_{rt}$, or increases toward 1 if $\varepsilon_r < \varepsilon_{rt}$. It can be observed that the bottom ground plane forces the electromagnetic field to be concentrated in the bottom



▲ *Fig. 7* ε_{ren} *(p, h/b,* ε_r*,* ε_{rt}*) as a function of p.*

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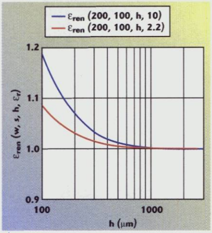
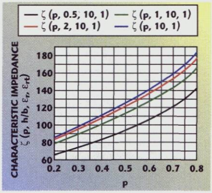


▲ *Fig. 8* ε_{ren} *vs. h.*

▼ *Fig. 9 Characteristic impedance vs. p.*



substrate. Since the maxima or minima of the curves correspond to p ≈ 0.6, the electromagnetic field for w/s ≈ 0.6 is maximally concentrated in the substrate. An interesting graph showing that $\varepsilon_{ren} \rightarrow 1$ for $h \rightarrow \infty$ is shown in ***Figure 8*** for w = 200 μm, s = 100 μm and ε_r = 10 and 2.2 vs. h in micrometers.

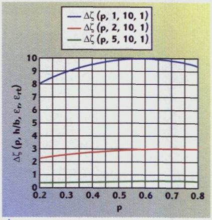
Figure 9 shows the characteristic impedance for the CBCPS for $\varepsilon_r = 10$ as a function of p and h/b equal to 0.5, 1 and 2. ζ_u is the impedance of the unlimited CPS (that is, the original CPS), given by

$$\zeta_u(p, \varepsilon_r, \varepsilon_{rt}) = \frac{120\pi}{\sqrt{\varepsilon_{re\infty}}} \frac{K(p)}{K(p')} \quad (25)$$

An interesting function is the percentage error $\Delta\zeta$ between ζ and ζ_u vs. p, defined as

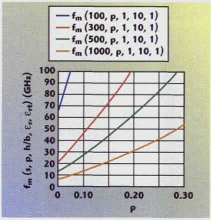
$$\Delta\zeta(p, h/b, \varepsilon_r, \varepsilon_{rt}) = 100 \frac{(\zeta_u - \zeta)}{\zeta_u} \quad (26)$$

and shown in ***Figure 10***. Note that since h/b ≥ 3 the error is below three percent, and this characteristic is quite independent of the ε_r value.



▲ *Fig. 10 Percentage error between the CPSG characteristic impedance and the impedance of the original CPS.*

▼ *Fig. 11* f_m *vs. p for various values of s.*



It is important to observe that small values of p mean small values for s and/or large values for w. However, this last condition is not advisable in practice since a large w value causes a possible growth of spurious modes. The existance of these unwanted modes in CBCPS can be rigorously justified with full-wave methods[15] and is still under investigation.[16] Higher order modes, essentially transverse modes, are also possible starting at a frequency f_m approximated by

$$f_m = \frac{v_o}{2w\sqrt{\varepsilon_{reh}}} \quad (27)$$

where

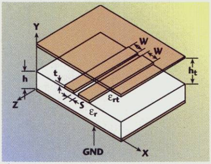
v_o = free space speed of light

Figure 11 shows the results when the expression in Equation 17 is substituted for ε_{reh}. Using different values of h/b it is simple to verify that the frequency f_m decreases if h/b is decreased.

[Continued on page 324]

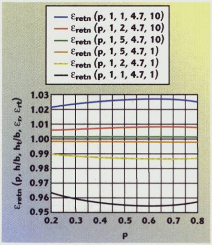
CONDUCTOR-BACKED AND TOP-SHIELDED CPS ANALYSIS

Figure 12 shows the geometrical structure of a conductor-backed and top-shielded CPS. In practice, a top ground conductor is placed over the CPS's two conductor layers at a distance h_t. The analysis of this structure is



▲ *Fig. 12 A conductor-backed and top-shielded coplanar strip.*

▼ *Fig. 13 ε_{retn} vs p.*



performed in a fashion similar to the previously completed evaluation of the bottom capacitance. However, in this case the analysis also must be applied for the region between the top ground conductor and the CPS layer. Therefore, the equivalent capacitance C_s of the structure and its effective relative dielectric constant are expressed as

$$C_s = 0.5\varepsilon_0\left[\frac{\varepsilon_{rt}K(p_t')}{K(p_t)} + \frac{\varepsilon_r K(p_b')}{K(p_b)}\right] \quad (28)$$

$$\varepsilon_{ret} = \frac{\dfrac{\varepsilon_{rt}K(p_t')}{K(p_t)} + \dfrac{\varepsilon_r K(p_b')}{K(p_b)}}{\dfrac{K(p_t')}{K(p_t)} + \dfrac{K(p_b')}{K(p_b)}} \quad (29)$$

where p_t is given by the previously displayed graph of ε_{ren} vs. h, replacing h with h_t. Note also in this case that

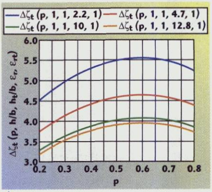
$$\lim_{h_t, h\to\infty} \varepsilon_{ret} = \varepsilon_{re\infty} \quad (30)$$

The characteristic impedance is now given by

$$\zeta_t = \frac{240\pi}{\sqrt{\varepsilon_{ret}}}\left[\frac{K(p_t')}{K(p_t)} + \frac{K(p_b')}{K(p_b)}\right]^{-1} \quad (31)$$

where ε_{ret} is given in Equation 29. Of course, the primed parameters p_b and p_t are the complementary parameters of p_b and p_t.

The value ε_{retn} (p, h/b, h_t/b, ε_r, ε_{rt}) of ε_{ret} normalized to ε_{reh} is shown in



▲ *Fig. 14 Change in characteristic impedance vs. p.*

Figure 13 as a function of p with h/b = 1 and ε_r = 4.7. Two sets of three curves each are displayed: one set is for ε_{rt} = 1; the other has ε_{rt} = 10. For each set, three curves are drawn in accordance with h_t/b = 1, 2, 5 values. Note that when h_t increases the value of ε_{retn} decreases toward 1 if $\varepsilon_r < \varepsilon_{rt}$, or increases toward 1 if $\varepsilon_r > \varepsilon_{rt}$. It is simple to verify that

$$\lim_{h_t\to\infty} \varepsilon_{ret} = \varepsilon_{reh} \quad (32)$$

The percentage error $\Delta\zeta_t$ between ζ_t and ζ vs. p, defined as

$$\Delta\zeta_t(p, h/b, h_t/b, \varepsilon_r, \varepsilon_{rt}) = \frac{100(\zeta - \zeta_t)}{\zeta} \quad (33)$$

is shown in ***Figure 14***, with h/b = h_t/b = 1.

[Continued on page 326]

CONCLUSION

A quasistatic approach has been used to study CBCPS. Formulas for characteristic impedance and effective dielectric constants have been given, which are well suited to be simply implemented in CAD simulation tools to help design microwave devices employing balanced transmission lines. The results of the analysis show that the effect of the bottom ground conductor decreases the characteristic impedance of the CPS. A top-shielded CBCPS also has been studied, and analysis formulas have been given for this transmission line configuration. ■

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Franco Di Paolo *received his doctorate degree in electronic engineering in 1984 from Università degli studi di Roma 'La Sapienza.' He started working at Ericsson, Rome in 1986 as an RF hardware designer and joined Elettronica SpA, Rome in 1992 as a microwave and RF hardware designer in wide bandwidth microwave circuits and MMICs. Currently, he is chief research engineer at TELIT SpA's Satellite Division in Rome. Di Paolo's research interests include applied electromagnetism and RF/microwave analog hardware design. He can be reached via e-mail at franco.di.paolo@ntt.it.*

DC and Pulsed IV Characteristics of GaAs MESFET Devices

New measurement procedures using a DC and pulsed IV characterization system illustrate the significant effect that the thermal and frequency dispersion phenomena in GaAs MESFETs have on the IV characteristics of the device. The new procedures presented enable the effects of self-heating and frequency dispersion and the interaction between the two to be observed independently.

The characterization of GaAs MESFET and HEMT devices under pulsed conditions[1,2] has been used extensively during recent years. This measurement idea was originally proposed because it enables the self-heating effect to be controlled. However, interpretation of the resulting data from such measurement systems is not as straightforward as it may appear. The complex interaction between self-heating and the frequency dispersion effect, which is temperature, frequency and electric field dependent, is usually not considered fully. In this article, a variety of IV measurements carried out under DC and pulsed conditions illustrate the strong influence of frequency dispersion and self-heating on device characteristics. The proposed measurements enable these two effects to be considered separately.

MEASUREMENTS

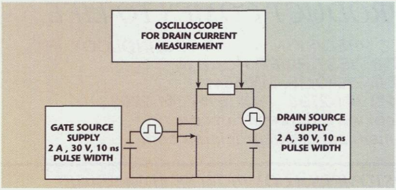
The measurement system employed to investigate the frequency dispersion and thermal effects in GaAs devices is shown in ***Figure 1***.[3] Under software control this system enables both static and pulsed IV measurements to be performed as well as pulsed measurements from different static points.

Static IV measurements can be performed over a 0 to 30 V voltage range, and large power devices can be accommodated since each DC supply is capable of delivering 2 A. A user-defined delay time can be used to control the time (after the DC bias voltages are applied and before the drain current is measured). This feature is useful in assessing the self-heating effect from a DC point of view.

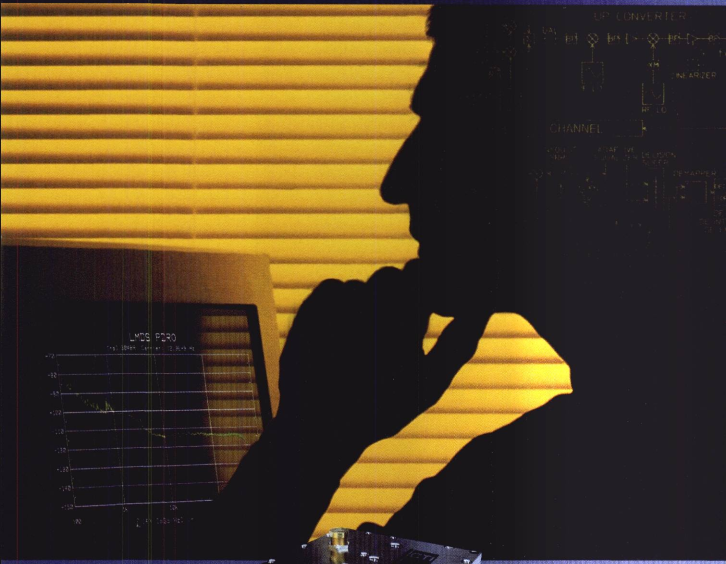
Pulsed IV measurements also can be performed over a 0 to 30 V voltage range with current levels of up to 2 A. The pulsed measurements are performed by pulsing the drain source and gate source terminals, pulsing only the gate source terminal while the drain source terminal is swept in a DC manner and pulsing only the drain source terminal while the gate source is swept in a normal DC manner. From a thermal point of view these three situations are the same provided the device is, from a static point of view, pinched off. However, as will be demonstrated, these three cases produce

[Continued on page 330]

Fig. 1 The two-pulse measurement system.



J. Rodriguez-Tellez
University of Bradford
Bradford, West Yorkshire, UK
T. Fernandez, A. Mediavilla
and A. Tazon
University of Cantabria
Santander, Spain



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dynamic characteristics that are quite different.

A pulse width of 1 µs with a repetition rate of 1 ms was employed for the results presented in this article. For the MESFETs considered this pulse width is sufficiently short to ensure that no significant self-heating takes place.[2] The 1 ms period also corresponds to a measurement frequency after the frequency dispersion effect has taken place. For the devices considered here, the dispersion effect was found to be pronounced in the 40 to 800 Hz region. In this frequency range, the variation of the drain-source resistance with frequency resembles the frequency response of a lowpass filter.[4–6] Beyond 800 Hz the device remained dispersive; however, this dispersion was found to be to a much lesser extent and remained reasonably constant over a broad frequency range.

The pulsed measurements described previously can be performed with the device biased from a static point of view at any user-defined position. This measurement procedure enables the self-heating arising from the static bias and its subsequent effect on the dynamic characteristics to be investigated. However, this procedure is not particularly useful from the point of view of observing the dispersion and thermal effects independently. It is also worth bearing in mind that the pulses generated to measure the dynamic characteristics can be positive, negative or zero depending on the static point selected and the dynamic bias point to be measured. This point is important since it has a bearing on the self-heating and frequency dispersion effects.[4]

The three described basic measurements and the conditions specified are by no means an exhaustive list of the capabilities of the measurement system. However, the results presented in this article only utilize these three simple techniques.

DEVICES CONSIDERED

In order to describe the general findings of this work, a 900 µm gate-width (four fingers with 225 µm gate width per finger), –0.8 V pinch-off voltage, 0.5 µm gate-length ion-implanted GEC Marconi Materials Research Ltd. MESFET is used as the demonstrator. Extensive thermal data concerning this and the other devices considered from a static point of view have been published previously.[7] Although similar trends in the measured data were observed with the other devices considered, interesting differences were discovered. These results were not unexpected since the device design (such as number of fingers, gate width and pitch between fingers) has a significant bearing on its thermal properties, which, in turn, modify the dispersive qualities of the device. However, this aspect is outside the scope of this article and the behavior reported here is generally true of the other devices.

SELF-HEATING DUE TO STATIC BIAS

The measured DC drain current of the device at V_{gs} = 0 V and V_{ds} = 4 V as a function of delay time is shown

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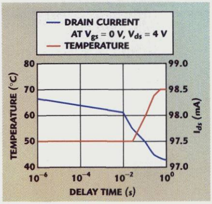


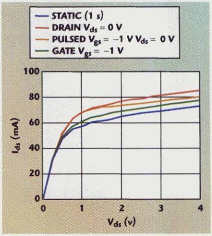
▲ *Fig. 2 Drain current and temperature vs. delay time for the 4 × 225 μm MESFET.*

in **Figure 2**. Even after the static bias is allowed to settle for one second, the drain current is not unduly smaller than when a faster acquisition time is employed. For delay times shorter than 10 ms, the drain current is not significantly affected. This result is in keeping with the observations of others[1,2,8] who have shown MESFETs to take a relatively long time before the self-heating effect has a significant impact on the IV characteristics of the device. At the bias point selected the temperature of the device was determined to be 70°C with the use of liquid crystals.

DC measurements performed at other bias points not unexpectedly also showed a relatively small change in the IV characteristics as the delay time was varied in the microsecond to millisecond range. The temperature of the device clearly varied as the power dissipated varied. For this device the thermal impedance was measured to be 125°C/W.

SELF-HEATING DUE TO PULSED BIAS

As a check on the self-heating issue considered previously, the drain current of the device was monitored with an oscilloscope as the drain source and gate source junctions were pulsed from the static point of $V_{gs} = -1$ V, $V_{ds} = 0$ V to the dynamic point of $v_{gs} = 0$ V, $v_{ds} = 4$ V. In this test the period was set to 0.1 s (10 Hz) to ensure that the frequency dispersion effect did not affect the measured data. This condition was confirmed by comparing the dynamic and static values of the drain current. With this period the pulse width was then increased from 10 ns until the self-heating had a measurable effect on the drain current. This point was determined to be when a pulse width of 10 ms was employed, which agrees with the earlier measurement.



▲ *Fig. 3 The MESFET's pulsed characteristics.*

Therefore, the use of a pulse width of 1 μs in order to measure the dynamic characteristics of the device seems appropriate as a means of eliminating the self-heating effect. This issue should be reconsidered for other GaAs devices such as HEMTs and HBTs since the thermal time constant of these devices may be faster. The period or measurement frequency also should be selected to ensure that the self-heating effects are eliminated. The use of 1 kHz seems appropriate for the MESFETs considered here. This frequency also ensures that the dynamic IV characteristics measured correspond to a frequency point after the dispersion effect has settled. The employment of different measurement frequencies is useful if the area where the device is strongly frequency dependent is to be observed.

DYNAMIC CHARACTERISTICS

A variety of curves measured under static and pulsed conditions are shown in **Figure 3**. For the pulsed cases a pulse width of 1 μs with a period of 1 ms was employed. For the static curve a delay time of 1 s was used to ensure a stable self-heating temperature. All of the curves correspond to the v_{gs} (or V_{gs}) = 0 V case.

Curve 1 corresponds to the case where the drain source is pulsed from the static point of $V_{ds} = 0$ V while the gate source is maintained at $V_{gs} = 0$ V (static). Curve 2 corresponds to the case where the gate source is pulsed

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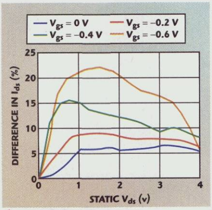
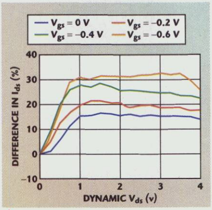
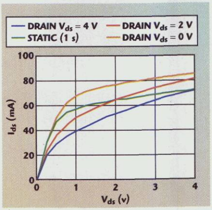


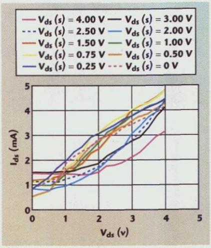
▲ *Fig. 4 Percentage difference in I_{ds} when gate is pulsed from V_{gs} (static) = –1 V.*



▲ *Fig. 5 Percentage difference in I_{ds} when drain is pulsed from V_{ds} (static) = 0 V.*



▲ *Fig. 6 Pulsing drain from various static points for V_{gs} = 0 V.*



▲ *Fig. 7 Pulsing drain from various static points for V_{gs} (static) = –0.8 V.*

from the static point of V_{gs} = –1 V while the drain source is swept in a normal DC manner. Curve 3 corresponds to the case where the gate source and drain source junctions are pulsed from the static points of V_{gs} = –1 V, V_{ds} = 0 V. From a thermal point of view these three pulse cases are the same. Since the device is, from a static point of view, in the off state, the ambient temperature and the pulse parameters are the same. It should also be remembered that the drain source resistance of the device is high (> 10 kΩ) when it is pinched off. If the intention is to ensure that no self-heating takes place, it is not necessary to pulse the gate and drain terminals. However, this facility does lead to interesting behavior as demonstrated in the data.

If it is accepted that for the pulsed curves the ambient and any self-heating temperatures are the same, then it follows that the differences between curves 1, 2 and 3 are due to frequency dispersion effects. Bearing in mind the previous results obtained with the DC measurements, the difference between curve 2 and the DC curve is due to thermal (approximately 1 mA) and frequency dispersion effects. Even if this difference was entirely due to thermal effects, it is still considerably smaller than the differences observed between the pulsed curves.

The presentation of the data as shown in the graph, while interesting, can lead to the erroneous conclusion that frequency dispersion effects are not relevant in the linear region. ***Figures 4*** and ***5*** show the same information but it is expressed as the percentage difference in the drain current between the static and the pulsed curves. Note that the dispersion effect increases as the gate source voltage becomes more negative and, therefore, the drain current in the device decreases. The data plots illustrate quite well the dependence of the dispersion effect on electrical field and reinforce the fact that it is not a thermal effect, which would have the opposite effect. Note also that pulsing the gate or drain produces a similar percentage difference in the drain current for the same change in the electric field. Also notice the almost linear dependence of the dispersion effect on electric field in the linear region.

DYNAMIC BEHAVIOR FROM DIFFERENT STATIC POINTS

Of course, the pulse measurements can be performed with the device biased from a static point of view at any point. Doing so means the amount of self-heating can be controlled and its effect on the dynamic characteristics observed. ***Figure 6*** shows the response of the device for the V_{gs} = 0 V pulse case when the V_{ds} static point is varied. The DC curve is superimposed for comparison purposes. The drain-source terminal is pulsed and the gate-source junction is kept at a fixed potential of 0 V only for the pulsed curves.

The pulsed measurements are performed for the case where the static value of V_{ds} is 4 V using negative pulses of 1 µs width with a period of 1 ms. This curve corresponds to the device at its hottest point because of the DC power dissipated. Since it has been previously demonstrated that a 1-µs-wide positive-going pulse is incapable of causing any significant self-heating, it follows that a 1-µs-wide negative-going pulse is unable to cool down the device. Therefore, from a thermal point of view, the device is at a constant temperature corresponding to the power dissipated at V_{ds} = 4 V. The same is true for the V_{ds} = 2 V curve where no additional heating is introduced above 2 V (positive-going pulses). Below 2 V (negative-going pulses), the device temperature corresponds to the power dissipated at 2 V.

While demonstrating that by altering the static bias the characteristics of the device are changed, the presented data should be viewed with caution. It would be incorrect, for example, to assume that the differences between the pulsed curves are entirely due to self-heating effects. Certainly by adjusting the static bias the self-heating has been altered, but by doing so the dispersion effect has also been modified. This complication arises not just because of the dependence of the dispersion effect on temperature but also because of its dependence on electric field and frequency. As shown in ***Figure 7***, the same experiment was re-

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peated, but this time the gate-source voltage was fixed at –0.8 V, which is very close to the pinch-off point of the device. Here the DC power dissipated and, thus, the self-heating effects are small, yet the changes between the pulsed curves are quite large. This result is in keeping with the results presented in the previous section.

The grouping of the displayed curves is worthy of attention. In the middle of the saturation region (for example, V_{ds} = 2.5 V), all the curves measured with static values less than 2 V are grouped. At this v_{ds} point the dynamic values of the curves are measured with positive-going pulses. Then there is a large gap and all the curves measured with static values greater than 2 V are grouped. At this v_{ds} point the dynamic values of the curves are measured with negative-going pulses. The eye, or area in the middle of the saturation region where none of the curves cross, is clearly evident. The grouping and crossover of the curves as v_{ds} varies illustrate the dependence of the dispersion on electric field and self-heating.

The lack of an eye from the characteristics shown in the previous data plot is believed to be a result of the increased temperature caused by the self-heating. This condition, combined with the change in the biasing conditions, obscures the hysteresis effect. For example, this particular device's frequency dependency was found to be at its strongest between the temperature range of –50° and +220°C. Outside of this temperature range the device exhibited frequency-independent IV characteristics.[4]

While appearing attractive, the previous measurements, where the pulse and static conditions are varied in order to modify the self-heating effect, provide data that are difficult to interpret because of the variables involved. Of these variables, the dependence of the dispersion effect on electric field is the most difficult to quantify in a meaningful form for modeling purposes. Performing pulse measurements with the device biased from a static point of view in the off state in a temperature-controlled chamber provides certain advantages. For example, the IV characteristics can be observed over a wider temperature range and the resulting change to the dynamic characteristics can be unmistakably attributed to such a temperature change. However, the dependency on electric field remains difficult to quantify unless the off state of the device is used as a reference point. This aspect is currently under consideration and will be reported upon at a later date.

CONCLUSION

A measurement system for observing the dependency of the device IV characteristics on frequency, electric field and temperature has been presented. The system uses pulse generators and DC power supplies to enable the gate source, drain source or both junctions to be pulsed from any static point. Results presented show the strong dependence of the device's dynamic IV characteristics on frequency dispersion effects and how this dependence is modified by thermal effects caused by the power dissipated in the device.

[Continued on page 338]

ACKNOWLEDGMENT

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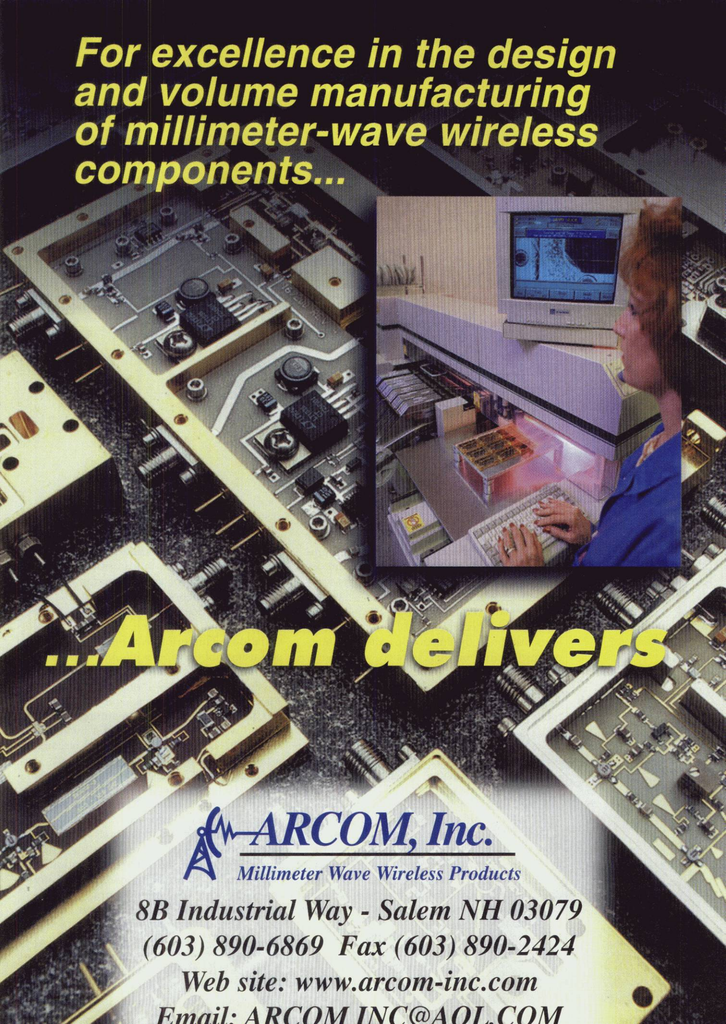
J. Rodriguez-Tellez *received his BSc, MPhil and PhD degrees in electrical engineering in 1979, 1982 and 1985, respectively, from Leeds and Bradford Universities, UK. He is also a Chartered Engineer (C. Eng.) and a European Engineer (Eur. Ing.). From 1979 to 1983, Rodriguez-Tellez worked for Standard Telecommunications Laboratories, Harlow, UK, as a research engineer in high speed communication systems. Since 1983, Rodriguez-Tellez has worked in the electronic and electrical engineering department at the University of Bradford, where he is currently a reader in solid-state devices. His research interests include Si and GaAs devices, interconnects and package modeling for microwave circuit applications.*

Tomas Fernandez Ibanez *received his PhD in physics from the University of Cantabria, Spain in 1996. Since 1998, he has been an assistant lecturer in the department of communications engineering at the University of Cantabria. His research interests include large-signal, nonlinear modeling of III-V compound transistors and SiGe devices.*

Angel Mediavilla Sanchez *graduated with honors in 1978 and received his PhD degree in physics in 1984, both from the University of Cantabria, Spain. From 1980 to 1983, he was ingenieur stagiere at Thomson-CSF, Corbeville, France. Currently, Mediavilla is a professor in the department of communications engineering at the University of Cantabria. His research interests include the simulation of devices and circuits using GaAs technology and its application in computer-based design.*

Antonio Tazon Puente *received his PhD degree in physics from the University of Cantabria, Spain in 1987. Since 1991, he has been a professor at the University of Cantabria, first in the department of electronics engineering and currently in the department of communications engineering. Tazon's research interests include the modeling of GaAs and SiGe devices from a linear and nonlinear point of view.*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Benefits of Automated Ribbon Bonding for Microwave Applications

With today's ever-increasing need for larger bandwidth in telecommunications, datacom, aerospace and defense applications, packaging challenges continue to grow. As the frequency at which the packages are required to operate increases, the wire itself becomes one of the larger problems. Although the impact of first-level interconnect (wire bonding) is fairly well understood, minimizing its influence on circuit performance can be interesting, to say the least.

Operating frequencies are rising faster than technology stocks, and soon it will be commonplace to manufacture circuits that operate in the 50 to 100 GHz range. At some point alternative solutions will have to be examined. This forcing function is not a generation away, but closer to five years. Until then, the challenge of solving today's (and some of tomorrow's) problems with today's technology remains. Fine ribbon wire first-level interconnects are a major part of the solution.

Fig. 1 0.5 × 1.5 mil ribbon interconnects on active and passive devices.

CHALLENGES

First-level interconnects are hazardous to the electrical performance of high frequency circuits! Interconnect variation, both in wire length and loop shape, makes high frequency circuit design all the more critical. For any substantial level of volume manufacturing, packaging engineers work very hard to design a circuit that does not require manual tuning and is robust in the face of uncontrollable variations. This effort can be an artful task, and using ribbon wire to interconnect the microstrip transmission lines, waveguides, and passive and active components, as shown in **Figure 1**, can assist in making it manageable.

Changing from round wire interconnects to ribbon wire can be considered a technology shift. Wire bonding high frequency circuits is a fairly well understood activity. Circuits are designed as well as possible to include the parasitic reactance functions of the traditional round wire interconnect. Variations associated with interconnect performance become one of the main challenges, and methods to minimize these variations can come at a high fiscal price. Portions of the variation equation can be controlled by attaching components automatically with very high accuracy, high repeatability and, unfortunately, high cost systems. When using round wire, these high ac-

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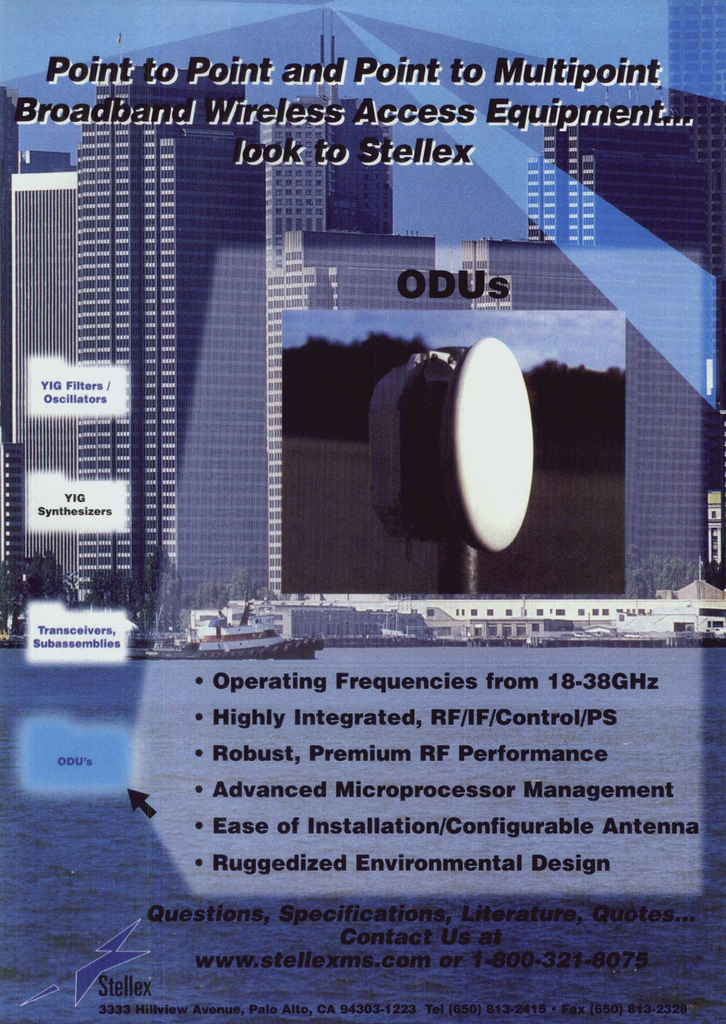
Bradley K. Benton
Palomar Technologies Inc.
Vista, CA



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curacy systems are generally a requirement. Ribbon wire enjoys some benefit in this area, but most manufacturers use automated component placement systems regardless of the interconnect media.

Modeling ribbon wire in a high frequency circuit is very similar to methods employed for round wire. Since wires interconnecting microstrip transmission lines can be made basically flat, the inductance of both round and ribbon wire has been expressed as[1]

$$L = 2 \times 10^{-4} l \left(\ln\left[\frac{2l}{(t+w)}\right] + 0.5 + \frac{0.2235[t+w]}{l} \right)$$

Ribbon Wire

$$L = 2 \times 10^{-4} l \left(\ln\left[\frac{4l}{d}\right] - 1 + \mu\varepsilon \right)$$

Round Wire

where

L = inductance in nanohenries
l = length of the wire
t = ribbon thickness
w = ribbon width
d = wire diameter
μ = permeability (assumed to be 1)
ε = skin effect correction factor (a function of wire diameter and frequency)

(All of the dimensional units are in micrometers.)

Microwave amplifiers are shrinking not only in surface area, but also in thickness. Twenty-eight gigahertz FETs have pad sizes as small as 1.4 mil square, forcing round wire wedge bonding to be accomplished with 0.0007" Au wire. Just last year, integrated circuits were 4 to 5 mils thick; this year they are as thin as 1 mil. Bonding pads on these active circuits are extremely fragile, especially if they are made of GaAs. Packaging engineers are constantly forced into a trade-off between performance and yield, and they need all the help they can get. Ultra-fine round wire is already being pushed to its limit; however, this is not the case for ribbon wire.

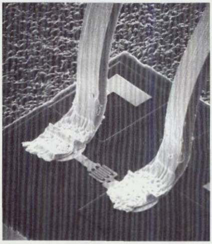
To obtain a high yield with a reasonable process capability on an automatic wire bonder when using ultra-fine round wire (≤ 0.0007"), enough ultrasonic power and force must be applied to deform the wire to almost two times the wire diameter, or approximately 1.4 mil. The width of the final deformed bond can be the same size as the bonding pad, if not larger. ***Figure 2*** shows 0.5 mil (thick) × 1.5 mil (wide) ribbon bonds on a FET with 1.8 mil round bond pads. Notice the minimal bond deformation that occurs with 0.5-mil-thick ribbon.

The initial bonder setup is another challenge. To bond the wire, the wire first must be threaded through a titanium carbide wedge tool (for gold wire) with an exceedingly small tool hole. The wire must be capable of being drawn easily through this guide hole in the tool. Threading a 0.7 mil wire through a tight-toleranced wedge tool is almost art in itself.

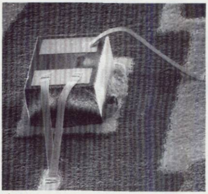
The smallest tool hole that is considered practical for 0.7 mil round wire is between 1.1 and 1.3 mil. Since the wire can position itself anywhere inside the tool hole, it can be assumed that the wire will be in that range under the bond tool foot when it is time to create the bond. Remember, even with the smallest possible tool hole (1.1 mil), the operator is attempting to put the 0.7 mil wire completely on the bonding pad, deforming the wire to approximately 1.4 mil and doing so on a bond pad that is only 1.4 mil wide. Round wire has provided a solution to this problem for as long as possible, but is at the end of the line. ***Figure 3*** shows 0.5 × 1.5 mil compound ribbon bonds to a 2 mil conductor.

If the wire is against the wall of the tool hole, the resultant bond could be off the bond pad by as much as 0.2+ mil (assuming that the tool foot was perfectly centered on the bond pad). Realistically, there are tolerances in this targeting that add to the problem. Ribbon that is 0.5 mil thick deforms approximately 1.1 to 1.4 times the ribbon width, while 1-mil-thick ribbon wire typically deforms one and a half to two times its width. Half-mil-thick ribbon clearly becomes a possible alternative to ultra-fine round wire bonding. Notice the minimal bond deformation. ***Figure 4*** shows minimal bond deformation on a 4 mil bond pad.

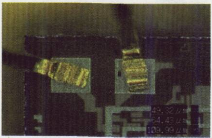
Ribbon wire geometries as small as 0.5 × 1.0 mil are theoretically possible, but, to the author's knowledge, are not being utilized in a production environment at this time. Until recently, creating the bonding tool itself was a difficult task. This geometry allows for the ever-shrinking wire bond pad of the future. Ribbon wire manufacturers can manufacture a wide variety of ribbon wires, including ultra-fine ribbon wire, at various tensile strengths. As the challenge to wire bonding increases over time, ribbon wire will remain a solution.



▲ *Fig. 2 0.5 × 1.5 mil gold ribbon bonds on 1.8 mil bond pads.*



▲ *Fig. 3 Compound ribbon bonds on a 2 mil conductor.*



▲ *Fig. 4 1 × 2 mil gold ribbon bond deformation on a 4 mil bond pad.*

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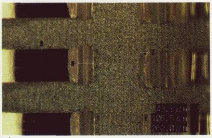
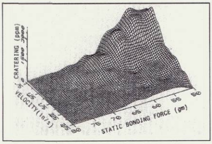


▲ *Fig. 5 1 × 10 gold ribbon used for high frequency power connects.*

Fig. 6 The effects of impact force and static bonding force on cratering. ▼



FORCING FUNCTIONS

Flip chip is a possible alternative (with its own measurable performance implications), but the cost — both in flexibility and design — suggests that the first-level interconnect will remain wire for an extended period of time. Eventually the industry may be forced into an alternative interconnect technology (possibly flip chip) that has extremely short conductors, but clock frequencies will have to push beyond 50 GHz to force that shift. Performance modeling is not as well defined for this emerging technology.

Substrate materials are constantly evolving and could extend the time of this shift's arrival. Passive components are being embedded with the goal of reducing and controlling parasitic inductances and capacitances associated with surface-mount components. Active circuits are becoming more embedded, and there is a strong desire to have many of today's discrete subsystems integrated into a single integrated circuit. All of these activities are making ribbon wire a reliable, known technology.

PERFORMANCE IMPROVEMENTS

One of the main electrical advantages of ribbon wire vs. round wire is the fact that at high frequencies ribbon wire impedance and inductance can be lower than round wire. (Both are very good qualities.) Skin or surface effects decrease the inductance, but at high frequencies can increase impedance. Close attention is required when balancing the thickness vs. width of the ribbon to minimize or eliminate this potential effect. In general, the higher the aspect ratio the better. This form factor is accomplished by determining the smallest wire bond pad or conductor width and matching it with the largest possible ribbon width. The use of 0.5-mil-thick ribbon is then employed and the best ratio possible is achieved.

Mechanical advantages are measurable as well. Complex microwave hybrids, certain types of multichip modules and most high frequency power amplifiers dissipate large amounts of power. Ribbon wire inherently carries larger amounts of power without forcing the interconnect media into a burnout condition. As power dissipation varies, all wires (both round and ribbon) actually flex. Flexing catalyzes bond heel fatigue (mechanical flexing of the wire at the point where the wire exits the bond site), which is the area that is structurally the weakest point of a wedge-bonded wire. Wire heel cracking with ribbon wire is less pronounced than with round wire, thus extending the life cycle of the ribbon wire interconnect. ***Figure 5*** shows very small deformation of both first and second bonds (both ends of the ribbon) on 1 × 10 mil Au ribbon. Note also the short bond tails.

There are at least two reasons for this low deformation. First, the bond deformation is less for ribbon than for round wire (thus resulting in more thickness of the wire at its weakest point, the first bond heel). Second, due to the rectangular shape of the ribbon, low wire looping profiles are easier to generate, allowing a kinder ascent angle from the first bond and minimizing aggravation to the heel during looping. Less kickback (reverse loop motion used to help the wire stand up) is required to keep the ribbon's loop from collapsing, allowing lower loops while minimizing the work hardening (flexing) of the heel of the bond. Very low, short wires can be automatically bonded with minimal stress to the ribbon wire itself.

With the reduction in overall wire length, reactive electrical components and impedance, ribbon wire bonded circuits generate lower return and insertion losses.[2] In this highly competitive marketplace, hard data to support reports of higher signal-to-noise ratios are difficult to gather in writing from an automated equipment manufacturer's users. However, it has been observed that the vast majority of known users who model the benefits of ribbon vs. round wire make the switch and never go back. It has been reported that a 3 dB gain is very typical when switching from round wire to ribbon, but, again, this is hearsay. Hopefully some of those circuit designers who read this article will take the time to model and measure the performance improvement.

In many ways, ribbon wire wedge bonding has an interesting domino effect of benefits. There are many good reasons to employ ribbon bonding, and very few reasons not to. Best of all, the operator does not have to be working strictly with MMICs, MESFETs or microstrip lines to enjoy the benefits or improvements associated with ribbon bonding.

PROCESS IMPROVEMENTS

It is a rare event in the microelectronics business when a technology shift yields both performance improvements and an increase in process capability; that is, until automated ribbon wire bonding became available. Not only are distinct, measurable electrical performance improvements observed, but process and yield improvements as well.

The lowering of interconnect-related impedance and other process benefits are derived in part due to the large bond area at both ends of a ribbon wire. The large bond area distributes the bonding force over a larger surface area of the bonding pad during the intermetallic formation process. This larger area improves yields by reducing the incidence of cratering (catastrophic bond pad failure) associated with the relatively high point contact force that occurs to the bond pad interface metallization with round wire.

This contact force vs. cratering is different from the potential for cratering caused by too low or too high an impact or static bond force applied during the generation of the bond. ***Figure 6*** shows a relationship for im-

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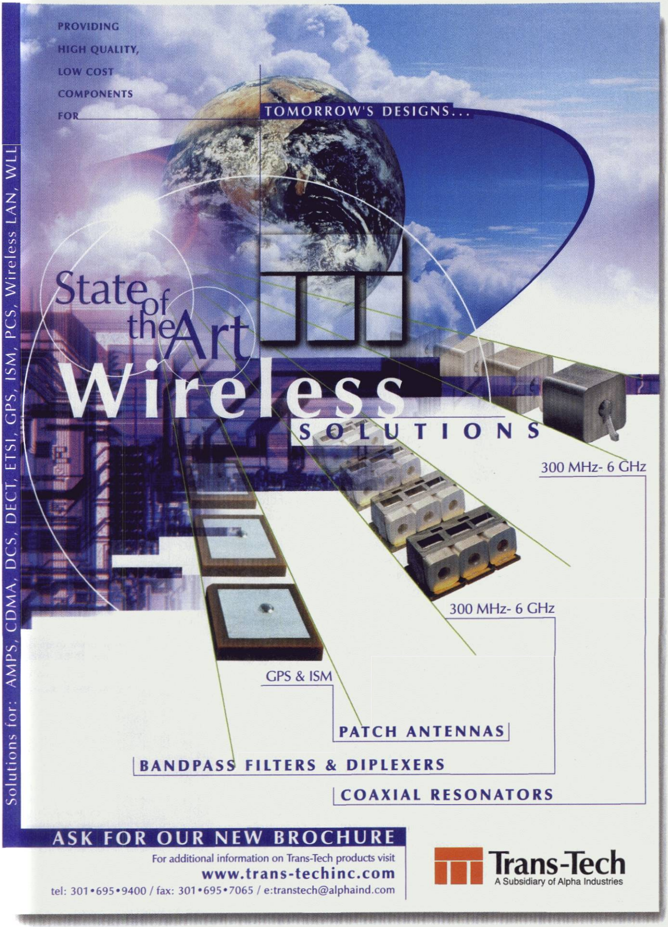

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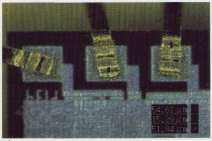
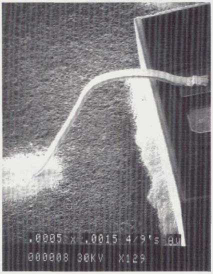


▲ *Fig. 7 1 × 2 mil gold ribbon on a 4 mil pad.*

▼ *Fig. 8 Low profile looping.*



pact force and static bond force with bond pad cratering for thermosonic ball bonding.[3] Low bond pad impact force is generally used when round wire wedge bonding delicate ICs such as GaAs, but this process decreases bonding speeds dramatically. When automatically bonding ribbon wire, this speed reduction is not necessarily the case.

The wedge bonder applies force through the ribbon by the bond foot (active area) of the wedge tool, as shown in ***Figure 7***. This force is distributed over the entire bond foot of the wedge tool, which has a much larger surface area with ribbon than with round wire. In today's high frequency packages, this force distribution is a very attractive process when dealing with small, fragile bond pads. Since a larger bonded area exists (with minimal deformation), the bond junction impedance also tends to be reduced.

Everything comes at a price, and since less deformation is required to bond ribbon wire, organic contamination at the bond site must be managed. While not a requirement, argon plasma cleaning is recommended to remove or control the organics prior to wire bonding. Surface oxides and contaminations are not scrubbed away as much as they are when utilizing the higher deforming round wires. Wedge tool tip-skid offsets this phenomenon if the bonding tool can continue motion in the z-axis, pivoting after the wire touches down on the bonding pad.

Elevated bonding temperatures are required for a robust process capability when using gold ribbon wire. This characteristic is classical thermosonic wire bonding, and hotter is better up to approximately 160°C. The effects of temperature above 160°C could be debated due to tradeoffs in yield, IC performance degradation and various material interactions. Some GaAs circuits have a maximum time at temperature that must be observed.

Aluminum wire is always bonded at room temperature (ultrasonic bonding) unless a true monometallic bonding condition is involved. A true Al-to-Al bond can be created at elevated temperatures, but, if care is not exercised, more problems can be generated than solved. Interestingly, almost all ribbon wedge bonding is done using gold in monometallic and bimetallic modes. The age of ribbon wire is an important variable to track. (Younger is always better.)

Due to ribbon wire's rectangular shape, very consistent loop profiles can be made, as shown in ***Figure 8***. Short wires that have large height differences between the ends of the ribbon can be bonded with exceptional repeatability and control. As with microstrip lines, near-planar ribbon bonding is a very robust process. Having the capability to control loop profiles accurately allows the generation of short, low loops. Both concepts address an improvement in repeatable reactive inductance associated with the interconnecting wire.

CONCLUSION

Some concepts are for certain: Shortening the circuit interconnect wire is, in general, beneficial to high frequency circuits. Making repeatable loop profiles and shapes is another plus when it comes to designing a circuit that is manufacturable. Reducing reactive electrical characteristics associated with the wire interconnect generally lends itself to simpler designs and more repeatable high frequency circuit performance. Finally, yields and reliability improve with ribbon wire.

Ribbon wire bonding improves performance, can carry higher current and is more delicate to fragile GaAs bonding pads. In addition, it generates stronger wire interconnects that last longer. Ribbon wire bonding is a known technology and can be modeled as easily as round wire. Until recently, ribbon interconnects were much larger and had to be soldered or welded into a circuit. Today, fully automatic fine wire ribbon bonders are available to assist circuit and packaging engineers with solutions to their formidable tasks.

Until first-level interconnects are forced into alternate packaging technologies, ribbon wire will bridge the gap. It is rare indeed that a required technology actually improves a process. For the foreseeable future, ribbon wire will remain the dominant high frequency package interconnect of choice. Automated ribbon wire bonding is a true win-win solution. ■

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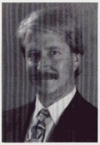

Bradley K. Benton *gained experience in various fields of electrical engineering, computer science and systems engineering at the University of Arizona from 1973 to 1983. From 1983 to 1995, he was a member of the technical staff at Hughes Aircraft Company, specializing in microelectronic assembly equipment design and factory automation. He has a patent in wire bond signature analysis. Currently, Benton is the product marketing manager for Palomar Technologies Inc. and can be reached at 2230 Oak Ridge Way, Vista, CA 92083 (760) 931-3600, fax (760) 931-5191 or e-mail: bkbenton@bonders.com.*

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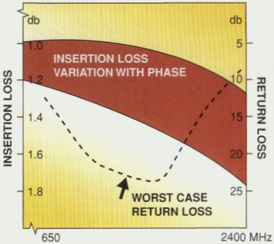

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TUTORIAL

DUPLEXER CONSIDERATIONS FOR X-BAND T/R MODULES

A transmit/receive (T/R) module's duplexer plays a critical role in determining a phased array's reliability, radar cross section (RCS) and performance. Several different block diagrams are typically used to realize the duplexer, but many common configurations do not satisfy basic duplexer requirements. This article discusses the capabilities of the three most common duplexer configurations as well as supporting component design considerations.

A duplexer connects a phased array's transmitter and receiver to an individual radiating element, as shown in ***Figure 1***. Since the duplexer insertion loss will directly degrade antenna noise figure and radiated power, it should provide a low loss connection from the antenna element to either the transmitter or the receiver. A duplexer also must have directional properties to ensure efficient phased-array operation (that is, transmitter energy is directed to the radiator, not the receiver, and received signals go into the receiver, not the transmitter).

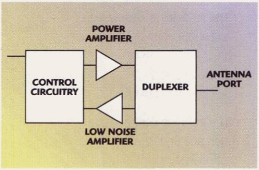
> **"Several different block diagrams are typically used to realize [a transmit/receive module's] duplexer, but many common configurations do not satisfy basic duplexer requirements."**

In addition to these requirements, the duplexer must isolate the transmitter and receiver from reflected or external signals. The level of isolation required can be determined from the phased array's intended operating environment and the receiver and transmitter design. Reflected energy into the duplexer can be created by many circumstances including a broken connector, ice on the radome or objects with a high RCS near the antenna.

The minimum level of duplexer protection is typically set equal to the transmitter's output power. The future use of wide bandgap power amplifiers will significantly increase the level of protection required. The amount of energy that is re-reflected by the duplexer is also important to control the phased-array RCS.

The final significant issue is load pulling. The antenna element's impedance varies as a function of scan angle and is often as high as 3:1 at large scan angles. This large variation can cause a corresponding variation in the output power as a function of scan angle. A duplexer must isolate the transmitting amplifier from impedance variations of the antenna element to prevent significant load pulling.

▼ *Fig. 1 The duplexer configuration.*



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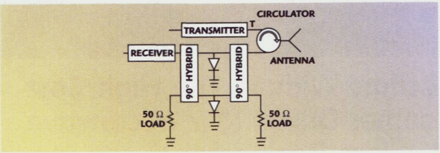
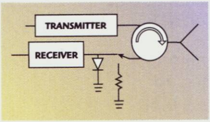
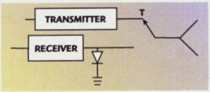
RENEE Z. JONES AND BRUCE A. KOPP
The Johns Hopkins University Applied Physics Laboratory
Laurel, MD



▲ *Fig. 2 A circulator/balanced limiter duplexer.*



▲ *Fig. 3 A circulator/limiter/switch duplexer.*



▲ *Fig. 4 A limiter/switch duplexer.*

CIRCULATOR/BALANCED LIMITER DUPLEXER

A circulator and balanced diode-limiter, shown in ***Figure 2***, can be used to satisfy all of the aforementioned T/R module duplexer requirements. The circulator directs any energy into the antenna to the receiver and any transmitter energy out of the antenna with less than 0.5 dB insertion loss at X-band.[1] The circulator will also typically isolate the transmitter from the input energy by > 15 dB. Very high receiver protection can be provided by limiter diodes. Reflected signals are dissipated in the input coupler 50 Ω load, and will prevent transmitter load pulling. This circuit will provide good RCS performance during receiver, transmitter or unbiased operation.

An isolator can be used instead of the balanced limiter to terminate the reflected limiter energy. However, this configuration typically is not used since an isolator often costs more than the additional limiter diodes and 90° couplers. The balanced circuit also doubles the limiter's power handling capability. If the receiver's low noise amplifier is placed within the balanced circuit its third-order intercept point also can be increased by 3 dB.

A circulator/balanced limiter may not provide adequate transmitter protection if the input 90° hybrid does not provide a good impedance match at the frequency of interest. This condition typically occurs outside of the coupler's normal operating bandwidth, and the signals are generally reduced by antenna and circulator impedance mismatches before they reach the 90° hybrid. A lowpass filter also can be inserted between the antenna element and the duplexer to provide increased isolation from external systems above the antenna's operating bandwidth.

CIRCULATOR/LIMITER/SWITCH DUPLEXER

A single-pole double-throw (SPDT) switch, limiter and circulator are also often used as a duplexer, as shown in ***Figure 3***. The switch is connected to the 50 Ω load during transmitter operation. The circulator and 50 Ω load protect the receiver and transmitter during transmission. This configuration also prevents load pulling of the transmitter and provides good RCS performance.

The switch is connected to the limiter during receive operation. The limiter then protects the receiver, but reflected limiter energy will be directed to the transmitter by the circulator. Transmitter isolation is provided solely by resistive losses along the microwave path. Excessive energy input from other systems can then lead to transmitter damage. This circuit also has poor RCS performance during the reception of signals large enough to turn the limiter on, unless a balanced power amplifier is used.

LIMITER/SWITCH DUPLEXER

An SPDT switch and limiter also may be used for the duplexer function, as shown in ***Figure 4***. This circuit is often attractive as a low cost option that allows the duplexer to be integrated with a transceiver MMIC. The switch provides no protection to the transmitter from reflected transmitted energy or external inputs. The transmitter is also not isolated from the antenna and load pulling can occur during scanning.

If a balanced power amplifier is used in the transmitter, RCS issues can be minimized during transmission. The balanced power amplifier still can be damaged by excessive inputs into the antenna during transmission. Energy reflected during receive will degrade RCS.

This duplexer should not be used if the anticipated operating environment includes external systems capable of damaging the transmitter during transmission, if reflected transmissions can damage the transmitter or if a balanced power amplifier is not used to prevent high RCS at sufficiently wide scan angles.

DUPLEXER COMPONENT DESIGN CONSIDERATIONS

Ferrite circulators are capable of providing robust performance for typical GaAs X-band applications and can support wide bandgap output power levels. The circulator cost is also typically less than five percent of the overall X-band T/R module cost. Active circulators have been proposed to provide lower cost,[2] but possess noise figure and power handling limitations for typical X-band applications.

Silicon PIN diodes provide satisfactory performance for current T/R modules and will be able to address future wide bandgap applications. Active bias to lower the diode resistance can be used to provide improved thermal management and decreased leakage. Thermal management also often requires the limiter diodes to be placed on thermal spreaders or the use of a high thermal conductivity substrate. The resulting silicon hybrid limiter has few parts and relatively low assembly complexity. Hybrid limiters typically compose less than five percent of the total X-band module cost. The limiter also can be realized with GaAs active devices to reduce the assembly complexity associated with the silicon hybrid.[3–5] However, the thermal conductivity of GaAs (0.47 W/cm°C) is considerably less than that of silicon (1.38

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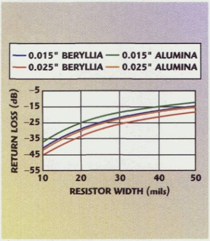

▲ *Fig. 5 Resistor return loss at 12 GHz.*

W/cm°C), and is a significant thermal design disadvantage.

Thermal design considerations are also important for the input 90° coupler. This resistor terminates limiter reflections that add in-phase through the coupler. Excessive heat caused by power dissipation can destroy the resistor or permanently change its resistance value. If either condition occurs, the mismatched load will begin reflecting power back into the coupler. Reduced film temperatures may be achieved by increasing the resistor area and/or using a higher thermal conductivity substrate.

Resistor thermal management is offset by the desire to keep the resistor area small to provide good return loss at X-band. Increasing the resistor dimensions would decrease the film temperature but would also degrade the electrical performance, as shown in ***Figure 5***. Thus, a BeO substrate, or material with similar thermal resistance, should be used in this case. ■

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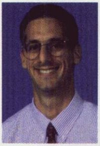
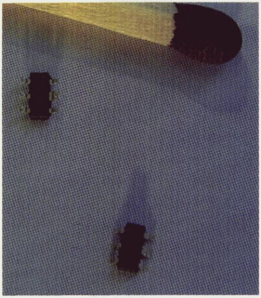
Renee Z. Jones *received her BSEE and MSEE from Virginia Tech and Johns Hopkins University, respectively. Currently, she is a senior staff member at The Johns Hopkins University Applied Physics Laboratory (JHU/APL) and works in the Radar Systems Development Group. Since joining JHU/APL in 1993, Jones has analyzed phased-array radar system performance and currently specializes in microwave and RF subsystems.*



Bruce Kopp *received his BSEE from Arizona State University and his MSEE from Stanford University. Currently, he is employed at the Johns Hopkins University Applied Physics Laboratory developing solid-state microwave technology, T/R modules and associated phased-array antenna hardware. Kopp also teaches a short course on T/R modules. Previously, he worked at Avantek as a microwave and RF component and system design engineer.*



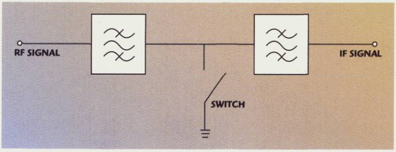
ULTRA-HIGH LINEARITY GaAs MIXERS

Mixers are common devices in modern communication and signal processing systems. They can serve as up- and downconverters and are combined in modulators for different balanced or unbalanced configurations. Current consumption, IP3 performance and conversion loss are critical factors in the successful design of mixer devices for mobile communication applications. In particular, excellent IP3 performance is mandatory for the nonconstant envelope modulation schemes utilized in American and Japanese mobile telephone or multicarrier systems. To address these needs, a new generation of mixers with outstanding intermodulation performance, minimum space requirements and remarkably low LO power levels has recently been developed.

MIXER BASICS

The new 200 series microwave mixer converters implement a GaAs FET as a switch. As shown in ***Figure 1***, the switch, in parallel with the RF-IF path, is commutated at a frequency equal to the pump frequency; the pump frequency drives the FET between on (conducting) and off (isolated) states. An integrated LO buffer loop ensures correct switching of the FET within a very wide LO level range. The incoming RF signal is alternately passed through to the IF port or reflected. Hence, the RF signal appearing at the IF load is interrupted by the switching action of the FET. The pump signal (on/off) is a periodic square wave, which can be developed in a Fourier series. The corresponding Fourier series to a square wave signal in the frequency plane is a sum of dirac pulses with an amplitude distribution according to sinx/x. The switching process is a multiplication of the square wave signal with the incoming RF signal in the time domain. A multiplication in the time domain corresponds to a confluation in the frequency domain. From modulation theory it can be shown that the sum and difference frequencies of pump and RF signals appear at the IF port as well as products of higher order. Since there is a DC component in the pump signal, a switching product with the frequency component of the fundamental RF signals appears at the IF port; therefore, no inherent isolation between the different ports is present (unlike a balanced configuration).

Fig. 1 Principle of operation.



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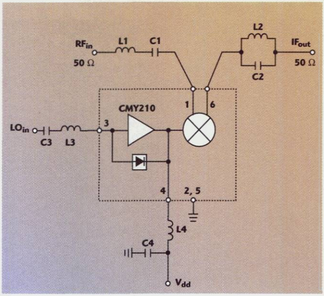

▲ *Fig. 2 The mixer's block diagram.*

Fig. 3 Current consumption as a function of LO frequency for a typical PCS CDMA application at V_{dd} = 3 V. ▼

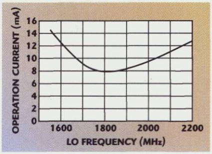

Fig. 4 Typical 900 MHz IP3 input and conversion loss as a function of LO power level at V_{dd} = 3 V. ▼

MIXER PERFORMANCE

The model CMY210 mixer is an all-port, single-ended, general-purpose up-/downconverter. Due to the implemented switching concept an outstanding input IP3 of +23 dBm is achieved, which makes this device especially suitable for highly linear systems such as CDMA (IS95), US TDMA (according to IS136), PDC or the upcoming standard, UMTS. ***Figure 2*** shows the internal block diagram of the mixer. To achieve the best performance, good port-to-port frequency separation is a must. The RF input filter must be a throughpass for the RF signal to be mixed; it has to reflect all sum and difference frequencies of the LO and RF as well as the harmonics of both. The IF filter is a tank circuit resonant at the RF; it reflects the RF and passes through the IF.

According to experimental investigations, even a stand-alone FET operating in the previously mentioned configuration can achieve very high IP3 performance. However, the major disadvantage of the single-FET configuration is the high LO power demand. In addition, a slight change in the LO power produces an unacceptable change in intermodulation performance. An integrated control loop for the LO power results in almost constant intermodulation performance (with L4 optimized for 1830 MHz operation).

Minimum current consumption of the loop can be adjusted by a properly chosen inductor L4 at the drain of the LO driver FET. L4 must be in parallel resonance with the input capacitance (approximately 2.1 pF present at pin 4) at the LO frequency in order to obtain a high LO voltage amplitude at the gate of the mixer FET. The LO voltage level at the mixer FET is detected and a control voltage is fed back to the LO driver. As soon as the LO voltage level at the gate of the mixer FET exceeds the threshold of the control loop, the operating current and gain of the LO driver drop. This mechanism ensures that device performance is stable over a wide LO power range. Therefore, sweeping the LO frequency over a broad bandwidth results in a minimum of current consumption of the LO loop, as shown in ***Figure 3***.

The mixer requires a low LO power level of only 0 dBm. ***Figure 4*** shows IP3 and conversion loss for a typical 900 MHz downconverter application. IP3 remains constant at +23

[Continued on page 358]

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Insertion Loss (Max.)	0.15dB	0.25dB	0.35dB
VSWR (Max.)	1.25:1	1.25:1	1.25:1
Incremental Phase Shift	90 degree min. @ 2GHz		
Electrical Delay	125 psec min.		
Nominal Impedance	50 ohm		
I/O Port Connector	SMA(F) / SMA(F)		
Average Power Handling	20W @ 2GHz		
Temperature Range	-30°C ~ +60°C		
Dimension (inch)	A type : 1.496*1.102*0.457 B type : 1.225*1.102*0.457		

KPH30OSCL000

KPH35OSCL000

Miniature CPS

Product Code No.	Drop-In type (KPH30OSCL000)			Connectorized type (KPH35OSCL000)		
Frequency Range	~ 1GHz	1 ~ 2GHz	2 ~ 2.5GHz	~ 1GHz	1 ~ 2GHz	2 ~ 3GHz
Insertion Loss (Max.)	0.15dB	0.25dB	0.35dB	0.15dB	0.25dB	0.35dB
VSWR (Max.)	1.3:1	1.3:1	1.3:1	1.25:1	1.25:1	1.25:1
Incremental Phase Shift	30 degree min. @ 2GHz			35 degree min. @ 2GHz		
Electrical Delay	41.7 psec min.			48.6 psec min.		
Nominal Impedance	50 ohm			50 ohm		
I/O Port Connector	Drop-In			SMA(F) / SMA(F)		
Average Power Handling	30W @ 2GHz			30W @ 2GHz		
Temperature Range	-30°C ~ +60°C			-30°C ~ +60°C		
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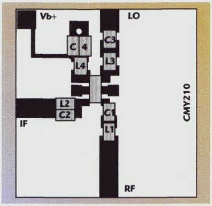

▲ *Fig. 5 A typical demoboard for downconversion operation.*

dBm for an LO driving level of 0 dBm due to the integrated LO driver. When the LO level at the FET's internal gates is too low the integrated driver's power level increases. As soon as the LO power level reaches approximately 0 dBm, the mixer operates in a saturated state and the IP3 performance remains at a constant level. Any further increase in LO power does not influence IP3 performance significantly. The achieved results for up- and downconversion in the cellular and PCS bands are comparable; however, current consumption of the LO driver increases slightly due to lower amplification at the higher frequency. Comparable ring diode mixers with the same IP3 performance require an LO driving level of +13 dBm. For this power level an additional LO driver is necessary, generating spurious signals throughout the system.

Since the CMY210 device is a passive mixer, conversion loss and noise figure are equal. Conversion loss remains almost constant at a level of 6 dB over an extremely wide LO level range. The on resistance of the mixer FET, one of the major parameters determining conversion loss of the mixer, is quite stable even at reduced LO power. However, intermodulation is mainly limited by the risetime of the mixer and, hence, much more sensitive to LO power. In any case, a hard switching of the mixer FET is required to achieve optimized IP3 performance.

The CMY210 devices can be utilized in both directions, that is, up- and downconversion. The LO frequency should not exceed 2.5 GHz due to increased losses above that frequency. The low side frequency should be higher than 200 MHz due to internal capacitive coupling between the mixer and LO driver. The device is housed in a small, low cost MW6 surface-mount package based on the SOT143 plastic body (6 PIN leadframe) configuration and operates down to a 3 V battery environment or below.

A TYPICAL MIXER CIRCUIT APPLICATION

A typical application for this mixer is a downconversion configuration for CDMA according to IS95 for the American PCS systems. Matching of the previously mentioned external filters can be realized with lumped elements, distributed elements (such as microwave strip lines) or drop-in filters. Blank standard boards, which can be matched according to the requirements of the application, are also available for order. ***Figure 5***

[Continued on page 360]

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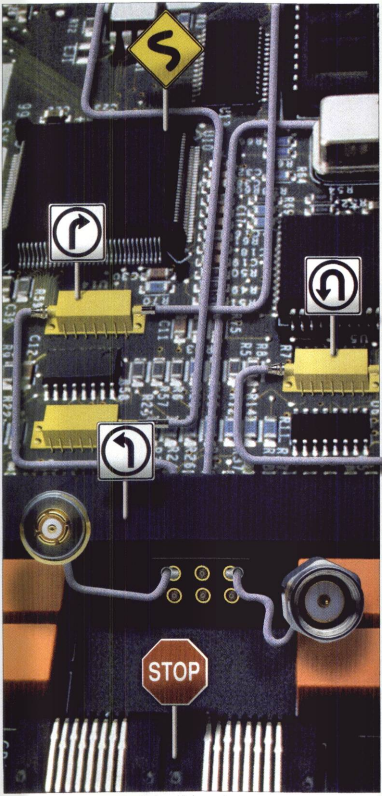

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TABLE I

DEMOBOARD COMPONENT VALUES FOR 1960 MHz to 130 MHz DOWNCONVERTER OPERATION

L1 (nH)	3.3
L2 (nH)	3.3
L3 (nH)	6.8
L4 (nH)	3.3
C1 (pF)	1.8
C2 (pF)	1.5
C3 (pF)	15
C4	15 pF + 1 nF + 1 µF

shows a matched demoboard for 1.96 GHz downconversion with an LO frequency of 1.83 GHz (actual size is 20 mm × 20 mm, $\varepsilon_r = 4.8$, thickness = 1.0 mm). ***Table 1*** lists the actual values of the used lumped elements.

The RF and IF ports achieve an input return loss of better than 10 dB in a 50 Ω system with the given filter configuration. The board was tested with a 3.6 V nominal battery voltage of Li ion batteries and a corresponding operating current of only 7.0 mA. The necessary LO driving level for the downconversion process is 1 mW as discussed previously. The achieved IP3 at the input port is typically 23.5 dBm with an associated conversion loss of 6.2 dB. ***Table 2*** lists the achieved values for this typical PCS CDMA operation at a 1960 MHz RF, 1830 MHz LO, 130 MHz IF and 0 dBm input LO power at 25°C.

TABLE II

TYPICAL PERFORMANCE FOR PCS CDMA APPLICATIONS

Operating current (mA)	7.0
Conversion loss (dB)	6.2
SSB noise figure (dB)	6.2
Third-order input intercept point (dBm)	23.5
RF/IF input return loss (dB)	> 10

CONCLUSION

The CMY210 device is a highly linear mixer operating in the cellular and PCS frequency range. It is an alternative to high cost and space-consuming ring diode mixers and can be utilized in up- and downconverter applications. The model CMY211, a low current derivative with a current consumption of 2.5 mA and an associated IP3 of 17 dBm, was recently introduced. The next move to higher integration will be a combination of an IF amplifier and this mixer cell (model CMY212).

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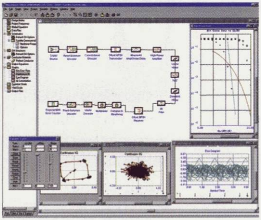


A Multilevel Design Environment for Wireless System Development

Simulation techniques have been in use for many years to support the design and evaluation of RF and microwave systems. During the past three decades, computer-aided engineering (CAE) techniques have matured and are now an integral part of both the circuit- and system-level design processes. The impetus for the increased use of CAE techniques has stemmed largely from the combination of reduced design cycles and the growing intractability of the more complex systems now being fielded. Both systems and signal environments have grown more complicated with the advent of digital communication techniques such as CDMA, which has placed additional pressures on circuit and system designers.

TRUE MULTILEVEL SIMULATION

The Microwave Office Wireless Design Suite (WDS) provides a new level of realism when predicting practical system performance through the use of CAE techniques. RF circuit designers now understand the need to test subsystems such as amplifiers under real-world operating conditions. It is necessary to answer questions like "How do amplifier nonlinearities affect spectral regrowth?" and "How do mixer spurs affect bit error rates (BER)?" The WDS allows RF/microwave engineers to both answer these questions during the conceptual development process and refine the simulations as transistor-level simulations or measurements become available.

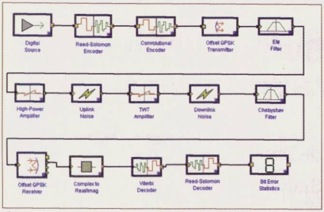
The WDS provides an optimal integration of modeling and simulation techniques for both circuit-level and behavioral-level (sometimes called system-level) evaluation. Complex-envelope representation allows the efficient end-to-end simulation of complete communication links at the system level. Measures of performance include BER, detailed spectral analysis and many other outputs used for digital communication and other signal processing systems. The simulation of detailed circuit models is fully embedded into the behavioral system simulation. New techniques allow the overall simulation to efficiently integrate data from EM, linear and nonlinear circuit models with the system-level simulation. This capability allows the user to realistically assess the statistical performance of real circuits using Monte Carlo techniques. Statistical measures of performance like BER may be collected for systems employing transistor-level and even EM-based models.

CAPABILITIES AND MODELS

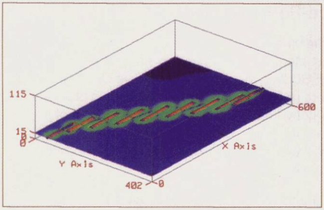
The integrated system/circuit solution represents the culmination of years of combined development effort between AWR and ICUCOM Corp., Troy, NY. The two companies collaborated to build an object-oriented solution from the ground up by leveraging ad-

[Continued on page 364]

Applied Wave Research Inc. (AWR)
El Segundo, CA



▲ *Fig. 1 A two-hop satellite link model.*

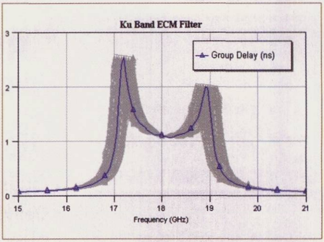


▲ *Fig. 2 E-fields surrounding a Ku-band edge-coupled microstrip filter.*

vances in computer science and engineering. This comprehensive CAE solution combines the acclaimed architecture and user interface of the Microwave Office 2000 product with a next-generation version of ICUCOM's Advanced Communication Link Analysis and Design Environment (ACOLADE) system simulation technology.

The new ACOLADE incorporates years of research and development in system-level simulation technology with one of the largest sets of functional models in the electronic design automation industry (more than 700). This enormous collection of models includes application-specific libraries supporting all popular communication standards, such as GSM, CDMA, 3G, Global Positioning System, digital video broadcast, high definition television and many others. In addition, ACOLADE's libraries have been validated over many years in conjunction with significant system development efforts. For example, the wideband CDMA (W-CDMA) library includes sophisticated system models such as Turbo encoders/decoders and all-digital RAKE receivers with advanced features such as multi-user detection.

ICUCOM was the first company to offer a comprehensive library for the simulation of the IS-95a CDMA communication standard and has maintained an unchallenged leadership position in the simulation of W-CDMA systems. The WDS GSM library incorporates full support for the Enhanced Data Rate for GSM Evolution and General Packet Radio Service standards. Full vocoder support for both GSM and CDMA systems is available, including an end-to-end speech play-through capability.



▲ *Fig. 3 The effects of etching tolerances and substrate variations on the filter's group delay.*

Since the WDS focuses directly on communication link modeling, a comprehensive set of channel models are available. Sophisticated models for fading, multipath, jamming and impulse noise are developed at a level of detail necessary for accurate assessment of real-world operating environments. For example, multipath channels have dynamically varying path delays, providing a testbed for assessment of dynamic channel sounding algorithms and RAKE finger assignment/tracking schemes.

The Microwave Office WDS interfaces to popular test equipment, accepting time domain data directly from arbitrary waveform generators and other common equipment. Measured noise spectra from elements such as frequency synthesizers may be imported to assess the impact of imperfect phase references. WDS also can be used to synthesize waveforms for export as a stimulus for real-world hardware. In addition, Microwave Office WDS interfaces to popular products such as Matlab. Users of this tool may run co-simulations with WDS or compile M-files directly into C++ code for direct and efficient implementation.

EXAMPLES

Figure 1 shows a two-hop satellite link employing Reed-Solomon and convolutional coding. A solid-state high power amplifier (HPA) amplifies an offset quadrature phase-shift keying signal on the uplink, and a traveling-wave-tube amplifier (TWTA) provides the gain for the downlink. The HPA is modeled at the circuit level, as the circuit diagram illustrates. BER is calculated for both coded and uncoded operation and plotted in conjunction with analytical bounds. The TWTA is modeled based on the manufacturer's supplied AM/AM and AM/PM characteristics. Laboratory measurements of these characteristics may be imported from popular spreadsheets.

The next two examples illustrate the results of analyzing the physical geometry and layout of a Ku-band edge-coupled microstrip filter used in the satellite communications example. ***Figure 2*** shows the actual E fields surrounding the filter and ***Figure 3*** shows the statistical variations that occur when the effect of etching tolerances and substrate variations is simulated on the group delay.

[Continued on page 366]

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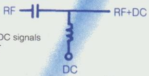

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▲ZFBT-4R2G-FT	10-4200	0.15	0.6	0.6	N/A	N/A	N/A	1.13:1	59.95
▲ZFBT-6G-FT	10-6000	0.15	0.6	1.0	N/A	N/A	N/A	1.13:1	79.95
▲ZFBT-4R2GW-FT	0.1-4200	0.15	0.6	0.6	N/A	N/A	N/A	1.13:1	79.95
▲ZFBT-6GW-FT	0.1-6000	0.15	0.6	1.0	N/A	N/A	N/A	1.13:1	89.95
★ZNBT-60-1W	2.5-6000	0.2	0.6	1.6	75	45	35	1.35:1	82.95
■PBTC-1G	10-1000	0.15	0.3	0.3	27	33	30	1.10:1	25.95
■PBTC-3G	10-3000	0.15	0.3	1.0	27	30	35	1.60:1	35.95
■PBTC-1GW	0.1-1000	0.15	0.3	0.3	25	33	30	1.10:1	35.95
■PBTC-3GW	0.1-3000	0.15	0.3	1.0	25	30	35	1.60:1	46.95
•JEBT-4R2G	10-4200	0.15	0.6	0.6	32	40	40	-	39.95
•JEBT-6G	10-6000	0.15	0.7	1.3	32	40	40	-	59.95
•JEBT-4R2GW	0.1-4200	0.15	0.6	0.6	25	40	40	-	59.95
•JEBT-6GW	0.1-6000	0.15	0.7	1.3	25	40	30	-	69.95

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▲ *Fig. 4 An ACPR measurement made on a CDMA signal.*

One of the problems encountered when designing with practical analog filters is nonlinear phase response as a function of frequency. Since group delay is the derivative of the phase response, this result is equivalent to a nonconstant group delay. When different delays are associated with different frequencies, pulse distortion can occur. In the systems analysis, the response of the EM filter is simulated with the input from the digital encoders such that the nonconstant group delay of the EM filter is apparent in the I/Q constellation diagrams.

Adjacent-channel power ratio (ACPR) has become an increasingly important measure of performance in wireless system design and development. Measures of performance such as BER characterize the effect of nonideal RF subsystems on the intended receiver's operation. ACPR, on the other hand, characterizes a transmitter's impact on other users occupying nearby frequency bands. ***Figure 4*** shows an ACPR measurement made on a CDMA signal. Spectral analysis has been performed on both the ideal modulator output and the nonlinear amplifier output. The spectral regrowth due to the nonlinear amplifier is evident. The spectral plot is zoomed to display a frequency band of interest.

The IS-95a air interface standard requires that the spread spectrum signal spectrum be below a specific level in a 30 kHz notch located just outside the allocated channel bandwidth. The mask corresponding to this specification is used to integrate the spectrum over this frequency region to calculate the ACPR value. The WDS incorporates a powerful spectral analysis capability that allows accurate spectral estimates to be calculated. Sophisticated digital techniques are employed to calculate long-term spectral averages of signals under observation. Powerful convergence techniques are employed to ensure arbitrary accuracy of ACPR and other spectral measurements. The actual samples of the digital spectral mask are shown to illustrate the fact that the spectrum is actually a digital spectrum. In this case, the spectral plots illustrate an accumulating average, which has been taken over 200 time windows. Results from system-level analyses can be presented in concrete units (for example, megahertz or kilohertz) that are familiar to hardware designers as opposed to arcane normalized units of time/frequency.

CONCLUSION

The Microwave Office 2000 design environment has been extended from EM and circuit-level simulation and now makes it possible to combine higher levels of abstraction in a more meaningful way. As opposed to previous total solutions, the Microwave Office WDS offers a truly integrated environment, allowing the labors of system and hardware engineers to flow together in a harmonious way. Combined behavioral- and circuit-level modeling promises to allow complex next-generation wireless systems to be designed in record time. Additional information may be obtained from the company's Web site at www.mwoffice.com.

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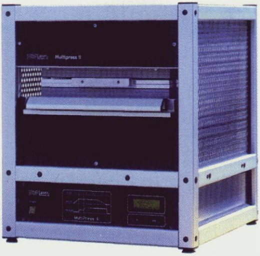

A MULTILAYER PRESS FOR RAPID PCB PROTOTYPE FABRICATION

Until now fabricating prototype multilayer PCBs has been a costly and time-consuming endeavor. Although single-layer prototype boards traditionally are constructed in house, designers have been forced to go to outside shops for their prototype multilayer PCBs. A new tabletop multilayer press for rapid PCB prototyping has been developed that permits these multilayer designs to be fabricated in the engineering lab for rapid evaluation. The MultiPress II multilayer press is extremely cost effective and specifically designed for use with circuit board plotters such as the ProtoMat® series plotter. The system easily operates in an engineering environment as a result of its compact size and safety-oriented design. The new press permits lab personnel to laminate multilayer PCBs up to six layers using all of the common multilayer materials currently available, including specialized microwave prepregs such as the new Rogers RO4403 material. The MultiPress II unit is also capable of handling board sizes up to 10" × 12" with a required pressure of 100 N/cm^2, resulting in a force of 15 t (for a gross pressing area of 16.5" × 14.1").

The MultiPress II unit is completely microprocessor controlled and features fully automatic operation. All of the important parameters, such as board size, pre- and main pressure, and pressing time for all individual process phases, can be programmed according to the specific material requirements and are automatically monitored. In addition, the new press laminates instant solder mask on any PCB prototype, an extremely useful feature when using fine pitch surface-mount technology or chip-on-board or ball-grid array components. Up to four processing programs composed of time, pressure and temperature parameters may be stored in the system for repeat use. When used with a ProtoMat circuit board

[Continued on page 370]

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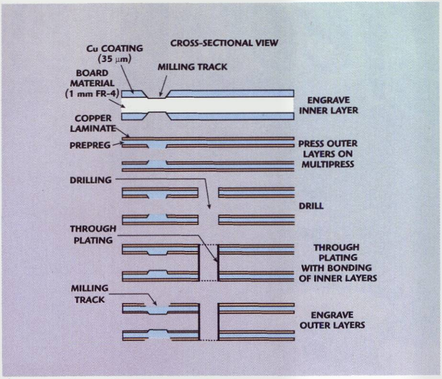


▲ *Fig. 1 Production of a multilayer circuit board.*

Fig. 2 Cross section of a six-layer plated through hole. ▼

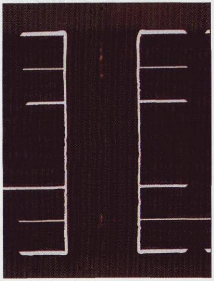


Fig. 3 The press' temperature/pressure/time profile. ▼

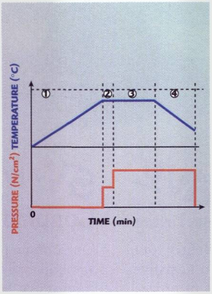


Fig. 4 The ProtoMat circuit board plotter. ▼

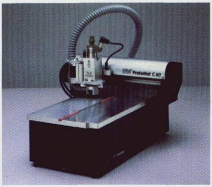
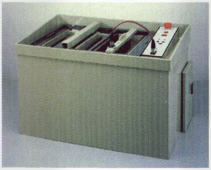


Fig. 5 The MiniContac electroplating tank. ▼



plotter and MiniContac® electroplating tank, the MultiPress II unit requires only a few hours to produce complete multilayer prototype PCBs in the lab.

THE PROCESSING METHOD

The fabrication process used to produce a typical multilayer prototype board involves five steps, as shown in ***Figure 1***. The first step is to engrave layers 2 and 3 of the double-sided FR-4 laminate using the circuit board plotter. Next, the outer layers (1 and 4) are laminated using the press. The PCB is left to cure a minimum of two hours, then the board is drilled using the circuit plotter. Next, the through holes in the PCB are electroplated using the Contac or MiniContac electroplating tank. (This process creates the interlayer electrical connections.) Finally, the outer layers are engraved using the appropriate artwork, and the multilayer board is ready for assembling. ***Figure 2*** shows a cross section of a plated through hole in a six-layer PCB fabricated using this process.

The MultiPress II unit features a footprint of approximately 0.25 m^2 (1 m^2 with a bench) and a weight of approximately 210 kg. The unit requires a 230 V/10 A or 115 V/20 A AC supply and a compressed air source of 6 to 8 bar at 30 in^3/min. The maximum processing temperature is 210°C. The duration of the press process after preheating is approximately 90 minutes plus a two-hour cure time before drilling. ***Figure 3*** shows the temperature/pressure/time profile used by the press for lamination. The associated ProtoMat circuit board plotter and MiniContac electroplating tank are shown in ***Figures 4*** and ***5***, respectively.

Short-run and prototype multilayer PCBs now may be fabricated in the engineering lab, saving both time and money. The new MultiPress II compact multilayer press brings one of the last remaining design steps in house without compromising the quality or reliability of the PCB.

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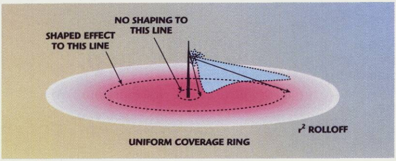
SHAPED SECTOR ANTENNAS FOR LMDS AND MMDS HUBS

A line of hub sector antennas for the 24 to 42 GHz local multipoint distribution system (LMDS) and 2.1 to 2.7 GHz multichannel multipoint distribution system (MMDS) wireless access frequency bands has been recently introduced. The goal of the designs is to provide the most uniform coverage possible within a sector while minimizing interference in adjacent cells. An exact electromagnetic formulation has been combined with artificial intelligence (AI) and a set of mechanical constraints to obtain the best possible antenna solution. The production constraints guarantee a cost-effective form factor. The addition of AI allows the electromagnetic formulation to be transformed from an antenna analysis tool to a design synthesis tool. The result is a family of antennas with previously unimaginable mechanical and performance characteristics.

Fig. 1 Elevation pattern characteristics.

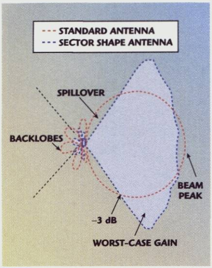


Each antenna's elevation pattern electric field follows an approximately cosecant-shaped distribution in order to provide uniform coverage as a function of distance from the hub mounting. Hence, a relative high field is directed toward the horizon relative to the field aimed at locations closer to the hub, as shown in ***Figure 1***. The patterns have uniform coverage in azimuth throughout the sector. Additionally, the units reduce the radiation spillover into adjacent cells and, hence, lessen interference.

Because the antennas do not waste power by directing it in unwanted directions they exhibit high gain relative to comparable products. This advantage is especially prevalent when comparing the worst-case performance within

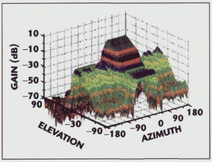
[Continued on page 378]

REMEC MAGNUM INC.
San Jose, CA

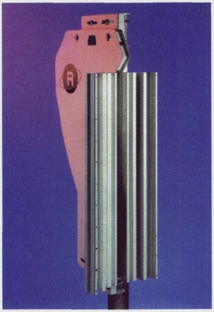


▲ *Fig. 2 Azimuth pattern characteristics.*

Fig. 3 The LMDS hub antenna's radiation pattern raster scan. ▼



the sector to that of previously offered hub antennas, as shown in ***Figure 2***. The new hub antennas are available in both vertical and horizontal polarizations. They typically provide better than 50 dB of cross-polar rejection



▲ *Fig. 4 The MMDS hub antenna.*

over the entire cell. As the popularity of wireless broadband increases, these antenna characteristics offer dramatically improved carrier-to-interference ratios when compared to more conventional solutions. The antennas are available in a variety of azimuth standard beamwidths, including 45°, 60° and 90°. Custom beamwidth and form factors are available upon request.

Due to the physical nature of the antenna, the patterns in regions off the principle planes are simply the product of the patterns on the principle planes; that is, the azimuth and elevation angles are separable, such that

$$E(\theta,\phi) = E(\theta) \times E(\phi)$$

where

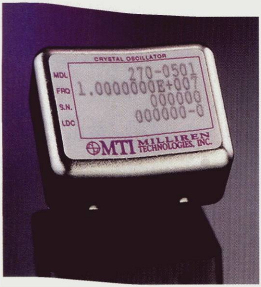
θ = elevation angle
ϕ = azimuth angle

Hence, the antenna maintains its desirable azimuth patterns for all elevations angles, regardless of the distance from the hub. ***Figure 3*** shows a raster scan of a 90° LMDS hub.

The LMDS versions of the antenna have a form factor similar to a typical LMDS radio in order to provide a compact integrated solution. The antennas are available with UL-registered heated radomes. (A photograph of the LMDS hub antenna was shown previously.) The MMDS versions are constructed out of lightweight sheet metal, and the brackets allow pole mounting by a single installer. In addition, the antenna provides the 3 kW CW power handling commonly required for video distribution hubs. The MMDS hub geometry is shown in ***Figure 4***. The antennas are particularly effective when used with the company's line of low sidelobe CPE antennas. Additional information may be obtained via e-mail at sales@remecmagnum.com.

REMEC Magnum Inc.,
San Jose, CA
(408) 432-9898.

Circle No. 456



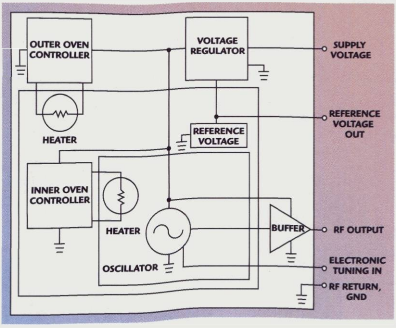
ULTRA-HIGH STABILITY MINIATURE OCXOs

The current drive for miniaturization and low cost commercialization is also affecting oven-controlled crystal oscillator (OCXO) products. Although burdened by a discrete oven that stabilizes the crystal oscillator's thermal environment, modern OCXO designs must be smaller and less expensive than their predecessors without sacrificing performance or reliability. The 270 series OCXOs utilize a double-oven configuration in a miniature package and feature ultra-high stability as well as high reliability. The new crystal oscillators have been designed with the industry-standard Euro CO-8 footprint and serve as a drop-in replacement for the 230 series oscillator products.

Housed in a hermetically sealed 1.423" × 1.071" × 0.765" package, the new OCXOs feature a thermal stability performance of 2.0E-10 to 5.0E-09 over the –30° to +70°C ambient temperature range that rivals rubidium clock performance. The 270 series OCXOs are the next generation of ultra-stable quartz frequency references, occupying five times less volume than the smallest frequency reference currently available today in the standard 2.0" × 2.0" × 1.5" package.

The OCXOs are capable of operating from 4.8 to 90 MHz and utilize a full-size TO-8 quartz resonator. **Figure 1** shows the oscillator's functional block diagram. The double-oven configuration utilizes a steady-state power consumption at 25°C of 1.7 W from a nominal 12 V DC supply. Warm-up power is typically 5.5 W and requires approximately 10 minutes to reach a frequency stability of 5E-09. Once stabilized, the oscillator's typical thermal stability over the –30° to +70°C temperature range is 1E-10. A typical 5 MHz unit's RF output is a 9 dBm ±2 dB sinewave, harmonics are –30 dBc and spurious are –80 dBc (max). Short-term stability at 1 s is 2E-12, and aging is 1E-10 per day and 3E-08 per year.

Fig. 1 The OCXO's block diagram.



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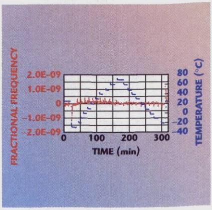
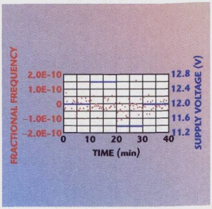
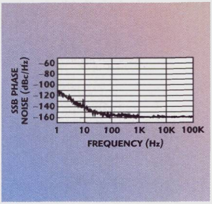
MTI-MILLIREN TECHNOLOGIES INC.
Newburyport, MA



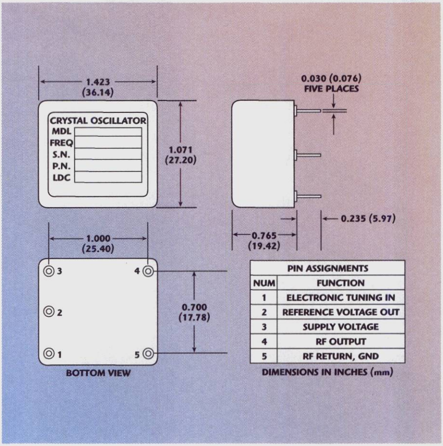
▲ *Fig. 2 A 5 MHz SC-cut third-overtone oscillator's thermal stability.*



▲ *Fig. 3 A 5 MHz SC-cut third-overtone oscillator's supply voltage sensitivity.*



▲ *Fig. 4 The 5 MHz oscillator's phase noise.*



▲ *Fig. 5 The crystal oscillator's mechanical outline.*

Figure 2 shows the thermal stability performance of a 5 MHz SC-cut third-overtone OCXO as it is swept from –30° to +70°C and then back to –30°C using automatic test equipment (ATE). Frequency measurements are made at +25°C before and after the sweep to eliminate any drift during the test period that is not temperature related. Each data point is taken by averaging 10 frequency readings of 1 s gate intervals approximately every 15 s.

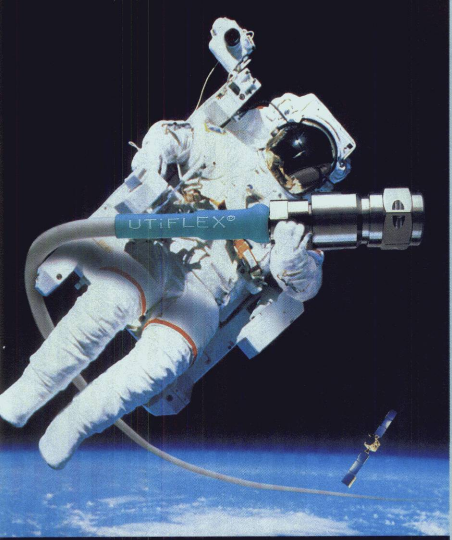
The new OCXO also displays good frequency stability in the presence of supply voltage and load impedance changes. The oscillator's supply voltage sensitivity dF/dV and load sensitivity dF/dL for a ±5 percent voltage change and a five percent load impedance change are both 5E-11. ***Figure 3*** shows the supply voltage sensitivity of a 5 MHz SC-cut third-overtone oscillator when the +12 V DC supply voltage is varied from +5 percent to –5 percent. Using ATE, the supply voltage is held at +12 V before and after the sweep to eliminate any drift during the test period that is not supply voltage related. Similar to the thermal measurement technique, each recorded data point is taken by averaging 10 frequency readings of 1 s gate intervals approximately every 20 s.

Low phase noise is a prime consideration. The oscillator's phase noise is a function of the output frequency and is typically specified at –100 dBc/Hz at 1 Hz offset and –155 dBc/Hz at 10 kHz offset for a 5 MHz output. A graph of the phase noise performance of two identical 5 MHz oscillators corrected for equal power source noise is shown in ***Figure 4***. The oscillator frequency is voltage tuned for minor output frequency adjustments using a 0.5 to 5 V DC external tuning voltage that has a positive slope. Tuning linearity is within 10 percent. The electrical tuning range for a 5 MHz SC-cut third-overtone oscillator is specified as ±4E-007 to ±8E-007. In addition, a 4.7 to 5.3 V high stability reference voltage output is provided with a source resistance of 100 Ω.

Figure 5 shows the new oscillator's mechanical outline. A very low active component count helps to ensure high reliability and low cost while preserving the oscillator's superior performance. The units have been designed for high volume production and are 100 percent tested for thermal stability, aging, output level and spectral purity, phase noise, short-term stability, warm-up and continuous power, reference voltage and electrical tuning range. Many standard frequencies and Stratum II- and Stratum IIIe+-compatible designs are available. Custom frequency outputs can be supplied upon request.

MTI-Milliren Technologies Inc., Newburyport, MA (978) 465-6064.

Circle No. 451



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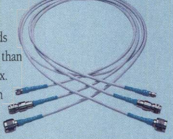

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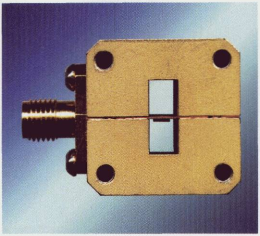


ELECTRONICALLY TUNABLE RF FILTERS FOR LMDS FREQUENCIES

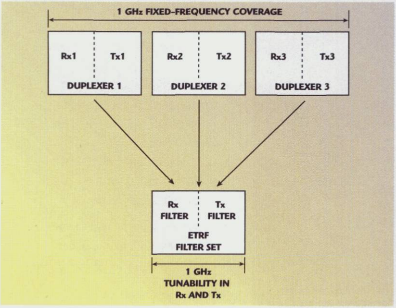
Local multipoint distribution service (LMDS) is a two-way digital wireless communication medium enabling voice, data and video traffic. LMDS applications are located in the 22 to 40 GHz range of the spectrum and provide an attractive solution to the last-mile problem of connecting consumers to broadband communication services such as high speed Internet and video without the limitations of copper lines and the prohibitive installation costs of fiber.

The radios currently used at LMDS frequencies utilize fixed filters. An electronically tunable RF (ETRF) filter has been developed that covers the frequency range for several fixed filters. ETRF filters provide fast tuning, maintain high Q values at LMDS frequencies and enable a single radio to operate at multiple frequencies. These attributes equip LMDS service providers with flexibility and scalability by enabling software control, frequency reuse, coexistence with adjacent systems and performance optimization. ***Figure 1*** shows a comparison of fixed-filter technology operating within a typical frequency range of 1 GHz and the ETRF filter solution. Multiple sets of fixed-frequency duplexers can be replaced by one set of ETRF filters.

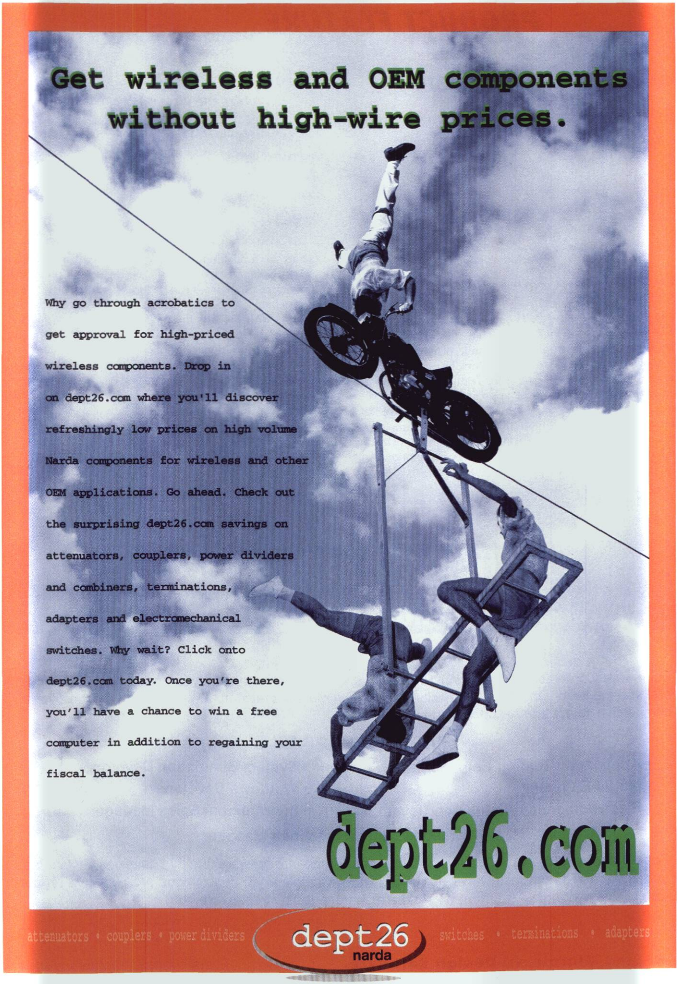
The new ETRF filter products represent the first commercially available high frequency, low loss, wideband electronically tunable filters of their kind. The typical performance of an ETRF Ka-band filter for LMDS applica-

[Continued on page 386]

Fig. 1 Fixed-frequency duplexer operation vs. ETRF filter capability.



PARATEK MICROWAVE INC.
Columbia, MD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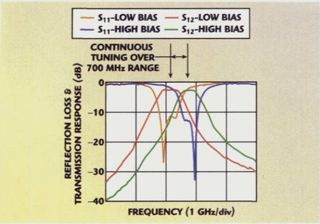


▲ *Fig. 2 Measured response of a Ka-band filter for LMDS applications.*

tions is shown in ***Figure 2***. The example bandpass filter is a two-pole Chebyshev finline waveguide design, which utilizes the company's proprietary ceramic planar varactors. By applying DC voltage to the varactors, fast tuning of the capacitance is achieved. The filter features low loss and fast tuning performance over approximately a 700 MHz tuning range, and offers a 1 dB relative bandwidth of 2.8 percent, tuning range of more than 3.2 percent of the center frequency and insertion loss of 2 dB. The filter exhibits high power handling with low DC power consumption and also features low intermodulation distortion of > 70 dBm.

TABLE I

TYPICAL ETRF FILTER SPECIFICATIONS AT LMDS FREQUENCIES

Frequency range (GHz)	22 to 40
Tuning range (% of f_0)	2 to 5
Bandwidth (MHz)	200 to 50
Insertion loss (dB)	2.0
Poles	2 to 4

Units are available in metal or metallized-plastic housings with a standard waveguide interface. The operating temperature range is –30° to +70°C, and the filter measures a compact 0.875" × 0.875" × 0.750" (excluding the bias port). ***Table 1*** lists the range of ETRF filter specifications at LMDS frequencies. Digitally controlled options are available. Additional information on ETRF filters for LMDS applications and other ETRF products such as tunable delay lines, phase shifters and electronically steerable antennas can be obtained from the company's Web site at www.paratek.com or via e-mail: info@paratek.com.

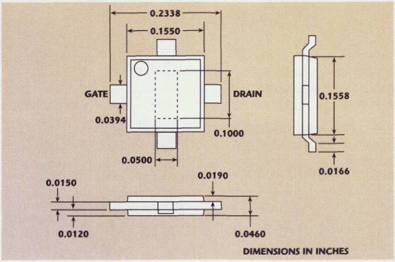
Paratek Microwave Inc.,
Columbia, MD (443) 259-0140.

Circle No. 452

Plastic-Packaged FETs for High Power Applications

With the advent of wireless communications, demands have increased for high power, high linearity and inexpensive power amplifiers. Devices capable of handling high power along with high linearity are being used to design power amplifiers that achieve the high performance and reliability required in these applications. Using one high power device instead of combining several low power devices reduces combining losses and circuit board area, increases efficiency and reliability, and ultimately reduces design time and costs.

Fig. 1 The TF series FET's package outline.



Traditional high power FETs are housed in relatively expensive ceramic packages. A new family of unique GaAs MESFET devices have been developed that are housed in a low cost plastic package. The new TF series high frequency devices are inexpensive and feature high power and high linearity. One of the unique features of the FETs is that they are not prematched, thus the devices can be used for high frequency, wideband designs.

Typical Performance

A typical example of the TF family is the model AM144MX-TF GaAs MESFET designed for high power microwave applications up to 8 GHz with a total gate width of 14.4 mm. The new plastic-packaged device is supplied with straight pretinned copper leads in a drop-in mounting style. Two of the leads are the RF input and outputs; the other two are the grounding leads. The bottom of the package serves simultaneously as a DC and RF ground as well as a thermal path. The unique packaging provides three heat sink paths for effective heat removal. ***Figure 1*** shows the package outline dimensions.

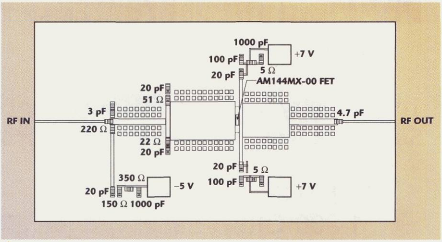
[Continued on page 390]

AMCOM COMMUNICATIONS INC.
Clarksburg, MD

TABLE I

DEVICE PERFORMANCE AT 2 GHz

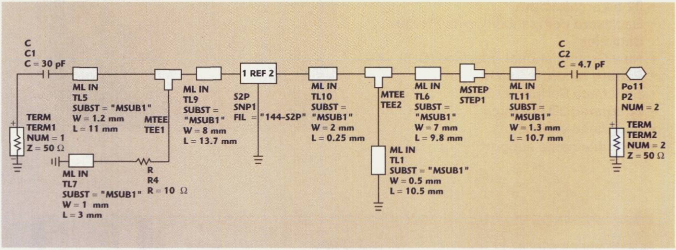
	V_{ds} = 7 V Minimum	I_{ds} = 0.5 I_{dss} Typical
P1dB (dBm)	35.0	36.5
Efficiency at P1dB (%)	26	40
Gain (small signal) (dB)	11	13
IP3 (dBm)	45	48

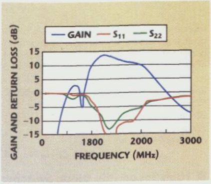


▲ *Fig. 2 The circuit layout.*

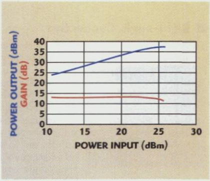
The new device features a 36.5 dBm saturated output power at 2 GHz and high gain. ***Table 1*** lists the AM144MX-TF device's performance at 2 GHz and 25°C. Typical saturation current I_{dss} for the device at V_{ds} = 3 V and V_{gs} = 0 is 3.4 A, and maximum pinch-off voltage at V_{ds} = 3 V is –2.6 V. The device's typical drain-to-

Fig. 3 A single-stage amplifier using the AM144MX-TF FET. ▼

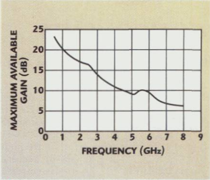




▲ *Fig. 4 The device's small-signal gain and return loss vs. frequency.*



▲ *Fig. 5 The device's power output and gain vs. power input.*



▲ *Fig. 6 Maximum available gain vs. frequency.*

gate breakdown voltage is 15 V and typical thermal resistance is 6.5°C/W.

A DESIGN EXAMPLE

A design example of a single-stage power amplifier using the model AM144MX-TF FET demonstrates the device's performance capabilities. The output matching circuit is designed for optimum power output while the input matching circuit is designed to obtain maximum gain and input return loss. ***Figure 2*** shows the circuit layout on a 20-mil board with a dielectric constant of 10.2, and ***Figure 3*** shows a simplified circuit diagram of the design. The device's measured small-signal gain and return loss vs. frequency at V_{dd} = 7 V and I_{ds} = 1.6 A are shown in ***Figure 4***. ***Figure 5*** shows the output power and gain achieved at 1.4 GHz. The measured output power at the 1 dB compression point is 37.2 dBm and the power gain is more than 13 dB for a V_{dd} of 7 V and I_{ds} of 1.6 A. ***Figure 6*** shows the device's maximum available gain as a function of frequency.

Applications for the new plastic-packaged high power FET include wireless local loop and wireless local area networks, PCS base stations, repeaters, hyperLANs and very small aperture terminals. The new FETs significantly reduce the cost of high power devices in these applications without compromising performance.

Amcom Communications Inc., Clarksburg, MD (301) 353-8400.

Circle No. 453

COMPONENTS

Nonreflective/Absorptive Switch

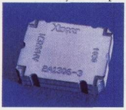
This variable rise time, high power (1 W), high isolation nonreflective/absorptive SPST switch operates from 500 MHz to 18 GHz (other frequencies are available) with the capability of adjusting the rise time in four discrete steps of 25, 50, 75 and 100 ns. Insertion loss is < 1.75 dB at 500 MHz and < 3.5 dB at 18 GHz. Isolation is > 80 dB at 500 MHz and > 85 dB at 18 GHz. In addition, SWR is 2 (typ).

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

Circle No. 377

Wideband, High Power Hybrid Coupler

The Xinger® series model 2A1306-3 surface-mount 3 dB hybrid coupler is designed for use in high power applications within a 1.8 to 2.5 GHz bandwidth. The unit provides an isolation of 21 dB (min) and insertion loss of 0.23 dB (max). In addition, the component features a phase balance of ±3° and a return loss better than 20 dB. Power handling is 100 W for digital audio broadcast and higher at lower frequencies. The unit measures 0.65" × 0.48" × 0.14". The coupler is manufactured using materials with x and y thermal expansion coefficients compatible with many common substrates, including FR-4, G-10 and polyimide, and can be used in a variety of high power applications.

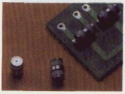


Anaren Microwave Inc.,
East Syracuse, NY (315) 432-8909.

Circle No. 378

SMD Surge Arrestor Gas Tubes

The company's two-element BA and three-element BM surface-mount surge arrestor gas tubes have been designed to protect telecom/datacom equipment against lightning surges and electrical transients. The nonradioactive tubes are half the size of conventional tubes and their surface-mount capability will allow original equipment manufacturers to save time and money. The units are currently available in 90 to 420 V. Prices: 40¢ to $2.00 each.



CITEL Inc.,
Miami, FL (305) 621-0022.

Circle No. 436

Right-angle Connectors

These factory-installed, right-angle connectors are designed for use with the company's SureFlex™ cable assemblies. The connectors provide the good electrical performance of a straight connector with the mechanical advantages of a right-angle connector. In factory tests, SureFlex 1/2" cable assemblies with right-angle connectors provide a return loss of 28 dB or better up to 2.5 GHz. The new right-angle connectors are available on SureFlex cable assemblies for 1/2", 3/8" and 1/4" HELIAX® superflexible foam dielectric cable.

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

Circle No. 380

High Power, 120 dB Attenuator

The model 100-SA-MFN-120 120 dB attenuator features an attenuation accuracy of ±1.5 dB. The convection-cooled unit operates at 100 W (avg) and 2000 W (peak). This 50 Ω attenuator also offers a frequency range of DC to 1 GHz with an SWR of 1.15. Size: 9.15" × 2.75" × 2.75". Weight: 52 oz. Available connectors are N-type male and female.

BCP, Largo, FL (727) 547-8826.

Circle No. 381

Replacement Electron Multiplier

The Magnum Electron Multiplier™ is a replacement electron multiplier that installs directly into existing ion-optic frames, eliminating the need to replace expensive mounts. No retrofitting with special ion-optic mounts is required, making replacement tool-free, fast and inexpensive. The unit utilizes Spiraltron™ technology to provide superior operational lifetime and output linearity. Multipliers are available for instrument models HP5770A, 5970, 5970B, 5971A, 5972A GCD, 5973, 5989A, 5989B, MS Engine and 5995 mass spectrometers.

Burle Electro-Optics Inc.,
Sturbridge, MA (800) 648-1800
or (508) 347-9191.

Circle No. 437

Coaxial Cable Assemblies

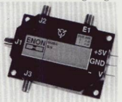
The model Lab-Flex™ 160 coaxial cable assemblies are designed for use up to 40 GHz where high performance and repeated flexing are required for RF interconnects. A solid center conductor and double-braid outer conductor ensure a long life without performance degradation. Low density dielectric yields low insertion loss. The extruded fluoroethylene propylene jacket provides good temperature performance. Specifications include a velocity of propagation of 76 percent, impedance of 50 ±2 Ω, capacitance of 27 pF, delay of 1.34 ns and temperature range of –65° to +200°C. Weight: 0.04 lb.

Florida RF Labs,
Stuart, FL (800) 544-5594
or (561) 286-9300.

Circle No. 383

High Speed PIN Diode Switches

The models ES0129, ES0130 and ES0133 10 W CW hot switching, high speed, PIN diode switches cover the frequency range of 2 to 18 GHz. Switching rate is 2 MHz with 35 ns switching speed. Insertion loss is < 2 dB at 18 GHz and < 1 dB from 2 to 8 GHz. Isolation is > 50 dB. The switches operate on +5 and –15 V DC to +85°C.



Enon Microwave Inc.,
Topsfield, MA (978) 887-8234.

Circle No. 433

Quartz Chip Components

These quartz dielectric passive components feature improved performance for operation up to 26.5 GHz. Volume production of spiral inductors, couplers and attenuators is available with a variety of metallizations and form factors down to 0.01" × 0.01". Tolerances on ion-milled features are typically less than 75 microinches and result in good lot-to-lot repeatability.

Ion Beam Milling,
Manchester, NH (603) 644-2326.

Circle No. 384

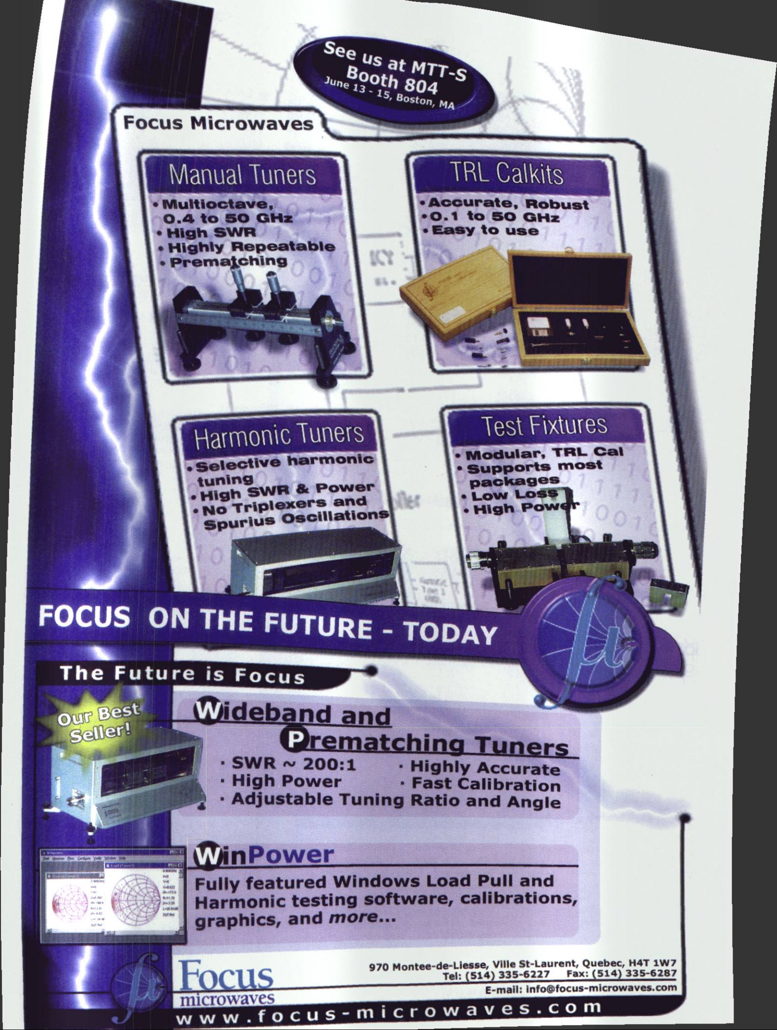
50 Ω Surface-mount Feedthru

This patented 50 Ω feedthru breaks the frequency, weight, mechanical versatility and cost barriers. With an SWR < 1.5 up to 15 GHz, this hermetic unit allows transformation of wideband and high frequency passive and active devices into true surface-mount applications. The low cost feedthru is then fitted into a lightweight aluminum housing as opposed to a traditional Kovar package.

Thunderline Z,
Hampstead, NH (603) 329-4050.

Circle No. 438

[Continued on page 394]


See us at MTT-S
Booth 804
June 13 - 15, Boston, MA
Focus Microwaves
Manual Tuners
• Multioctave, 0.4 to 50 GHz
• High SWR
• Highly Repeatable
• Prematching
TRL Calkits
• Accurate, Robust
• 0.1 to 50 GHz
• Easy to use
Harmonic Tuners
• Selective harmonic tuning
• High SWR & Power
• No Triplexers and Spurius Oscillations
Test Fixtures
• Modular, TRL Cal
• Supports most packages
• Low Loss
• High Power
FOCUS ON THE FUTURE - TODAY
The Future is Focus
Our Best Seller!
Wideband and Prematching Tuners
· SWR ~ 200:1
· Highly Accurate
· High Power
· Fast Calibration
· Adjustable Tuning Ratio and Angle
WinPower
Fully featured Windows Load Pull and Harmonic testing software, calibrations, graphics, and *more*...
Focus microwaves
970 Montee-de-Liesse, Ville St-Laurent, Quebec, H4T 1W7
Tel: (514) 335-6227 Fax: (514) 335-6287
E-mail: info@focus-microwaves.com
www.focus-microwaves.com

NEW PRODUCTS

Cellular and DCS-/PCS-band Directional Couplers

These cellular and DCS-/PCS-band directional couplers are suitable for forward and reflected site power monitoring, handset test stands/general instrumentation and signal injection for antenna testing applications. The units are configured with passbands of 800 to 980 MHz for the cellular band and 1700 to 2000 MHz for DCS/PCS. Insertion loss within the passbands is specified at 0.2 dB (max), and passband return loss is specified at 20 dB (min) at all ports. The units offer 30 dB coupling ports with tolerance of ±0.75 dB (max) and directivity of 30 dB (min). Maximum power handling is rated at 500 W CW and 20 kW peak instantaneous. Intermodulation products are specified at –110 dBm (max) with two +43 dBm CW carriers applied as input into the device with coupled ports terminated. The operating temperature range is –20° to +70°C. These units measure 4.5" × 2.0" × 1.0" for the 800 to 980 MHz passband and 3" × 2" × 1" for the 1700 to 2000 MHz passband (excluding connectors). Connectors are N-F at all ports.

K&L Microwave Inc., Salisbury, MD (410) 749-2424.

Circle No. 385

BNC Connectors

This family of BNC connectors meets the needs of industry-standard RF connectors in many kinds of radio, telecommunications, medical equipment, computer network and test instrumentation applications. The units are available in both 50 and 75 Ω versions and are provided in a choice of styles, including crimp, clamp, PC board mount, chassis mount and bulkhead mount. Customers can choose from a wide variety of plating options as well as custom-configured connectors to meet their specific requirements. The RF connectors meet all industry standards and provide an SWR of less than 1.3 across the DC to 4 GHz frequency range with a maximum center contact resistance of 1.5 mΩ at DC 1 A. Prices for the BNC

[Continued on page 396]


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

NEW PRODUCTS

connectors varies according to quantity, options and mounting style. Typical pricing for a standard BNC crimp style is 28¢ each (10,000).
Methode RF Products,
a division of Methode Electronics Inc.,
Union, NJ (908) 688-8000.
Circle No. 426

Three-way DIN Power Splitter

The model D3-24FD three-way power splitter is designed using gasketed 7-16 mm Deutsche Industrial Norms (DIN) connectors for use in base stations, leaky line and similar applications in the 800 to 2200 MHz frequency range. The unit splits high power signals evenly with minimal reflections, passive intermodulation or insertion loss up to 700 W average power. The mechanical shape allows simple attachment to a pole or wall using the bracket provided.

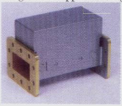
Microlab/FXR,
Livingston, NJ (973) 992-7700.
Circle No. 387

Surface-mount, Common-mode Choke Coil

The model PLW3216S wire-wound, surface-mount, common-mode choke coil provides an electromagnetic interference (EMI) filtering solution to manage the increased data transmission speeds necessary for the next-generation electronics devices. The new high speed interfaces are ideal for this surface-mount, common-mode choke coil. These recent innovations have enabled significant increases in data transmission speeds between digital consumer products and PCs. Such transmissions generate EMI noise on the data lines and require filtering to meet Federal Communications Commission (FCC) requirements. The unit provides good EMI suppression in a compact 1206 package size and enables electromagnetic compliance set forth by the FCC. The choke coil utilizes the company's winding technology, which enables a high coupling coefficient and good common-mode noise suppression in the gigahertz range. The unit is also a lead-free product.
Murata Electronics North America,
Smyrna, GA (770) 433-5782.
Circle No. 390

Waveguide Bandpass Filter

The model 7892D waveguide bandpass filter is designed to suppress strong out-of-band interference caused by marine or airport radar systems. Coastal and marine navigational radar frequencies (2.9 to 3.65 GHz) are just below the television receive only (TVRO) band and frequently wipe out transponders 1–5 in the TVRO installed near harbors. The airport altimeter band (4.2 to 4.4 GHz) affects transponders 22–24 at TVRO sites near airports. The filter features an insertion loss of 0.5 dB (typ) at the center frequency and 1.25 dB (max) (1 dB (typ)) at 3.7 and 4.2 GHz. Suppression is 25 dB (min) at 3.65 and 4.25 GHz and 50 dB (min) below 3.55 GHz and above 4.35 GHz. Group delay variation is less than 8 ns (typ). The filter measures 5.75" long (flange to flange). The flanges are rectangular CPR229G (grooved) and CPR229F (flat).



Microwave Filter Co. (MFC),
East Syracuse, NY (800) 448-1666
or (315) 438-4700.
Circle No. 388

DC - 6 GHz Termination

The model ROSE-50 termination is designed for use in a wide range of applications in the DC to 6 GHz band, including cellular, test set-up, instrumentation and PCS. The unit features a half-watt rating to 70° ambient (derated linearly at 0.005 W/°C to 0.35 W at 100°), 50 Ω impedance and minimum return loss of 30 dB in the DC to 2 GHz band, 22 dB from DC to 4 GHz and 17 dB band wide. The unit is equipped with an SMB plug connector and is available off the shelf for $9.95 each (1–9).

Mini-Circuits,
Brooklyn, NY (718) 934-4500.
Circle No. 389

Wireless Isolator

The model CIC01A1723-01 wireless isolator performs over the frequency range of 1700 to 2300 MHz and is designed for an insertion loss of 0.3 dB (max). The isolator provides isolation of 22 dB (min) with an SWR of 1.15 (max). With input power rated at 25 W, the unit operates from 0° to +55°C. This high performance isolator can be used for amplifier output-stage protection. Delivery: stock.

Narda Microwave-West,
Folsom, CA (916) 351-4500.
Circle No. 391

Power Divider/Switched Combiner

The model SDU-2162 switch combiner is suitable for base station and/or high power amplifier designers working at 1850 to 1975 MHz. The device provides for separate contributions of modular amplifiers. This approach allows power summation without the loss associated with using common combiners that require loading unused ports. The unit sums up numerous (two, three, four) coherent signals of

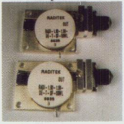
150 W each and survives random peak powers of 1800 W. The unit is optimized for insertion loss in both the three-port and four-port active condition. Typical specifications for both the power divider and power combiner include an insertion loss of 0.5 dB (max) and phase balance of ±2° (max). SWR is 1.25 and input power is rated at +23 dBm. Amplitude balance is 0.4 dB (max) for the power divider and 0.3 dB (max) for the combiner. The unit operates over a temperature range of 0° to +80°C and at altitudes up to 13,000 feet. The power divider/switched combiner is packaged in a rugged connectorized housing.

Signal Technology Corp.,
Olektron Operation,
Beverly, MA (978) 524-7211.

Circle No. 394

Isolator

This 1.93 to 1.99 GHz SMA/stripline isolator features a stripline or surface-mount (microstrip) interface on the input and SMA female on the output. Other custom frequency configurations are possible. The company also manufactures waveguide and microstrip (to > 100 GHz) isolators.



Raditek, San Jose, CA (408) 266-7404.

Circle No. 392

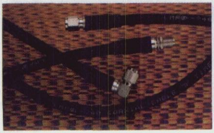
Custom EMI Filtered Solutions

The company works with design and manufacturing teams to create any unique filtering or power conditioning design necessary. Current and voltage ratings can be specified to meet any stringent requirements. Application-specific options include transient suppression, circuit breaker protection, voltage cutoff, reverse polarity and power distribution. These custom EMI power filters can be used in various industries, including the medical, telecommunications, computer and general industrial areas. Specific applications include cellular base stations, communications racks, telephone switching equipment, UPS, industrial controls and welders, computer/peripheral equipment, PC work stations and servers.

Spectrum Control Inc.,
Fairview, PA (814) 835-1650.

Circle No. 395

SMA Connectors



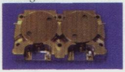
The models TC-240-SM, TC-240-SM-RA and TC-240-SF-BH SMA male straight, male right-angle and female bulkhead connectors, respectively, are designed for the company's LMR-240 flexible low loss coaxial cable and are fabricated from passivated stainless steel with gold-plated solder-pin contacts and crimp-style outer contact attachment rings. The male connectors have hex coupling nuts. These high quality, low loss connectors are designed to operate at frequencies up to 18 GHz.

Times Microwave Systems,
Wallingford, CT (203) 949-8424.

Circle No. 434

Dual-junction Isolator

The model DSW1054-A dual-junction isolator is designed for use in base station filter subsystems, combiners and amplifiers. The unit is available in PCS1900, DCS1800, European Digital Extended Group Special Mobile and AMPS frequencies. The isolator features good IM3 performance, internal loads and standard outline.



Trak Microwave Ltd.,
Dundee, Scotland +44 (0) 1382 833411.

Circle No. 396

AMPLIFIERS

Broadband Test Amplifier

The model 150W1000 broadband test amplifier offers 150 W minimum power and frequency response from 80 to 1000 MHz. The unit provides the extra margin of power needed when testing to International Electrotechnical Commission 10 V/m requirements at 3 m from 80 to 90 MHz. The amplifier is also suitable for use in automotive bulk current injection applications. The unit is equipped with a digital control panel that provides local and remote control. A four-line digital display, menu-assigned softkeys, rotary knob and four dedicated switches offer extensive control and status reporting capability. Operational presentation of forward and reflected power, control status and reports of internal amplifier status are also provided. Special features include gain control, internal/external automatic level control (ALC) with front-panel or remote control of the ALC threshold, pulse input capability and RF output level protection. The amplifier limits reflected power to 100 W. All amplifier control functions and status indications are available remotely in GPIB/IEEE-488 and RS-232 formats. Price: $27,000.

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

Circle No. 398

[Continued on page 398]

NEW PRODUCTS

RF Power Amplifier

The model GRF2064 RF power amplifier operates from 869 to 960 GHz with 100 W of linear power and 20 W CDMA. The unit is designed for linear applications in the cellular frequency range, utilizing linear power devices that provide good linearity, high gain and wide dynamic range. High efficiency operation is achieved by employing unique microstrip networks and advanced laterally diffused metal oxide semiconductor (LDMOS) devices. The unit is designed for high reliability with such features as built-in voltage-regulated bias supply and EMI/RF interference (RFI) filters. Each amplifier undergoes extensive burn-in prior to final test and quality assurance.

Ophir RF, Los Angeles, CA (310) 306-5556.

Circle No. 399

Dual-band 3 V LNA

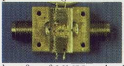
The model RF2363 dual-band 3 V low noise amplifier (LNA) is designed for use as a front end for 950 MHz GSM and 1850 MHz DCS applications, featuring a good combination of low noise figure and high linearity at a low supply current. The 900 MHz LNA is a single-stage amplifier, while the 1900 MHz LNA is a two-stage amplifier. The part can also be tuned for applications in other frequency bands. Distinguished by a low noise and high intercept point, the amplifier operates with a gain of 18 dB at 900 and 1900 MHz. The device is produced using GaAs heterojunction bipolar transistor technology and the company's Optimum Technology Matching® Manufactured in a small industry-standard SOT-23 eight-lead package, the unit is available for immediate shipment. Price: 82¢ each (10,000).

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

Circle No. 400

MMIC-based Amplifier

This high gain, broadband, MMIC-based amplifier is designed to meet the demanding requirements of commercial communications systems while providing the cost benefits of MMIC technology. The amplifier features a 21 ±0.5 dB small-signal gain over a 37 to 40 GHz operating frequency range. P1dB is +18 dBm and P_{sat} is +21 dBm. The unit operates from +4.5 V DC at 310 mA. S_{11} and S_{22} are –12 and –10 dB, respectively.



Microwave Development
Company Inc. (MDC),
Salem, NH (603) 870-6280.

Circle No. 439

X-band Driver Amplifier

The model CHA5010b two-stage monolithic driver amplifier is manufactured with a standard MESFET process, via holes through the substrate, air bridges and electron beam gate lithography. The unit is available in chip form. Specifications for the amplifier include broadband performance of 9 to 10.5 GHz, output power of 27 dBm, gain of 15 dB, gain flatness of ±1.5 dB and a chip size measuring 2.09 × 1.27 × 0.10 mm.

United Monolithic Semiconductors SAS,
Orsay, France +33 (0) 1 69 33 03 08.

Circle No. 401

PCS Band Low Noise Amplifier

The model QBH-8756 hybrid surface-mount packaged LNA operates in the PCS band from 1850 to 1910 MHz with a high dynamic range for wireless base stations or similar applications. The latest version has been improved to provide a gain of 22.5 ±0.5 dB, noise figure ≤ 1.0 dB, low input/output SWR and excellent OIP3 performance of +37 dBm.

REMEC Q-bit Inc.,
Palm Bay, FL (800) 226-1772.

Circle No. 440

ANTENNA

2.4 GHz Fiberglass Antenna

The model MFB24010 industrial, scientific and medical band omnidirectional antenna provides stable 10 dBi gain performance over 2.4 GHz frequencies with an SWR of less than 1.5. The unit is vertically polarized and terminates in a type-N female connector. Other electrical fea-

tures include an impedance of 50 Ω, a bandwidth of 100 MHz at 1.5 SWR and a 9° vertical beamwidth at half power. The antenna is encased in a pultruded UV-stable fiberglass radome measuring 5/8" in diameter, which provides maximum durability and can withstand winds of up to 125 mph. The unit measures 36" tall with a mounting base of 1.25" and is designed for long-range wireless data collection requiring RF coverage. Suitable applications include traffic monitoring in the transportation industry, inventory tracking on factory floors and wireless Internet communications.
Maxrad Inc.,
Hanover Park, IL (800) 323-9122
or (630) 372-6800.
Circle No. 402

INTEGRATED CIRCUITS

■ 868/915 MHz RF Transceiver Chip

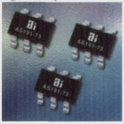
The model CC900 totally integrated RF transceiver chip is designed for use in the European 868 MHz and US 915 MHz short-range device RF bands. Offering high flexibility and integration, the unit also complies with all requirements for communication in all 868 MHz subbands. The frequency-hopping spread spectrum option of the unit as well as other features that improve the communication security make the unit a good choice for critical applications such as wireless alarm and security systems. The programmable carrier frequency from 800 to 1000 MHz gives customers flexibility to use the unit in their products for the worldwide market. The long communication range (up to 500 m with 4 dBm output power) makes the product well suited for a broad range of wireless applications. The chip's high level of integration enables high performance communication and low system cost. The fine frequency programming steps (250 Hz) enable communication in 25 kHz channels without the use of a temperature-compensated crystal oscillator (TCXO).
Chipcon Components AS,
Oslo, Norway +47 22 95 85 44.
Circle No. 407

■ 3G CDMA Chipset and System Software Solution

The model MSM5000™ Mobile Station Modem (MSM™) is a 3G CDMA 1× multicarrier solution for CDMA handsets that is compliant with the 3G standard as specified by the International Telecommunications Union (ITU). The chipset and system software allow manufacturers to design 3G handsets that, in addition to offering a rich application and feature set in small form factors, provide longer standby times and higher data rate capabilities. The unit is pin compatible with the model MSM3000™ chip and its software architecture. Pin compatibility allows the 29 handset manufacturers using the MSM3000 to introduce 3G handsets rapidly by reusing existing handset designs and software applications. The new MSM5000 exceeds the ITU's 3G requirements for data rates in full wide-area mobility of 144 kbps by enabling data rates of 153.6 kbps on both the forward and reverse links. The solution gives operators up to twice the overall capacity of IS-95A and IS-95B systems by providing features such as fast 800 Hz forward power control and new modulation and coding schemes.
QUALCOMM Inc.,
San Diego, CA (858) 587-1121.
Circle No. 409

■ pHEMT GaAs IC SPDT Switch

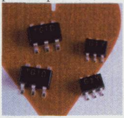
The model AS191-73 pHEMT GaAs FET IC high linearity SPDT switch features +2.5 to 5 V



linear operation at input power levels greater than +35 dBm. This low insertion loss (0.5 dB at 0.9 GHz), high isolation (27 dB at 0.9 GHz) switch is manufactured in the ultraminiature SOT-6 package. The switch can be used in many analog and digital wireless communication systems, including cellular, GSM and Digital Enhanced Cordless Telephony applications. Price: $1.05 each (50,000).
Alpha Industries,
Woburn, MA (781) 935-5150.
Circle No. 405

■ PA Driver Amplifiers

The models UPG2110TB and UPG174TA power amplifier (PA) driver amplifiers feature



low voltage, low current operation and low adjacent-channel power leakage to help ensure minimal distortion. Specifications for the UPG2110TB and UPG174TA include a V_{DD} of 3 and 3.3 V, I_{DD} of 20 and 37 mA (typ), and adjacent-channel power leakage of –60 and –42 dBc, respectively. In addition, the UPG2110TB features external input and output matching and an on-chip variable gain control function, eliminating the need for additional circuitry in the design. Housed in the 2.1 × 2.0 mm six-pin super mini-mold S06 package, the UPG2110TB is priced at $1.50 each (1,000,000). The UPG174TA is housed in the 2.8 × 2.9 mm six-pin mini-mold T06 package and is priced at $1.30 each (1,000,000).
California Eastern Laboratories,
Santa Clara, CA (408) 988-3500.
Circle No. 406

■ High Resolution DDS

The model HSP45314 direct digital synthesizer (DDS) features a high performance architec-

ture that delivers the fine-tuning resolution, accurate digital control and good spurious performance required by today's evolving communications standards. The unit integrates a 48-bit programmable carrier numerically controlled oscillator, a high speed 14-bit digital-to-analog converter and a comparator circuit for square-wave generation into a single 48-pin LQFP package, and is suitable for use in point-to-point microwave sys-

[Continued on page 400]

tems, wireless local loop, LMDS, MMDS, satellite terminals, communications instrumentation, cable modems, NTSC/PAL video systems and last-mile wireless applications. The DDS is a monolithic IC that uses programmable numerically controlled oscillator technology together with an internal high speed, 125+ MHz D/A converter and comparator to form a complete, digitally controlled frequency synthesizer and clock generator. The device's architecture allows the generation of output frequencies of up to one-half the reference clock frequency (62.5 MHz). Frequency shift-keying modulation is accomplished by updating the offset frequency register or toggling an enable pin. The 48-bit tuning word permits an output tuning resolution of 0.444 microhertz with a 125 MHz reference clock input. The device operates over the extended industrial temperature range of –40° to +85°C. Price: $10.20 (1000).
Intersil Corp.,
Melbourne, FL (888) 468-3774.
Circle No. 430

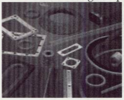
MATERIALS

Carbon-loaded Microwave Absorbers

The ECCOSORB® AN HR series carbon-loaded foam microwave absorber materials are lightweight, offer good broadband absorption and are cut easily to specific shapes. The products can be supplied in preconfigured shapes to meet customer specifications. The units are available with peel-and-stick adhesives with a coating (to reduce dusting), a metal back and a dielectric film layer. For outdoor use the weatherproofed AN-W series is also available. Applications for the specular absorbers include lining high performance shrouded antennas to reduce back radiation, lining antenna caps for testing aircraft surface-mounted antennas, lining antenna housings to improve antenna performance, lining shielded antenna test boxes, reducing RF interference around antenna feeds and improving the performance of antennas mounted on ground planes.
Emerson & Cuming Microwave Products,
Randolph, MA (800) 650-5740
or (781) 961-9600.
Circle No. 412

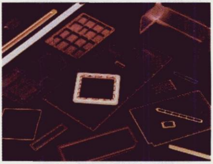
Wire Mesh Gaskets

These metal-based EMI shielding gaskets include a broad range of products, including knitted wire mesh, mesh over elastomer core, oriented wires in elastomers and metal screen-impregnated elastomers. The gaskets provide 60 to 100 dB of EMI shielding between 20 MHz and 10 GHz. The units are typically applied in seams and apertures in metal enclosures. The company's manufacturing technology provides economical, quality wire mesh EMI gaskets in bulk and pre-cut custom lengths. New mesh cutting and termination technology eliminates frayed ends. High speed wire knitting, secondary mesh-forming processes and foam core design and manufacture are used to develop and produce a wide variety of standard and custom metal-based shielding products. Typical wire mesh prices start at less than 25¢ per foot.



Chomerics,
a division of Parker Hannifin Corp.,
Woburn, MA (781) 939-4163.
Circle No. 411

Telecommunication Enclosures

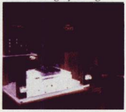


These standard and custom aluminum die cast and sheet metal enclosures feature integral environmental, EMI, RFI and ESD seals and gaskets for use in the telecommunication industry. The turnkey assemblies are suitable for use in areas where moisture and high electronic noise are common, such as cellular telephone base station enclosures, amplifiers and switching equipment. Detailed machining and finishes with decorative/protective coatings are available to meet any telecommunication and corporate standard. With on-site applications engineers, carrier-to-noise ratio machining and a full tool and die shop, companies can quickly produce prototypes and production parts for demanding schedules. All parts can be finished or machined with seals and gaskets molded in place prior to delivery. Integral seals and gaskets are precision molded or extruded elastomers with both metal and fabric impregnation, Teflon skin and combinations of elastomers to meet all environmental and EMI requirements.
Alloy Die Casting Co.,
Buena Park, CA (714) 521-9800.
Circle No. 410

PROCESSING EQUIPMENT

User-configurable Workstation

The WS4000 series user-configurable workstation is a highly integrated microwelding system that combines power supply, weld heads, motion control and parts handling into semi- and fully automated platforms. The unit provides manufacturers with a flexible, cost-effective standardized platform for implementing robust and highly repeatable application-specific welding processes without incurring the expense of developing full custom welding and motion systems. The workstation can be built around a variety of high frequency inverter, linear DC, AC or capacitive



discharge power supplies connected to a head using parallel gap, series, step or opposed gap electrode configurations. Z-axis movement and force control is handled via precision pneumatic actuators, which are complemented by a wide range of stepper motor-driven X, Y and θ motion-control capabilities. For demanding production-oriented applications, the workstation can be readily integrated as either an in-line process or stand-alone production cell and can reliably deliver sustained rates of up to 3600 welds per hour. All welding parameters, motion-control sequences and test functions are fully programmable using the workstation's Windows NT®-based intuitive graphic user interface, which also supports full data logging and interface to production-wide statistical process control systems.
MicroJoin Inc.,
a subsidiary of Palomar Technologies Inc.,
Poway, CA (858) 877-2100.
Circle No. 413

SOFTWARE

■ Smart Bidirectional Translator

The AnsoftLinks™ for Cadence® Analog Artist® series bidirectional translator allows design sharing between Cadence's Analog Artist and Ansoft's Serenade® design environments. High frequency IC designers of today's communication modulation formats can now utilize each tool to reduce time-to-market pressures. AnsoftLinks, coupled with Serenade version 8.5, allows manufacturers of MMIC, RFIC and wireless communication devices to use the company's Harmonica and Symphony software. AnsoftLinks or Cadence Analog Artist offers bidirectional active translation to/from Virtuoso® Composer and Serenade, support for Artist extensions to Composer, seamless operation between RF/microwave tools from both companies, compatibility with custom libraries and standards for symbols and parts, fast translation times, the ability to delete components and the ability to add standard Harmonica components as well as custom components.
Ansoft Corp.,
Pittsburgh, PA (412) 261-3200.
Circle No. 431

■ RF and DC Parameter Testing Software

The GPTS general-purpose RF and DC parameter testing software is designed for measuring de-embedded RF and DC parameters of transistors and other RF components under constant or swept input power, frequency and DC bias. GPTS processes CW as well as modulated and pulsed signals; it includes 3T and TRL characterization of test fixtures and wafer probes. An "Adapter Removal" module allows measurement of S parameters of mixed-connector-type structures, such as networks of amplifiers. All measured data can be processed to cartesian plots and spreadsheet listings and prepared for transfer to optimization software.
Focus Microwaves Inc.,
St-Laurent, Quebec, Canada
(514) 335-6227.
Circle No. 441

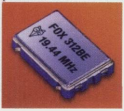
■ Software Interface

This interface can be used between the company's Pantheon series PCB/hybrid/multichip module design software and Viewlogic's XTK™ series Crosstalk tool kit. The interface allows designers to transfer data between Pantheon and XTK, solving signal integrity problems through analysis and simulation. The interface also allows Pantheon users to benefit from XTK's prelayout analysis, which provides good choices in system topology, line termination and driver/receiver selection. The Pantheon design software can export information directly into the XTK format without the need of a translator. By directly transferring the PCB database information from Pantheon to XTK, designers can quickly analyze signal quality, predict preroute delay and system level noise, calculate the electrical parameters of multiconductor configurations and simulate transmission lines and interconduction coupling. The XTK interface is available currently as an option to new and existing customers of Pantheon. The interface is supported on HP-UX, Linux, Solaris and PC (Windows '98/'00/NT) platforms.
Intercept Technology Inc.,
Atlanta, GA (404) 352-0111.
Circle No. 432

SOURCES

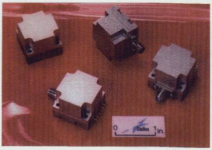
■ Subminiature TCXO

The model 312BE TCXO is designed for portable, telecommunications, data and test equipment applications. The unit operates from 12.6 to 19.8 GHz and features a frequency tolerance at 25°C of ±0.5 ppm and frequency stability of ±2.5 ppm over the operating temperature range of –20° to +75°C. Storage temperature range is from –40° to +80°C. The TCXO requires a supply voltage of 3 ±0.15 V. Its output waveform is a clipped sinewave with a minimum peak-to-peak level of 0.8 V and input current of 2 mA (max). Prices: start at $8 each (1000). Delivery: eight to 10 weeks (ARO).



Fox Electronics,
Fort Myers, FL (888) 438-2369.
Circle No. 416

■ Low Cost Miniature YIG

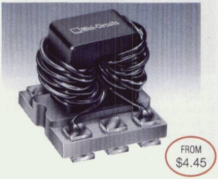


This miniature yttrium iron garnet (YIG) is designed for applications requiring a low cost oscillator with low phase noise and broad tuning range. The 1" square YIG-tuned oscillator is available in 2 GHz bandwidths from 2 to 14 GHz and features the low tuning power consumption of permanent magnet construction. Power output is 16 dBm (typ) over lower bands with +13 dBm output above 8 GHz. The miniature YIG has been designed specifically for good phase noise and low manufacturing costs.
Stellex Electronics Inc.,
Palo Alto, CA (800) 321-8075.
Circle No. 417

[Continued on page 404]

NEW PRODUCTS NO. 70

RF/IF MICROWAVE COMPONENTS



2 TO 500MHz RF TRANSFORMER HAS 3:1 IMPEDANCE

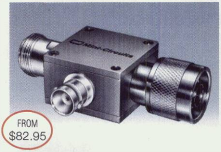
Mini-Circuits has unveiled the TCM3-1T, a 2 to 500MHz broad band surface mount RF transformer operating with a 3:1 impedance ratio. Referenced to midband loss (0.5dB typ), insertion loss is 1dB from 5MHz to 300MHz, and 2dB band wide. Maximum operating temperature is -20°C to +85°C. Open case design has plastic base with solder plated leads, and applications include impedance matching. RF power is 250mW (max.).

LEVEL 7 MIXER FOR CELLULAR AND VHF/UHF RECEIVERS

it™ Mini-Circuits has added a 200 to 1000MHz mixer to their low cost, low profile family of patent pending "Innovative Technology" surface mount mixers. The ADE-4 typically features low 6.8dB conversion loss, good 53dB L-R, 40dB L-I isolation, and 15dBm IP3 at center band. The ultra-low profile 0.112" package is equipped with solder plated leads for excellent solderability. A 5 year Ultra-Rel® guarantee is included.

800 TO 2500MHz MIXER HAS REPEATABLE PERFORMANCE

Mini-Circuits patented family of MBA model Blue Cell™ mixers deliver a unique combination of low conversion loss, superb temperature stability, thin 0.07" profile, and low cost. This level 17 (LO) MBA-12H model for 800MHz to 2500MHz operates with 30dB L-R, 13dB L-I isolation and low 6.8dB midband conversion loss (all typ). Wide ranging applications include satellite, ISM, PCMCIA, WLAN, PCN/PCS wideband LDMA, and cellular. Operating temperature is -40°C to +85°C.

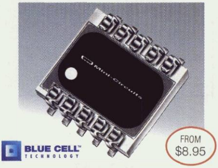


2.5 TO 6000MHz BIAS TEE HAS BROADBAND COVERAGE

Mini-Circuits has developed the ZNBT-60-1W, a new broadband bias tee for 2.5MHz to 6000MHz. Ruggedly constructed with Male-N and Female-N connectors standard, these high power 1W RF (0.5A dc current), low cost units typically provide low 0.6dB insertion loss and good 1.10:1 VSWR. Applications include biasing of laser diodes and active antennas, biasing amplifiers, and test accessory. Maximum operating temperature is -55°C to +100°C.

VHF VCO PERFORMS WITH LOW NOISE

This 125 to 175MHz JCOS-175LN voltage controlled oscillator from Mini-Circuits features low -158dBc/Hz phase noise at 1MHz offset, flat 3-5MHz/V typical tuning sensitivity, and operates from a 12V power supply (20mA max. current). The VCO is designed for 50 ohm VHF-TV applications requiring 1 to 17V (min. to max.) tuning voltage and 3.7dBm typical power output. Typical 3dB modulation bandwidth is 2900kHz. Available from stock.



1.8 TO 2.2GHz 2WAY SPLITTER IS FEATURE RICH

Outstanding characteristics of Mini-Circuits patented 2way-0° SBA-2-2 Blue Cell™ power splitter/combiner includes superb temperature stability within the 1800 to 2200MHz band, low 0.07" height, ceramic multi-layer design, high repeatability, and low cost. Electrically, these 50 ohm units display low 0.5dB typical insertion loss and excellent 0.7dB amplitude, 7 degrees phase unbalance (max.). Typical isolation is 22dB. Applications include PCS.

NEW PRODUCTS

622 MHz BAW VCXO

The model CFPV-2365 high frequency voltage-controlled crystal oscillator (VCXO) is designed using bulk acoustic wave (BAW) crystal technology and delivers a good combination of frequency stability and voltage control (frequency pulling) to conventional surface acoustic wave (SAW) devices. A range of 622 MHz BAW VCXOs based on fundamental crystals produced from inverted mesa blanks combines frequency stability of ±20 ppm from 0° to +70°C, or ±30 ppm from −25° to +85°C, with frequency pullability of between ±80 and ±120 ppm. The oscillator circuit operates at 155.52 MHz, but its fourth harmonic is selected and amplified to provide the 622.08 MHz output frequency. This frequency generation method provides good jitter performance to multiplying up the signal from a low frequency oscillator: less than 2 picoseconds between 12 kHz and 150 MHz from the output frequency. The unit can also operate from a 3.3 V power supply, making it easy to interface to emitter-coupled logic families. The VCXO is supplied in an industry-standard, hermetically sealed metal package measuring 20.7 × 20.7 × 9.9 mm. Price: $48 each (1000), depending on specification.

C-MAC Frequency Products (CFP), Durham, NC (919) 941-0430.

Circle No. 415

100 MHz VCXO

The model 220100 100 MHz VCXO, introduced as part of the company's fast-turnaround program, operates on +12 to +15 V DC with very low phase noise. The unit has a low profile for PC board mounting. Full specifications and program details are available from the company. Delivery: two weeks.

Techtrol Cyclonetics Inc., New Cumberland, PA (717) 774-2746.

Circle No. 442

925 – 1650 MHz VCO

The model V585ME20 VCO has been engineered for the cable modem market and offers linear, broadband tuning and single-sideband phase noise performance. The unit generates frequencies from 925 to 1650 MHz within 3 to 21 V DC of control voltage and covers the frequency range with an average tuning sensitivity of 57 MHz/V. The VCO also exhibits good spectral purity of −102 dBc/Hz (typ) at 10 kHz from the carrier while drawing 16 mA of current from an 11.5 V DC supply. The unit offers 7 ±2.5 dB of output power into a 50 Ω load and is designed for tough outdoor applications over the extended commercial temperature range of −40° to

+85°C. In addition, the device can optimize any cable modem phase-locked loop with its 1.1:1 linearity over frequency and temperature. The VCO also pulls less than 20 MHz with a 14 dB return loss, any phase, and a pushing specification less than 2 MHz/V within a five percent change in the supply voltage. The unit is supplied in an industry-standard low profile miniature SMT package measuring 0.50" × 0.50" × 0.22". The device is suitable for automated surface-mount assembly and reflow and is available in tape-and-reel packaging for production requirements. Price: $15.95 each (5). Delivery: stock to six weeks.
Z-Communications Inc.,
San Diego, CA (858) 621-2700.
Circle No. 418

SUBSYSTEMS

Integrated Modular Assemblies

Designed for microwave, RF, video and audio test applications in the DC to 18 GHz range,

these integrated modular assemblies provide a good interface between test equipment and complex, sophisticated systems with multiple inputs and outputs that need to be tested. The company's switch matrix technology provides the basis of the integrated assemblies. A variety of passive components are added, depending on the schematic, to provide customization and increased functionality to testing processes. The units' modular design adds flexibility by allowing the removal of sections from the complex assembly for easy maintenance and service. The switches range from SPST to SP6T, transfers, T-switches and a family of waveguide designs as well as waveguide blocks, matrices and integrated assemblies.
Dow-Key Microwave Corp.,
Ventura, CA (805) 650-0260.
Circle No. 419

TEST EQUIPMENT

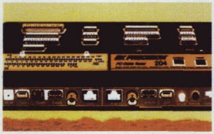
Noise Figure Analyzers

The NFA series dedicated noise figure analyzers offer an integrated, 17 cm color display with single- or split-screen view, limit lines for easy pass/fail testing, comprehensive marker functions, a real-time clock to time stamp data files and printouts, and an intuitive user interface for easy operation. The units are a family of one-box, dedicated noise figure analyzers designed to provide comprehensive characterization of any device under test at a reasonable cost. The analyzers offer a graphical display of noise figure or gain vs. frequency, easy measurement setup, built-in data storage and an easy way to download measurement reports or further processing. In addition, the units provide simultaneous noise figure and gain measurement, low instrument uncertainty, correction for measurement system noise, true single- and double-sideband measurement, the ability to characterize frequency-translating devices and flexible solutions above 2 GHz.
Agilent Technologies,
Englewood, CO (800) 452-4844.
Circle No. 422

Digital Delay/Pulse Generator

The model 555 digital delay/pulse generator provides multichannel 1 ns resolution timing, delaying, gating, pulsing and syncing functions, and includes selectable TTL/CMOS or adjustable amplitudes up to 15 V into a high impedance. Available configurations are two, four or eight channels of output, with each channel providing both delays and width. The model 555 also offers a full numeric keyboard, spinner knob and four-line status display, making it a powerful yet user-friendly product. Price: starts at $1705. Delivery: 60 days (ARO).
Berkeley Nucleonics Corp. (BNC),
San Rafael, CA (800) 234-7858
or (415) 453-9955.
Circle No. 435

Stand-alone Cable Tester



The model 205 universal cable tester is a lightweight, portable, battery-AC-powered unit that can be used for testing any cable or harness. The stand-alone cable/harness tester can be used for testing any type of wired assembly with up to 128 points. A universal connector card is designed to accept up to 28 of the most commonly used cable connectors. The device detects opens, shorts and miswires in less than 50 ns. The user-configurable connector card allows the user to mix/match connector types and plugs into the tester with two 96-pin DIN connectors. An easy-to-follow menu displayed on the two-line × 26-character liquid crystal display (LCD) simplifies testing and operations. Battery backup memory permits up to 50 nonstandard cable/wiring configurations to be stored. Wiring messages are shown on the built-in LCD and can be sent to an external printer via a standard 25-pin parallel printer interface port. A test probe is provided for single wire identification or troubleshooting. Weighing 6 lb and measuring 13.8" × 9.0" × 2.1", the tester is equipped with a DC 12 to 14 V, 500 mA AC adapter, universal connector card and probe. Price: $895.
BK Precision Corp.,
Placentia, CA (714) 237-9220.
Circle No. 423

Liquid Cell Dielectrometer

The model 3000T liquid cell dielectrometer is designed to perform measurements of dielec-

[Continued on page 407]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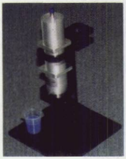
FOR CONFERENCE ENQUIRIES :
Nicola Jedrej, Operations & Marketing Executive
Tel : +44 (0) 20 7861 6391 Fax : +44 (0) 20 7861 6251
Email : nicola.jedrej@unmf.com

NEW PRODUCTS

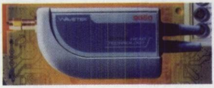


tric constant of coarse materials. The unit can be used in several applications, including evaluation of the dielectric constant and conductivity of soils in the design of ground-penetrating radar systems. Specifically, the unit is designed for granular and coarse materials that cannot be measured in smaller cells. It is used to measure wet soils, clays, contaminated oils and sludge, grains, foods and biological liquids. The dielectrometer operates from below 1 MHz to above 1 GHz. It measures dielectric constant (ε), loss tangent ($\tan\delta$) and bulk conductivity (σ) under the instrument control of the company's MU-EPSLN software package for common Anritsu and Agilent analyzers. The unit is available with calibration standards, a vertical stand, a carrying case and an optional holder for μ/ε-type measurements of solid materials.

Damaskos Inc.,
Concordville, PA (610) 358-0200.

Circle No. 427

Oscilloscope Calibration Workstation



The model 9550 Active Head oscilloscope calibration workstation provides a high precision 25 ps pulse to allow oscilloscope manufacturers and calibration service providers to calibrate the latest oscilloscopes. The company's Active Head Technology® provides the technology platform to meet the calibration needs of existing and future generations of oscilloscopes. The unit generates a pulse with rise and fall times of 25 ps at the terminals of the unit under test, guaranteeing the integrity of the signal. The workstation is controlled by model 9500 oscilloscope calibrators. Price: $5995.

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

Circle No. 421

Cable Network and Interference Emulator

The model 8250 cable network and interference emulator emulates critical hybrid fiber/coax (HFC) cable network impairments in a controllable laboratory instrument.

The unit emulates both upstream (5 to 42 MHz) and downstream (50 to 860 MHz) HFC channel characteristics in a single integrated instrument. Impairments emulated by the emulator include amplitude tilt, intermodulation distortion, group delay distortion, noise and interference. The impairments can be emulated independently to isolate the effect of a particular impairment on a product's performance or simultaneously to evaluate product performance in a real-world environment. A built-in diplex filter combines the upstream and downstream channels from the cable modem termination systems (or headend) into a single interface, allowing single or multiple subscriber devices (cable modems) to be tested. The company's TASKIT/8250 series software provides a graphical user interface for controlling the emulator's parameters.

Telecom Analysis Systems Inc. (TAS),
Eatontown, NJ (732) 544-8700.

Circle No. 425

50 GHz Automated Tuner

The model MT984A broadband 50 GHz automated tuner is capable of presenting a high

mismatch (15:1) over a broad frequency range (8 to 50 MHz). Designed to operate with the MT980 series automated tuner systems, the unit is designed to perform measurements where a high mismatch is required. The tuner offers good repeatability of better than 40:1 (min) over the entire frequency and matching ranges, and is able to perform noise, power, intermodulation and adjacent-channel measurements used for device characterization and circuit design. This precision slide-screw tuner features the capability of fully retracting the pair of probes and linear drive (via precision anti-backlash mechanical assemblies) to achieve high resolution and good repeatability and resetability. Each end of the tuner is equipped with an optoelectronic limit switch to define the end stops for linear travel. The unit is supplied with precision 2.4 mm connectors to ensure an accurate, repeatable interface.

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

Circle No. 428

Base Site Analyzer

The model 1900 base site analyzer meets TIA/EIA-136 specifications in the 400 to 800 MHz and 1900 MHz bands. It provides full-service monitor functionality from 10 MHz to 2 GHz. The unit's test capabilities include low level power measurements to –40 dBm (useable to –60 dBm), which allow the field engineer to test a base station without taking it off line. The analyzer derives its speed and power from a dual-digital signal processor design.

[Continued on page 408]

NEW PRODUCTS

Other features include full crossband duplex test and automated bit error rate test capabilities. The analyzer includes a full-function spectrum analyzer, duplex operation, line fault analysis, cable sweep and off-the-air monitoring of site operation. In addition to the TIA/EIA-136 testing capabilities, the analyzer also provides the required ability to fully test AMPS base stations. Price: $43,995. Delivery: four to eight weeks (ARO).

IFR Inc., Wichita, KS (800) 835-2352 or (316) 522-4981.

Circle No. 424

TUBE

■ 28 GHz TWT

The model ITW-28GC-150WA 28 GHz, 150 W traveling-wave tube (TWT) is a high performance, single-beam unit for use in LMDS, wireless communications or satellite uplink amplifier service. The LMDS TWT features a coupled cavity circuit, which improves reliability over the traditional helix design used currently in the West. The coupled cavity design is widely regarded as a good technique for high power mm-wave tubes. EIA WR-28 waveguide and UG 599/U flange transitions provide RF input and output access. Input and output SWR does not exceed 1.3 with integral ferrite isolators. An integral vac ion pump ensures good vacuum conditions, good performance and a long lifespan. General electrical characteristics include an operating frequency of 27.5 to 29.5 GHz, RF output of 150 W (mimimum saturated mode) and $\leq$ 60 W (linear mode), voltage of 5.5 ±0.5 V, current at 5.5 V of 1.65 A, gain of 47 dB (saturated mode) and 50 dB (linear mode), and third-order intermodulation level at 6 and 10 dB below saturation of –24 and –28 dB, respectively.

Svetlana Electron Devices Inc., Huntsville, AL (256) 882-1344.

Circle No. 429

NEW LITERATURE

■ Systems Approach Catalog

This 20-page catalog describes a systems approach to wireless RF transmission lines, overviewing electrical, mechanical, system and supplier performance; transmission line cable; water migration; connectors; electrical performance; installation issues; RF systems; quality; and options. Product photographs are included.

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

Circle No. 369

■ Digital Broadband Brochure

This six-page brochure details digital broadband test components, including analog and digital recorders, high speed data capture, arbitrary waveform generators, digital vector generators, mixed-signal and distortion measurement test sets, broadband modules and channel simulators, and custom test solutions.

Celerity Systems,
an L3 Communications company,
Cupertino, CA (888) 274-5604.

Circle No. 365

■ EMI Commercial Measurement Program Brochure

This two-page brochure describes the company's electromagnetic interference (EMI) commercial measurement program for Anritsu spectrum analyzers. Prices/terms are listed.

EMC Consulting,
Silver City, NM (505) 388-5512.

Circle No. 366

■ Oscillator Technical Brochure

This six-page brochure describes the expanded range of Just-In-Time Oscillators (JITO-2®), including a new line of plastic-encased programmable oscillators. The JITO-2 program, which ships oscillators with standard or custom frequencies from 340 kHz to 250 MHz in 10 working days or less, is also highlighted.

Fox Electronics,
Fort Myers, FL (888) 438-2369.

Circle No. 367

■ Quartz Crystal Oscillator Data Sheet

This two-page data sheet describes the model FE-101A subminiature oven-controlled commercial quartz crystal oscillator. Features include a warm-up time to stabilized frequency of less than two minutes and temperature stability of 5×10^{-8} at –50°C. Specifications, available options and an outline drawing are included.

Frequency Electronics Inc.,
Mitchel Field, NY (516) 794-4500.

Circle No. 368

■ 2000 MMIC Product Designer's Guide

This updated 600-page catalog includes 16 new MMIC product data sheets as well as new wireless application selection guides, application notes and trade journal article reprints. More than 95 products covering DC to 40 GHz are detailed.

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

Circle No. 370

■ Telecom Catalog

This 116-page catalog overviews a range of tool kits, hand and specialty tools, cable, telephone and electrical test equipment, and service aids. The company's line of JTS telecom test sets are also featured.

Jensen Tools Inc.,
Phoenix, AZ (800) 426-1194
or (602) 453-3169.

Circle No. 371

■ Phase Noise Analyzer System Brochure

This eight-page brochure describes the company's model NTS-1000B phase noise analyzer, which can be used in conjunction with model DCR-14000A or DCR-2500A downconverters. Specifications are provided.

RDL Inc.,
Conshohocken, PA (610) 825-3750.

Circle No. 372

■ Microwave Absorber Catalog

This 20-page catalog describes a new line of narrowband resonant absorbers, which are designed to resonate at particular frequencies (1 to 18 GHz) with less than one percent reflectivity at the design frequency. Raw materials, insert loads and microwave terminations are described.

Resin Systems Corp.,
Amherst, NH (603) 673-1234.

Circle No. 373

■ Global Antenna Solution Brochure

This four-page brochure describes the company's capabilities in producing antennas for several markets, including models for use in the wireless, GPS, satellite communications and defense industries. Product photographs are included.

Tecom Industries Inc.,
Chatsworth, CA (818) 341-4010.

Circle No. 374

■ Wireless Infrastructure Brochure

This brochure highlights technical ceramic capabilities, current and future ceramic technologies for all of the company's product lines, bandpass filters, diplexers, coaxial and dielectric resonators, and magnetic materials.

Trans-Tech Inc.,
a subsidiary of Alpha Industries,
Adamstown, MD (301) 695-9400.

Circle No. 375

■ Aluminum Electrolytic Capacitor Catalog

This 480-page catalog details the company's full line of aluminum electrolytic capacitors. A 28-page special section detailing precautions and guidelines for using the products is included.

United Chemi-Con Inc.,
Rosemont, IL (847) 696-2000.

Circle No. 376

The Essential Guide to RF and Wireless

Carl J. Weisman
Prentice Hall PTR
232 pages; $34.99
ISBN: 0-13-025962-4

Here is a book on RF and wireless components and systems that is strictly intended for a nontechnical audience. It has two simple objectives: to provide a conceptual understanding of RF components and wireless systems, and to expose the reader to the vocabulary used in the wireless communications industry.

> ***"[This book provides] a conceptual understanding of RF components and wireless systems..."***

Although the book can be read in parts depending on the interest of the particular reader, the author suggests Chapters 1 and 2 should be read by all since they lay the groundwork for basic RF concepts and behavior. Subjects such as basic electronic terminology, transmitters and receivers, device loss and gain, and the meaning of impedance match are among the topics covered.

Chapter 3 describes basic system components, offering block diagrams of a typical receiver and transmitter, antenna characteristics, amplifier operation, the function of filters and mixers and their properties, sources and how they work, and the basic voltage-controlled oscillator. Other components, such as switches, attenuators, dividers and combiners, and couplers, are covered in Chapter 4 along with circulators and isolators, transformers and detectors. In each case a block diagram of the item is presented along with a description of the device's function and system use. Chapter 5 discusses circuits and signals, beginning with a description of diodes, transistors and integrated circuits, then proceeding to circuit technologies and modulation techniques. Various forms of signal transmission means, such as cables, waveguide and printed circuit traces, are described.

Chapter 6 begins the section on older RF systems by describing radio and television broadcasting, radar and satellite communications. System operation is explained as is the role each plays in modern communications. Chapter 7 describes the newer wireless systems, including point-to-point microwave, wireless local loop and spread spectrum technology. Mobile telephony is covered along with the cellular radio concept and next-generation systems.

This book is ideal for nontechnical personnel such as advertising agents, sales administrators, marketing and communications personnel, and financial analysts who desire a basic understanding of the technology and its operation.

To order this book, contact: Prentice Hall PTR, PO Box 11073, Des Moines, IA 50336 (800) 947-7700.

Wideband CDMA for Third Generation Mobile Communications

Tero Ojanper and Ramjee Prasad
Artech House Inc.
439 pages; $99, £68
ISBN: 0-89006-735-X

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

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