Vol. 51 • No. 5
May 2008

Microwave Journal

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MICROWAVE JOURNAL 50 years 1958 2008 as the Industry Standard

MTT-S IMS Show Issue

Atlanta, GA

Symposium and Exhibition Preview

IMS 2008: Building the Future, Honoring the Past

Battle Between HF and UHF RFID

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Founded in 1958

MAY 2008 VOL. 51 • NO. 5

2008 IEEE MTT-S International Microwave Symposium & Exhibition

COVER FEATURE: THEN AND NOW

28 Why the Microwave Engineer Should Join PGMTT

Richard F. Schwartz, University of Pennsylvania

This article, first published in April of 1960, highlighted the many benefits of joining a professional society, in this case the IRE Professional Group on Microwave Theory and Techniques

34 PGMTT National Symposium for 1960

Microwave Journal *staff*

Reprint of the PGMTT technical program for the society's 1960 symposium, first held May 9 to 11 in San Diego, CA

40 IMS 2008: Building the Future, Honoring the Past

Joy Laskar, General Chair, 2008 International Microwave Symposium

A preview of this year's IEEE MTT-S International Symposium and Exhibition, as well as a nod to the past with a look back at the 1960 PGMTT National Symposium

SPECIAL REPORTS

50 Georgia on My Mind

David Vye, Microwave Journal *Editor*

An overview of Atlanta's burgeoning role in the microwave industry, particularly its role as host of the 2008 IEEE MTT-S International Symposium and Exhibition

54 Welcome to Atlanta

Scott Wood, Milestone Marketing Inc.

A primer on Atlanta and the surrounding area, including what to see and where to eat

70 2008 IMS Exhibitors

An alphabetical listing of companies participating in the Microwave Week exhibition and their respective booth numbers

80 Georgia World Congress Center Floor Plan

The layout of halls A1 and A2 of the Georgia World Congress Center for use in conjunction with the exhibitor list to locate participating companies

84 2008 IEEE MTT-S Technical Program

A complete day-by-day schedule of the technical presentations that compose the MTT-S, RFIC, ARFTG and µAPS conferences

51 Years of Publishing Excellence

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Microwave Journal

FEATURES

TECHNICAL FEATURES

152 **The Battle Between HF and UHF RFID**

F. Mohd-Yasin, M.K. Khaw and F. Choong, Multimedia University; M.B.I. Reaz, International Islamic University Malaysia

Comparison of high frequency and ultra high frequency in determining the best suited technology for today's commercial applications

170 **An Improved BSIM4 Model for 0.13 μm RF CMOS Using a Simple Lossy Substrate Extraction Method**

Chien-Cheng Wei, Hsien-Chin Chiu and Wu-Shiung Feng, Chang Gung University

Presentation of an improved BSIM4 large-signal model for a 0.13 μm radio frequency complementary metal-oxide semiconductor with a lossy substrate description

188 **Liquid Crystal Polymer: Enabling Next-generation Conformal and Multilayer Electronics**

Nickolas Kingsley, Auriga Measurement Systems

Overview of the advantages, limitations and challenges in using liquid crystal polymer as a substrate or packaging material

202 **Software-defined Radio Transmitters for Advanced Wireless and Satellite Communications Systems**

Fadhel M. Ghannouchi, University of Calgary

Discussion of the critical issues in designing software-defined radio-based transmitters for wireless and satellite applications

218 **Analysis and Design of a Compact Multi-band Antenna for Wireless Communications Applications**

Abdelnasser A. Eldek, Jackson State University

Introduction to a compact, multi-band and single-feed microstrip antenna for wireless communications applications at 0.9, 1.8, 1.9 and 2.4 GHz

232 **Harmonic Load Pull with High Gamma Tuners**

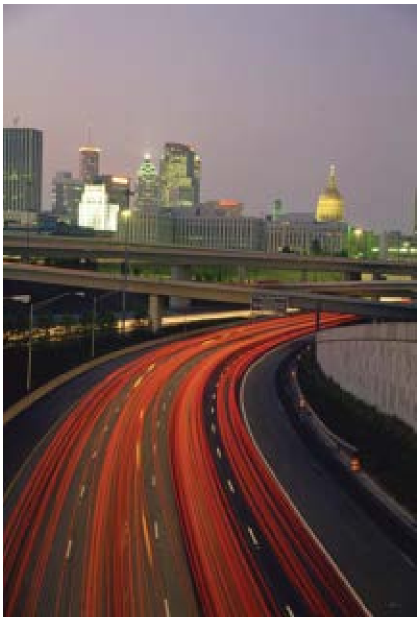
Gary Simpson, Maury Microwave Corp.

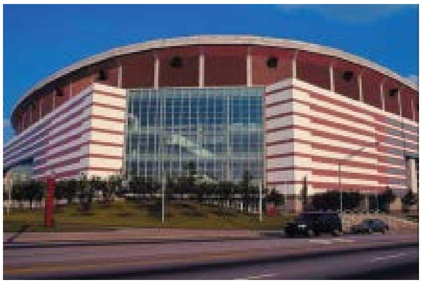
Review of the various types of tuners used for load pull, along with the methods used for harmonic tuning

244 **A Harmonic and Size Reduced Ring Hybrid Using Hairpin-type LUCs**

Hong-Seop Lee and Hee-Yong Hwang, Kangwon National University

Application of hairpin-type low-pass unit cells to the design of a microstrip hybrid ring for size reduction and harmonic suppression





Microwave Journal

FEATURES

TECHNICAL NOTE

252 Calculating Mismatch Uncertainty

Tony Lymer, Satori-Technology Ltd.

Explanation of mismatch uncertainty, a common and often underestimated source of error in microwave power measurements

PRODUCT FEATURES

256 Extending Electromagnetic Simulation and Analysis from Verification to Design

Agilent Technologies Inc.

Introduction to a three-dimensional planar electromagnetic simulator with algorithmic innovations in meshing and solving to improve simulation speed

264 To 20 GHz and Beyond: An Investigation into Passive Temperature Compensation

Florida RF Labs/EMC Technology

Use of a technique to accurately predict temperature variable attenuator performance, thus reducing the overall development cycle for radio frequency temperature compensation

272 New Generation Travelling Wave Tubes

e2v technologies (UK) Ltd.

Introduction to three mini-travelling wave tubes with proven rugged design and enhanced radio frequency performance characteristics

276 An RF Front-end Module for LTE/EUTRAN

Skyworks Solutions Inc.

Development of a highly integrated, fully matched, 16-pin surface-mount module for Long-Term Evolution and evolved UMTS terrestrial radio access network applications

DEPARTMENTS

23 . . .Coming Events
24 . . .Workshops & Courses
131 . . .Defense News
135 . . .International Report
139 . . .Commercial Market
142 . . .Around the Circuit
282 . . .New Products
330 . . .New Literature
332 . . .The Book End
334 . . .Career Corner
336 . . .Ad Index
342 . . .Sales Reps

We received several e-mails from readers of our March cover story on the history of the network analyzer. **John Barr** from Agilent EEsof RFIC product marketing wrote to thank us for the article and to identify the individuals standing by the HP8510 shown in Figure 3. John also provided clarification of some of the capabilities offered by several network analyzer models cited in the article. See John's full response at the end of the posted article at www.mwjournal.com. **Dr. Ulrich Rohde**, Partner at Rohde & Schwarz GmbH & Co., also directed us to a 1952 *IEEE Proceedings Letters*, which describes an analyzer "which can handle Z, G and S-parameters." This analyzer and paper from Rohde & Schwarz clearly predates the information presented in our story. We thank our readers for bringing this information to our attention and congratulate the network analyzer on its 56th birthday. It's hard to believe, but the VNA doesn't look a day over 50.

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Webinars

MWJ/Besser Associates Webinar Series
Tune-up your skills. Join the thousands of engineers and managers who have participated in this series on RF/microwave theory and practical applications.

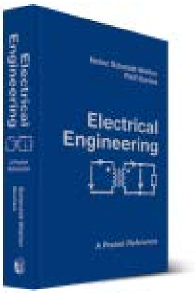
Power Amplifiers: This month's webinar discusses basic power amplifier concepts, classes of operation, linearity, techniques to enhance efficiency and other critical design trade-offs.

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

Live webcast: 5/15/2008, 11:00 AM (EDT)

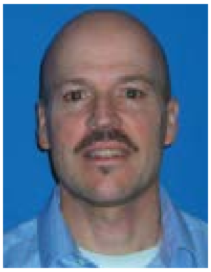
Sponsored by **AWR** and **Mimix Broadband**

Expert Advice



Microwave Journal asks a noted industry expert to provide commentary related to the month's editorial theme. Respond with comments and win a complimentary copy of *Electrical Engineering: A Pocket Reference* from Artech House (see www.mwjournal.com for details). Come join the discussion, happening now.

May: Looking to get the most out of exhibiting at IMS2008? **Pat Hindle**, *Microwave Journal* technical editor and former Marketing Communications Manager at M/A-COM, shares his knowledge on the best practices for IMS exhibitors. Read about Pat's tricks and share your own thoughts.



Online Technical Papers

Modified Wilkinson Power Divider with Harmonic Suppression
S.C. Bera, R.V. Singh and V.K. Garg, Indian Space Research Organization

Improving Multi-carrier PA Efficiency with Envelope Tracking
Gerard Wimpenny, Nujira

Gallium Nitride HEMT Applications
Tony Balistreri, R&D Manager, TriQuint Semiconductor

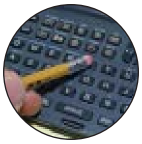
Software-defined Radio: The Next Wave in RF Test Instrumentation?
Michael Millhaem, Principal RF Application Engineer, Keithley Instruments Inc.

Retrospective: MTT-S/IMS

Microwave Journal online reprints a classic article from former MWJ editor Ted Saad, which appeared in the 1983 *IEEE MTT-S Transactions* covering the Symposium's first 25 years.

Executive Interview

In this month's executive interview, **Greg Maury**, President and CEO of Maury Microwave Corp., discusses the history of active device characterization, the impact of load impedance on performance and the need for high gamma tuners to accurately determine load requirements for today's low impedance power transistors.



CALL FOR PAPERS

Asia Pacific Microwave Conference (APMC 2008)
by June 1, 2008
IEEE Radio and Wireless Symposium (RWS 2009)
by July 14, 2008

JULY

IEEE International Symposium on Antennas and Propagation (AP-S)
July 5–12, 2008 • San Diego, CA
www.apsursi2008.org

AUGUST

IEEE EMC Symposium
August 18–22, 2008 • Detroit, MI
www.emc2008.org

SEPTEMBER

IEEE International Conference on Ultra-wideband (ICUWB 2008)
September 10–12, 2008 • Hannover, Germany
www.icuwb2008.org

Antenna Parameter Measurements by Near-field Techniques
September 16–18, 2008 • Boulder, CO
www.nist.gov

WiMAX World Americas
September 30–October 2, 2008 • Chicago, IL
www.wimaxworld.com

OCTOBER

AOC International Symposium and Convention
October 19–22, 2008 • Reno, NV
www.crows.org

International Symposium on Antennas and Propagation (ISAP 2008)
October 27–30, 2008 • Taipei, Taiwan
www.isap08.org

European Microwave Week
October 27–31, 2008
Amsterdam, The Netherlands
www.eumweek.com

NOVEMBER

WCA International Symposium
November 4–7, 2008 • San Jose, CA
www.wcai.com

electronica 2008
November 11–14, 2008 • Munich, Germany
www.electronica.de/en

Antenna Measurement Techniques Association (AMTA 2008)
November 16–21, 2008 • Boston, MA
www.amta2008.org

Military Communications Conference (MILCOM 2008)
November 17–19, 2008 • San Diego, CA
www.milcom.org

DECEMBER

Asia Pacific Microwave Conference (APMC 2008)
December 16–19, 2008 • Hong Kong, China
December 19–20, 2008 • Macau, China
www.apmc2008.org

JANUARY

IEEE Radio and Wireless Symposium (RWS 2009)
January 16–23, 2009
San Diego, CA
http://rawcon.org

WORKSHOPS & COURSES

DESIGN CHALLENGES: OPTICAL SIMULATIONS WITH CST MW

■ **Topics:** Users of CST software are invited to attend the first of CST's Design Challenge Workshop Series dedicated to optical applications. Attendees will get the chance to see how modern simulation technology can simulate and optimize structure in the optical frequency range utilizing CST's "Complete Technology" approach. The latest feature of CST MWS 2008 will be demonstrated and a preview of CST MWS 2009 will be given.
■ **Site:** University of Twente Enschede, The Netherlands
■ **Date:** June 3, 2008
■ **Contact:** For more information, visit www.cst.com.

PRACTICAL RF/MICROWAVE DESIGN

■ **Topics:** This intensive, five-day course provides acceleration through the RF design learning curve by presenting a comprehensive introduction to RF and microwave design theory, techniques and measurements. Many of the lectures rely on the use of live demonstrations involving test equipment and computer-based simulation tools to illustrate concepts. For more information, visit www.conted.ox.ac.uk.
■ **Site:** Oxford, UK
■ **Dates:** July 14–18, 2008
■ **Contact:** University of Oxford Continuing Education, Rewley House, 1 Wellington Square, Oxford, OX1 2JA +44 (0)1865 270360.

DESIGN CHALLENGES: EMC AND SI-PI SIMULATION

■ **Topics:** This workshop, concomitant to the IEEE International Symposium on EMC, is designed to give to SI and EMC engineers insight into the latest simulation technology for analyzing the most complex SI and EMC/EMI issues. With CST STUDIO SUITE™ 2008, attendees will get the chance to see how modern simulation technology can simulate and optimize all electromagnetic issues associated with increasingly complex 3D designs.
■ **Site:** Detroit, MI
■ **Date:** August 18, 2008
■ **Contact:** For more information, visit www.cst.com.

MAKING ACCURATE LOW LEVEL ELECTRICAL MEASUREMENTS

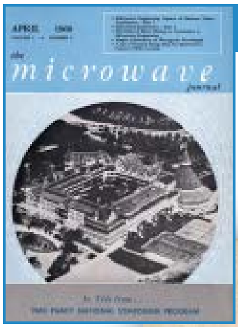
■ **Topics:** This course provides users with a detailed understanding of how to make accurate low level electrical measurements. Users will learn what constitutes a low level measurement, the limitations of these measurements, sources of measurement error and techniques to eliminate these errors. Additional topics include selecting the proper product for a desired measurement and understanding the basics of how to communicate with an instrument from a PC.
■ **Site:** Cleveland, OH
■ **Dates:** September 15–16, 2008
■ **Contact:** For more information, visit www.keithley.com.

VF USER GROUP CONFERENCE

■ **Topics:** This conference will provide the exchange of information and ideas as well as a series of presentations and talks presented by the company's software users. This networking forum will discuss the techniques employed to gain the best possible results in conjunction with software. Vector Fields (VF) will also highlight forthcoming developments and enhancements. In conjunction with this two-day conference, VF is holding three workshops and a two-day course on advanced topics in particle beam simulations.
■ **Site:** Oxford, UK
■ **Dates:** September 22–26, 2008
■ **Contact:** For more information, visit www.vectorfields.com.

THE ENTREPRENEURIAL ENGINEER

■ **Topics:** This short course is an efficient and memorable introduction to the personal, interpersonal, business and organizational skills necessary to help engineers of applied science and mathematics perform at high levels in today's increasingly opportunistic organizations and enterprises. For more information, visit http://online.engr.uiuc.edu/shortcourses/tee/index.html.
■ **Site:** Archived on-line course.
■ **Dates:** Archived on-line for anytime viewing.
■ **Contact:** University of Illinois at Urbana-Champaign, 117 Transportation Bldg., 104 S. Mathews Avenue, Urbana, IL 61801 (217) 333-0897 or e-mail: deg@uiuc.edu.



WHY THE MICROWAVE ENGINEER SHOULD JOIN PGMTT

RICHARD F. SCHWARTZ

ASSISTANT PROFESSOR OF ELECTRICAL ENGINEERING
The Moore School of Electrical Engineering
University of Pennsylvania • Philadelphia, Pennsylvania

THIS EDITORIAL IS DIRECTED on the surface toward the specific question of why a microwave engineer should join the IRE Professional Group on Microwave Theory and Techniques. It is impossible to answer this question unless the reader is convinced of the worth of professional societies in general. The writer has frequently been shocked by finding engineers (and fairly competent ones at that) who could see no value in technical associations. The argument advanced is usually that the journal of a particular society can be read in a library without one's being a member, or that the cost of belonging is too great. In these days of spiraling inflation it is all too easy to eliminate such expenses from ever-tightening family or personal budgets.

Professional societies are not new, of course. It may be difficult to trace the exact history, but it would seem reasonable to assume that professional organizations, like trade unions, have roots in the guilds of medieval Europe. Here, people of like interests banded together for the protection and regulation of the various callings. At a somewhat later date the intellectual elite organized societies for the exchange of ideas, the honoring of cultural achievements, and the promotion of learning. In this manner the Royal Society of Great Britain and the French Academy of Sciences were born. Most modern professional societies fall somewhat between these two extremes.

It was, of course, inevitable that such groups should flourish. Man is by nature gregarious. He must communicate with others. The success of our civilization is, in fact, due very largely to man's sociability — born partly from the need for protection — for with interdependency came specialization, the exchanging of ideas between men of common interest, and the flourishing of culture and technology.

Present-day professional societies vary greatly in objectives, but among engineering organizations one of the prime aims is the promotion of the exchange of technical information and the reporting of new engineering developments. No one working in design or development engineering can do a creditable job for long without referring to specialized periodicals, a large percentage of which are published by technical societies. It would be well at this point for the young engineer to pause and ask himself: "Do I use the technical societies' journals in my work?"

If the answer is "yes," let the young engineer next ask: "Who should support, govern, and write for these publications? Salesmen? Businessmen? Advertising agencies? Or engineers?" It shouldn't take much reflection to decide that engineering societies' magazines should be largely by and for engineers.

As for the technical meetings, the critic of technical societies will claim that these are dull affairs at which he can learn nothing. Most of us will agree that the oral presentation of technical papers usually leaves something to be desired. Nevertheless, such a presentation has some value. First, it is valuable to the per-

(*Continued on page 11*)

RICHARD F. SCHWARTZ was born in Albany, New York in 1922. He received the B.E.E. and M.E.E. degrees in 1943 and 1948 respectively, from Rensselaer Polytechnic Institute, and the Ph.D. degree in electrical engineering from the University of Pennsylvania in 1959.

In 1948 he joined RCA where he did advanced development work on UHF transmitting systems and some early transistor circuit work. In 1951 he joined the staff of the Moore School of Electrical Engineering at the University of Pennsylvania where he has been engaged in research and is presently an assistant professor of electrical engineering. Among his technical fields of interest are radio interference problems, microwave techniques and components, high-frequency transmission lines, and solid-state devices.

He has authored a number of technical papers and research reports, and he holds three patents.

Dr. Schwartz is a senior member of the IRE, a member of the AIEE, the American Association for the Advancement of Science, the American Society for Engineering Education, *Sigma Xi*, and *Eta Kappa Nu*. A member of the PGMTT National Administrative Committee, Dr. Schwartz heads the Membership Committee and also serves on the editorial board for the *PGMTT Transactions*.

PGMTT (*Continued from page 9*)

son giving the talk; it places him in contact with his peers in the field. Secondly, for the small number who bother to listen carefully to the presentation, it gives first-hand knowledge of what someone else has done, a full six months or more earlier than they could know if they waited for publication. And finally the meetings provide a means for getting to know others of like interest from whom a great deal can be learned.

But what of the expense? Since many engineers either claim they cannot afford to belong to a technical society, or else that they cannot pay the additional expense of a professional group, let us see what can be said on this question.

If the individual were a bricklayer instead of an engineer, the chances are high that he would have no choice; he would have to join the union. The same can be said of most trades. If he were a businessman he would find it to his business advantage to belong to Rotary, Kiwanis, the Chamber of Commerce, or even some exclusive golf club. The physician usually is a member of the American Medical Association or at least of the County Medical Society; it affects his livelihood. The lawyer finds the State Bar Association an aid in pursuing his profession. In a like manner the engineering society affects the engineer's work and livelihood. The expense should be viewed as a legitimate professional expense — the cost of the privilege of remaining in the engineering field.

But what of PGMTT? Or for that matter why professional groups at all? The subdivision of the IRE into such units was a post-World War II development that came about because of the mushrooming specialization in the radio-electronic-communication field. No longer could the "radio" engineer hope to remain well-versed in all phases of the art. New technical languages were developing in all specialties, and the IRE recognized that these special groups needed new outlets for the exchange of information.

Professional group subdivision actually was only an extension of the philosophy that led to technical societies in the first place, and it is interesting to note such subdivision is not unique in the IRE. The AIEE, the Society of Communication Engineers of Japan, The American Institute of Physics, to name a few — each have a structure within a structure based upon specialization.

PGMTT, of course, serves microwave engineers. Time was, for a few years following World War II, that the prime reference source for microwave engineers was the Radiation Laboratory Series. True, there were some other isolated works, and occasionally an interesting article in the *IRE Proceedings*, but the main body of reference knowledge was the half-dozen or so appropriate volumes of this set. This is no longer the case. Not that a profusion of *books* have replaced the Radiation Lab Series; rather the *Transactions of PGMTT* (together with the present journal) have provided the extension needed. Today the microwave engineer keeps abreast in *his journal* — a work so specialized that computer engineers, transistor experts, and audio workers scarcely understand a word of it; yet to the microwave worker it is indispensible.

Again the question: "Who should support and contribute to this periodical and its sponsoring group?" The answer should be clear.

From the editor

1960 PGMTT SYMPOSIUM

We will be watching the 1960 PGMTT Symposium to be held in San Diego on May 9, 10, 11, with a great deal of interest. This meeting will be held under somewhat different conditions than past PGMTT meetings. Previous meetings of this group have been held in either a large city in and near which much microwave work is taking place; such as, New York, Philadelphia, or Boston, or in an area which is an acknowledged center of microwave activity; such as, Palo Alto.

Although our friends may protest violently, San Diego does not quite fill either category. Of possibly even greater interest is the fact that the entire program will take place in the confines of the del Coronado Hotel, including technical sessions, rump sessions, banquet, and cocktail party. In addition, it is anticipated that most of the people attending the conference will stay at the hotel. This isolation and concentration may well result in a 24-hour per day meeting.

There will undoubtedly be many outside attractions, but this will be the first time in the history of PGMTT symposiums that such complete concentration has been encouraged. The experiment may prove to be an interesting one. The results will undoubtedly affect PGMTT technical meetings for years to come.

If the technical isolation approach is successful, who knows, next year we may go to Hawaii. If it fails, on the other hand, back to New York, Palo Alto, Philadelphia, or Boston. Other groups have made such a transition with great good fortune.

We have heard of technical meetings that have been held in Mexico City, Miami Beach, and other equally exotic locations, with resulting good effects. We hope the same will be true of the 1960 PGMTT Symposium.

One added bit of interest for probable attendees. We have been advised that the del Coronado Hotel was the scene of some of the filming of the motion picture "Some Like It Hot."

We have it on good authority, however, that Marilyn Monroe will not attend the Symposium.

Ted Saad

PGMTT NATIONAL SYMPOSIUM for 1960

SAN DIEGO, CALIFORNIA . . . MAY 9-11

San Diego's Hotel del Coronado will be the scene of the 1960 PGMTT National Symposium, May 9, 10 and 11.

The Symposium will open Monday morning, May 9, with a welcome by David Proctor, Convair-Astronautics, the Symposium Chairman, and opening remarks will be given by Dr. Arthur Oliner, Polytechnic Institute of Brooklyn, National Chairman of the PGMTT.

The customary banquet will be held in the Crown Room of the Hotel del Coronado on Tuesday evening, May 10. Dr. W. A. Edson, Manager, Klystron Subsection, General Electric Company, will be the banquet speaker. His subject will be "Future Microwave Power Sources," and will deal with trends in microwave power tubes. He will rely on the known history of devices and applications, together with foreseeable trends such as space travel and world-wide communications, to provide a reasonable basis for projecting future activities.

The technical program will include papers and panel discussions on the general subjects of Microwave Components and Systems, Parametric Amplifiers, Ferrites, Millimeter Waves and Diode Applications, Microwave Propagation in Plasmas and Solids, and Filters and Measurements.

Program of technical sessions follows:

1960 PGMTT National Symposium Committee. Left to right: W. E. Moore, Convair, Recorder; H. B. Babbitz, Convair, Publicity; Mrs. K. Abbey, Women's Activities; B. I. Small, Naval Electronics Laboratory, Financial; D. Proctor, Convair-Astronautics, Chairman; R. C. Hansen, Space Technology Labs, Administrative Committee Representative; D. B. Medved, Convair, Technical Program; H. D. Dickstein, Cubic Corporation, Local Arrangements. Not present were R. E. Honer, Convair, Section Representative, and C. E. Moe, San Diego State College, San Diego State Representative.

82 *the microwave journal*

TECHNICAL PROGRAM

Monday Morning, May 9

SESSION 1

Microwave Components and Systems

Chairman: T. N. ANDERSON

FXR, Inc., Long Island City, N.Y.

1. "New Developments in Microwave Communication Systems," *C. C. Cutler*, Bell Telephone Labs., Holmdel, N.J.
2. "Mode Conversion in Helix Waveguide," *H. G. Unger*, Bell Telephone Labs., Holmdel, N.J.
3. "Some Properties of Dielectric Loaded Slow Wave Structures," *G. B. Walker* and *C. G. Englefield*, Univ. of British Columbia, Vancouver, B.C., Canada.
4. "UHF Strip Transmission Line Hybrid Junction," *I. Tatsughuchi*, Bell Telephone Labs., Whippany, N.J.
5. "A Variable Slope, Non-Dispersive Microwave Phase Shifter," *G. D. Carey* and *R. E. Horda*, Autonetics, Div. of North American Aviation, Downey, Calif.
6. "A Wide-Band Turnstile Junction and Direction Finding Antenna," *R. C. Honey* and *J. K. Shimizu*, Stanford Res. Inst., Menlo Park, Calif.
7. "Microwave Phase Analyzer," *K. D. Claborn* and *R. E. Jones*, Bendix Radio, Div. of Bendix Aviation Corp., Baltimore, Md.

Monday Afternoon, May 9

SESSION 2

Parametric Amplifiers

Chairman: A. BERK

Research Labs., Hughes Aircraft Co. Culver City, Calif.

1. "Gallium Arsenic Point Contact Diodes," *W. M. Sharpless*, Bell Telephone Labs., Holmdel, N.J.
2. "Characterization of Microwave Variable Capacitance Diodes," *S. T. Eng*, Development Lab., Hughes Semiconductor Div., Newport Beach, Calif.
3. "A Perturbation Theory for Parametric Amplifiers," *R. H. Kingston* and *A. L. McWhorter*, Lincoln Lab., MIT, Lexington, Mass.
4. "A Study of the Optimum Design of Wideband Parametric Amplifiers and Up-Converters," *G. L. Matthaei*, Stanford Res. Inst., Menlo Park, Calif.
5. "A Low-Noise X-Band Parametric Amplifier," *R. D. Weglein*, Research Labs., Hughes Aircraft Co., Culver City, Calif., and *F. Keywell*, Semiconductor Div., Hughes Products, Costa Mesa, Calif.
6. "A Four Terminal Low Noise Parametric Microwave Amplifier," *W. Eckhardt* and *F. Sterzer*, RCA, Princeton, N.J.
7. "Design and Operation of Four-Frequency Parametric Up-Converters," *J. A. Luksch*, *E. W. Matthews*, and *G. A. Verwys*, RCA, Moorestown, N.J.
8. "A Study of the Herated Traveling Wave Parametric Amplifiers," *C. V. Bell*, Walla Walla College, College Park, Wash.

April, 1960 83

PGMTT Symposium

(*Continued from page 83*)

Monday Evening, May 9

SESSION 2A

Parametric Amplifiers

Panel Discussion:

A. Berk, Hughes Aircraft Co., Research Labs., Culver City, Calif.
C. J. Carter, Space Technology Labs., Los Angeles, Calif.
J. C. Green, Airborne Instruments Lab., Melville, L.I., N.Y.
E. M. T. Jones, Stanford Res. Inst., Menlo Park, Calif.
N. Uenohara, Bell Telephone Labs., Murray Hill, N.J.
G. Wade, Stanford Univ., Stanford, Calif.

Tuesday Morning, May 10

SESSION 3

Ferrites

Chairman: N. SAKIOTIS
Motorola, Inc., Scottsdale, Arizona

1. "Non-Linear Effects in Ferrites," *M. Weiss*, Research Labs., Hughes Aircraft Co., Culver City, Calif.
2. "Ferroxplane Type Materials at Microwave Frequencies," *I. Bady*, U.S. Army Signal Res. & Dev. Lab., Fort Monmouth, N.J.
3. "Antiferromagnetic Materials for Millimeter and Sub-millimeter Devices," *G. S. Heller* and *J. J. Stickler*, Lincoln Lab., MIT, Lexington, Mass.
4. "Design Problems Associated with Rectangular Waveguide Reciprocal Phase-shifters," *A. Clavin*, RANTEC Corp., Calabasas, Calif.
5. "Magnetstatic Modes and Ferrites with Conventional Waveguide Geometrics," *G. P. Rodrigues*, Sperry Microwave Electronics Co., Clearwater, Fla.
6. "Wide Band Resonance Isolator," *W. W. Anderson* and *M. E. Hines*, Bell Telephone Labs., Murray Hill, N.J.
7. "An Electrically-Variable, Reciprocal Ferrite Phase Shifter," *R. W. Kordos* and *V. J. McHenry*, Research Lab., Div., Bendix Aviation Corp., Detroit, Mich.

Tuesday Afternoon, May 10

SESSION 4

Millimeter Waves and Diode Applications

Chairman: P. VARTANIAN
Melabs, Palo Alto, Calif.

1. "Millimeter Wave Generation," *B. Epsztein*, Microwave Res. Inst., Brooklyn, N.Y. (on leave from Compagnie General TSF, France).
2. "Millimeter Wave Generation by Parametric Methods," *G. H. Heilmeier*, RCA Labs., David Sarnoff Res. Center, Princeton, N.J.
3. "A Pulsed Ferrimagnetic Microwave Generator," *B. J. Elliott*, *T. Schaug-Pettersen* and *H. J. Shaw*, Stanford Univ., Stanford, Calif.
4. "Maser Operation at Signal Frequencies Higher Than the Pump Frequency," *F. R. Arams*, Airborne Instruments Lab., Melville, L.I., N.Y.
5. "Generation of Microwaves by Means of Esaki Diodes," *R. F. Rutz*, Research Labs., IBM, Poughkeepsie, N.Y.
6. "The Large Signal Behavior of a Cavity Type Parametric Amplifier," *F. A. Olson* and *G. Wade*, Stanford Univ., Stanford, Calif.
7. "A Solid State Microwave Source from Reactance Diode Harmonic Generators," *T. M. Hyltin* and *K. L. Kotzebue*, Texas Instruments, Dallas, Texas.

Wednesday Morning, May 11

SESSION 5

Microwave Propagation in Plasmas and Solids

Chairman: L. GOLDSTEIN
Univ. of Illinois, Urbana

1. "Propagation of Waves in a Plasma in a Magnetic Field," *W. Allis*, Research Lab. of Electronics, MIT, Cambridge, Mass.
2. "Plasma - Electromagnetic Interaction," *N. Marcuvitz*, Microwave Res. Inst., Polytechnic Institute of Brooklyn, Brooklyn, N.Y.
3. "Magnetoplasma Effects in Semiconductors," *B. Lax*, Lincoln Labs., MIT, Lexington, Mass.
4. "Coherent Excitation of Plasma Oscillations in Solids," *D. Pines*, Univ. of Illinois, Urbana (work done at General Dynamics Corp., San Diego, Calif.).

Panel Discussion:

O. T. Fundingsland, Raytheon Mfg. Co., Waltham, Mass.
R. Gould, California Institute of Technology, Pasadena.
H. Margenau, Yale University, New Haven, Conn.
R. F. Whitmer, Sylvania Electronic System, Mountain View, Calif.

Wednesday Afternoon, May 11

SESSION 6

Filters and Measurements

Chairman: K. TOMIYASU
General Electric Microwave Lab.
Palo Alto, Calif.

1. "Lossy Waveguide Resonators," *H. Riblet*, Microwave Development Labs., Inc., Wellesley, Mass.
2. "Peak Internal Fields in Direct Coupled Cavity Filters," *L. Young*, Westinghouse Electric Corp., Baltimore, Md.
3. "Strip Transmission Line Directional Filter," *R. L. Sleven* and *P. E. Dorato*, Airborne Instruments Lab., Melville, L.I., N.Y.
4. "Application of the Smith Chart to Problems of Propagation in a Magneto-Ionic Medium," *G. A. Deschamps* and *W. L. Weeks*, Univ. of Illinois, Urbana.
5. "Microwave Measurements of Electron Attachment Rates," *V. A. J. van Lint* and *E. G. Wikner*, General Atomic, Div. of General Dynamics Corp., San Diego, Calif.
6. "Fractional Millimicrosecond Electrical Stroboscope," *W. M. Goodall* and *A. F. Dietrich*, Bell Telephone Labs., Holmdel, N.J.

— mwj —

IMS 2008: Building the Future, Honoring the Past

When the world's premier microwave event comes to Atlanta, GA, June 15 to 20, attendees will witness a very different event from the three-day National Symposium that met in San Diego, CA in May 1960 under the auspices of the Professional Group on Microwave Theory and Techniques (PGMTT). The 2008 IEEE International Microwave Symposium (IMS 2008) at the Georgia World Congress Center will reflect a world dominated by wireless technology, miniaturization, microelectronics, communication technology and enormous commercial penetration. It's a very different world from the San Diego gathering, where many basic microwave technologies were still being formulated.

Yet much of the theory and technique presented at IMS 2008 (www.ims2008.org) will be rooted in the same fundamentals and the same expertise in evidence at the 1960 event. Essential building blocks such as radio architectures have not changed that much.

What has changed are the components, the applications, and the scope of radio and microwave technology. Today, many components are tiny and power-efficient; applications are often consumer-oriented and distributed, and the scope is now worldwide and ubiquitous.

The result is a marriage of classical theory and applications with the economic power of the communication economy—a powerful amalgam of the worlds of 1960 and 2008. It is precisely this synergy that has given worldwide leadership status to the International Microwave Symposium and to the Microwave Theory and Techniques Society (MTT-S) of IEEE—today's PGMTT.

We have only to look at this year's IMS Plenary Session speakers to see solid evidence of this kind of synergy. Joe Taylor is a physicist, Princeton professor and Nobel Laureate who discovered gravity waves using microwave technology. His work provides a thread that leads back to the classical concepts of Maxwell, on which electromagnetic theory is based.

The other Plenary Speaker is Mike Farmwald, a "serial entrepreneur" if there ever was one. Farmwald, who holds a doctorate from Stanford, has founded six companies to date including Rambus and Matrix, and he is a venture partner at Benchmark Capital in Menlo Park, CA. He is a technologist, and also an investor who views RF, microwave and wireless as fields of great and ongoing opportunity.

Without the work of great scientists from Maxwell to Joe Taylor, we would not be here. And without the expertise, vision and energy of entrepreneurs like Mike Farmwald, we would be, well, back in 1960.

The Wireless Revolution

As we look back on the microwave world of that era, it's interesting how mature much of the technology already was at the system level. It was capable of sophisticated applications in radar, Earth to satellite communications, and certain sensing tasks. But applications of that day consisted largely of point-to-point links. The equipment consisted mostly of larger elements and discretes, including the venerable vacuum tube. Integrated technologies such as GaAs, silicon and mixed-signal designs were nowhere to be seen.

Joy Laskar
General Chair,
2008 International
Microwave Symposium

The wireless revolution, which had roots in the original PGMTT, helped to change all that, and it continues to change the world. Very few people in the PGMTT in 1960 would have thought that RF and microwave applications would be so widespread in 2008, where they are found in nearly everything related to communications and computing.

Indeed, today's RF and microwave industry is large and covers a broad array of technologies and applications, including cell phones and Wi-Fi among others. Hardware has been miniaturized and integrated in ways that microwave engineers of 45 to 50 years ago would have had trouble envisioning. Many cumbersome applications that cost thousands in 1960 are found today in devices the size of your thumbnail that cost a few dollars or less.

Another important distinction is that the point-to-point applications that prevailed in 1960, though still critical in many areas, no longer dominate. Instead, increasingly sophisticated systems for communication, sensing and radar are helping to push the cutting edge of RF and microwave, pointing the way to new levels of functionality and integration.

Today's research is focusing on next-generation applications that would astonish 1960s microwave technologists. The wireless roadmap for the next five years includes multiple advances in cognitive radio technology and systems; low-cost, low-power millimeter-wave systems; multiple-input/multiple-output technology; sub-terahertz and terahertz applications; 4G and 4G+ mobile applications, interactive mobile broadcasting applications, and more, including a true mobile internet.

Of course, in other application areas things have not changed that much. As I walk around IMS 2008 in Atlanta, I will see waveguides not unlike the ones on the cover of a 1960 issue of *Microwave Journal*. I will also see large-scale antennas, filters and duplexers. In a block diagram form, we still are using many of the same technologies that we had in 1960.

Yet even these more traditional applications are part of a broad new cross-section of commercial, consumer and defense applications, including massive satellite antennas at CNN, communications and surveillance equipment on military aircraft, and DIRECTV dishes on many homes. This, too, is a rich and growing field that most people could not have imagined five decades ago.

Yes, we are still the keepers of Maxwell's equations; we are still the microwave society and the technical disciples of Maxwell. But we are also using concepts from Moore's Law, from communication theory, from microelectronics, from imaging, sensing and much more.

A Great Society

Of course, today's MTT-S is a very different organization from the PGMTT. It is much larger, both in size and technical coverage, and few electrical engineers would question the importance and utility of membership in the society.

It was not always that way. When a special microwave group was approved on March 7, 1952, by the Professionals Groups Committee of the Institute of Radio Engineers (IRE), the response was not deafening. By January 1953, there were 942 members, but only 471 had paid their $2 annual membership dues. The first symposium, held for a single day in New York City in November 1952, attracted 210 people and 10 papers.

To get a sense of those early days, we have only to look at an article in the April 1960 issue of *Microwave Journal*, written by professor Richard F. Schwartz of the University of Pennsylvania. Schwartz's piece is titled, "Why the Microwave Engineer Should Join PGMTT."

Apparently, microwave researchers were not yet flocking to join the young society. Schwartz's appeal for increased membership touched on a number of points, including the notion that an electrical engineer specializing in microwaves/RF would receive benefits from *Microwave Journal* and PGMTT gatherings that would be worth the modest membership expense.

His argument includes points that most of us today take for granted, particularly his notion that "mushrooming specialization" in the RF and microwave field meant that engineers needed to swap ideas in "special groups" in order to stay current and competitive.

Clearly, the professor's arguments, and other efforts similar to his, were ultimately persuasive. Today the IEEE Microwave Theory and Techniques Society (MTT-S) has grown to more than 9000 members worldwide and 80 chapters, and for more than 50 years has been promoting microwave theory and applications including RF, microwave, millimeter-wave and terahertz technologies. It sponsors some 45 national and international symposiums, conferences and workshops for MTT-S members.

It's hard to track the growth of the group's yearly symposium; specific historical information on the earlier gatherings is rather sketchy. We do know that the 1960 PGMTT Symposium in San Diego was something of a departure for the group, for it was the first time the meeting had been held in a city that was chosen for its tourist amenities rather than for proximity to microwave research and applications hubs. Earlier meetings had been held in centers of microwave activity such as New York, Philadelphia, Boston and Palo Alto.

At the time, *Microwave Journal* editor Ted Saad suggested that if the San Diego meeting was a success, in coming years the gathering might be held in such exotic destinations as Hawaii, Miami Beach or even Mexico City.

Onward to Atlanta

This year, of course, the IMS Symposium comes to a city that is both a technology center and a destination. Atlanta is a center of microwave activities at the Georgia Institute of Technology (including the Georgia Tech Research Institute and the Georgia Electronic Design Center), as well

as many area companies including EMS Technologies, Scientific Atlanta (now a Cisco company), AT&T Mobility, Cox Communications and many others. The city is quickly becoming known as the “wireless capital of the US.”

Atlanta, home of the 1996 Olympic Games, prides itself on being a tourist and convention destination. Attendees will have all the attractions of the Atlanta metro area at their feet, including the CNN Center, the Georgia Aquarium, the Atlanta Braves, the World of Coke exhibition, some excellent museums, and a large number of fine hotels and world-class restaurants that reflect Atlanta’s world-city status.

Just as the MTT-S and its technological world are decidedly different from that of the PGMTT, IMS 2008 will not bear much resemblance to the 1960 PGMTT Symposium. The three-day San Diego gathering offered only 36 technical presentations and two panel discussions. Of course, its sessions focused on topics that are still important today—microwave components and systems, amplifiers, parametric amplifiers, ferrites, millimeter-wave and diode applications, microwave propagation in plasmas and solids, and filters and measurements.

By contrast, the June 15 to 20 Atlanta gathering will offer well over 100 oral sessions, plenary sessions, workshops, short courses, interactive forums, poster sessions, student competitions and socials, among other events. At least 10,000 professionals from around the world are expected to attend the six-day meeting, and more than 450 companies will be displaying a vast array of technologies, products and services at over 800 booths.

Of historical interest is the fact that paid exhibits by industry and others were not allowed at the yearly MTT symposiums until 1972. Until then, the annual gatherings were strictly for scientific and technical presentations. Despite some early opposition, exhibitors gradually became a significant part of the annual meetings. That presence has not only aided MTT-S finances but also helped bring microwave technologists closer to the world of industry, which has greatly enhanced the growth of both microwave theory and technique.

It’s important to remember that the IMS 2008 symposium will be only part—albeit the largest part—of Microwave Week in Atlanta. Microwave Week will also include a microwave exhibition, a historical exhibit on technology growth in Georgia, the RFIC Symposium

(www.rfic2008.org) and the ARFTG Conference (www.arftg.org). There will also be an MTT-S GOLD Pavilion, where MTT GOLD members can relax, network and receive GOLD-related information during IMS 2008.

Atlanta truly is a fitting location for IMS 2008. Its universities graduate more engineers—some 2300 annually—than any US area except Los Angeles, and it ranks fourth among the nation's cities for spending on university research. This city of nearly five million people also has the third-highest concentration of Fortune 500 company headquarters in the US, and it's home to such leading corporations as Turner Broadcasting Systems/CNN, Coca-Cola, Home Depot, Cox Enterprises, United Parcel Service, Delta Airlines and SunTrust Banks.

At IMS 2008, we have tried to make the schedule as convenient as possible. The technical sessions will take place Tuesday, Wednesday and Thursday, while workshops will be held on Sunday, Monday and Friday. A one-page, all-inclusive daily schedule is available at the beginning of the IMS 2008 official guide for attendees' convenience, with more complete information in the succeeding pages.

Those who attended the 1960 San Diego symposium would probably be surprised if they found themselves at IMS 2008. Imagine what those engineers would make of presentations on "High Data Rate 60 GHz Radio Link Applications and Design," "Low-voltage RF Design in 45 nm and Beyond," "Automotive Radar" or "Wireless Medical Technology." The sheer breadth of the technologies and applications on display everywhere at IMS 2008 bespeaks a world beyond the San Diego attendees' expectations, if not their imaginations.

One IMS highlight not to be missed is a full roster of student competitions. This will include an Interactive Forum/Student Paper Competition, a Student High Efficiency Power Amplifier Design Competition, a Student Low Power Consumption FM Radio Receiver Design Competition and a Student Packaged X-band Filter Competition. It should be exciting and challenging as students from around the world compete. For more information on the Student Competitions, visit the IMS 2008 web site at www.ims2008.org.

Much of the world of the 1960 San Diego symposium is still recognizable, yet much more has been added to modify and expand that world many fold. As we enjoy Atlanta's IMS 2008, let's be proud of how far we've come and look forward to a future of even greater accomplishment. ■

Georgia on My Mind

It's back! For the first time since the 2003 event in Philadelphia, Microwave Week—featuring the International Microwave Symposium (IMS), the RFIC Symposium and the ARFTG Conference—returns to a city east of the Mississippi. That's right, the largest show dedicated solely to our industry will be held in Atlanta: Home of Coca-Cola, CNN, the Atlanta Braves, the world's largest aquarium and, of course, the capitol of the state lauded in that famous Ray Charles song, shamelessly re-used for this editorial.

This year, over 240 reviewers on the Technical Program committee were responsible for selecting the 279 papers for oral presentation and the 132 papers for the interactive forums. Choosing from over 750 submitted papers, the quality of the technical content will undoubtedly be exceptional. Organizers also rearranged the schedules of the regular sessions so that the IMS attendees could have more flexibility to attend the RFIC sessions.

The panel sessions will focus on automotive radar, multi-gigabit wireless, wireless medical, system/service engineering and cognitive radio. An evening Rump Session, hosted by Sonnet Software, will feature a talk by Nobel Laureate and Princeton professor, Dr. Joe Taylor, entitled "The Discovery of Gravity Waves Amidst the Noise." Thirty-eight workshops, four of which were jointly organized by IMS/RFIC and one organized by IMS/ARFTG, will take place on Sunday, Monday and Friday. This year's IMS will also include a student paper competition as well as three design competitions.

The return of the conference and exhibition to the east coast is of no small significance for many attendees, in particular those whose travel budgets restricted their participation last year in Hawaii. Judging by the nearly 500 microwave components, materials, instruments and software vendors signed up to exhibit in Atlanta, the desire to participate this year is clear. After all, the event has historically been the premier opportunity to observe and showcase the latest technology while networking with peers. Microwave Week 2008 should be no exception and we at the *Journal* look forward to reporting on the event with our most comprehensive, multi-media on-line show coverage to date. The on-line coverage begins the week before the show and will feature exclusive information from the conference itself as well as news and information from the exhibitors. If you are not planning on attending the show but would like to keep on top of the news coming from the event, check out www.mwjournal.com/2008/IMS starting June 9th.

From the earliest days of the MTT-S annual symposium, *Microwave Journal* has

David Vye
Microwave Journal *Editor*

enjoyed a close relationship with both the conference and the exhibition. Our two organizations were formed at roughly the same time and bore witness to an evolving communication industry whose technical developments span from Sputnik to mobile WiMAX, LTE and beyond.

While looking back at the history of our MTT-S Symposium coverage, as part of our 50 years in publishing celebration, we uncovered two gems from the 1960 April issue: "Why the Microwave Engineer Should Join PGMTT" by Richard Schwartz and "PGMTT National Symposium for 1960" by our editorial staff (**note:** the PGMTT was later renamed as the MTT-S). Both appear in this issue as special "Then" reprint articles from the past. The companion cover story, focusing on the "Now," was written by this year's IMS general chair, Joy Laskar. Joy does a fantastic job of linking the past to the present. I found it to be an enjoyable read and hope you do as well.

In addition, our editorial staff also uncovered an article on the first 25 years of the IMS, which appeared in a 1983 issue of *IEEE Transactions on Microwave Theory and Techniques* by *Microwave Journal* founding editor, Ted Saad. This article is currently posted on the *Microwave Journal* web site as a special retrospective article. The history and evolution of the society, conference and exhibition are captured in great detail in this feature. For all the microwave history buffs out there, this is good reading. Special thanks to both the IEEE MTT-S and Ted Saad for their permission to reprint it on our web site.

Over the years, working closely with IMS organizers has allowed us to keep the industry well informed about this important event—before, during and after the show. Once again, our May issue is dedicated to the conference with show and host city information, messages from event organizers, as well as the complete technical program and exhibitor listings.

This year does mark the end of an era as the exhibition management and conference registration duties that had been handled by Horizon House for many years (*Microwave Journal*'s parent company) is handed off to MP Associates starting with IMS 2009.

Looking ahead, we anticipate that the close relationship between *Microwave Journal* and IMS planners will continue for many years to come. Currently, MWJ publisher Carl Sheffres, technical editor Patrick Hindle and I are serving on the IMS 2009 Steering Committee. As volunteers, we are working with the many other committee members to ensure that attendees and exhibitors get the most from next year's event. Maintaining close ties to the show and its organizers is important to us and we believe it helps our efforts to promote and report on the conference and exhibition. At the moment, however, we have Georgia on our minds.

Greater Atlanta has a long and rich history in the microwave industry with more than its share of innovative companies developing commercial and consumer communications equipment. Over 60 companies employing nearly 5000 people identify their primary business as the manufacture of communication equipment. Specific products designed and built in Georgia include broadband transmission and distribution equipment, optical transmission equipment and fiber optic cable, wireless communication equipment and components, and cable telecommunications equipment.

Much of Georgia's legacy in high-technology can be traced back to the strength of its engineering schools. The Georgia Institute of Technology claims to produce more RF/analog/EM and signal-processing engineers than any other US program. Outreach programs bring the expertise of university faculty and staff to locations throughout Georgia. Additionally, R&D centers at the Georgia Institute of Technology and other state schools offer cutting-edge research facilities and access to faculty exploring topics from nanometer-scale optoelectronic devices to improved wireless technology.

My earliest connection between Georgia and engineering came by way of my father. No, he was not an engineer. He was an educator and college football coach. As a big college football fan, he would frequently recite various college cheers to the dismay of his children. Not too many of these chants have stayed with me, but I will never forget the one for Georgia Tech. Clearly written in a different era, the lyrics are quite colorful:

I'm a Ramblin' Wreck from
Georgia Tech
and a hell of an engineer,
A helluva, helluva, helluva,
hell of an engineer,
Like all the jolly good fellows,
I drink my whiskey clear,
I'm a Ramblin' Wreck
from Georgia Tech
and a hell of an engineer.

Go ahead, feel free to hum this little ditty to yourself on the plane as you head to this year's triumphant return to the east coast of the biggest microwave show on Earth—the venerable IMS 2008. Safe travels and I'll see you in the sessions or on the exhibition floor. ■

For complete coverage of the IMS 2008 conference, event news, exhibitor product information and special reports from the editors of *Microwave Journal*, visit our online show daily at www.mwjournal.com/IMS2008 starting June 9th.

Welcome to Atlanta

Atlanta in June is at its very best. The weather is great, it's not too hot or too humid, the evenings are cool and the bugs (most of them) are still dormant. As you make your plans to attend IMS 2008 at the Georgia World Congress Center, build some time into your schedule to enjoy all that Atlanta, the hub of Southern hospitality, has to offer.

IMS organizers have done a fine job creating a guest program that offers the highlights of Atlanta and other nearby Georgia attractions. Dining and after-hours activities are also researched and noted elsewhere in this issue of *Microwave Journal*. The purpose of this article is to simply welcome you to Atlanta and point out a few of the city's finer, but perhaps lesser-known attractions that are a short cab ride from your downtown hotel.

Creative Loafing

Making a fine art of leisure time for many years, *Creative Loafing* magazine is one of the best sources of entertainment news and tips for 'what's doing' in town. You can access it online at www.creativeloafing.com. For a fast start to Atlanta tickets, music, food and entertainment, *Creative Loafing* is an excellent source.

Time Out

Even the most dedicated microwave enthusiasts in downtown Atlanta have to take a break. Here's a short list of places to visit during your downtime:

Fresh Air and the Great Outdoors

The Atlanta Botanical Garden

The Garden is open Tuesday through Sunday from 9 AM to 7 PM. Located at 1345 Piedmont Avenue, the Garden is actually part of centrally located Piedmont Park.

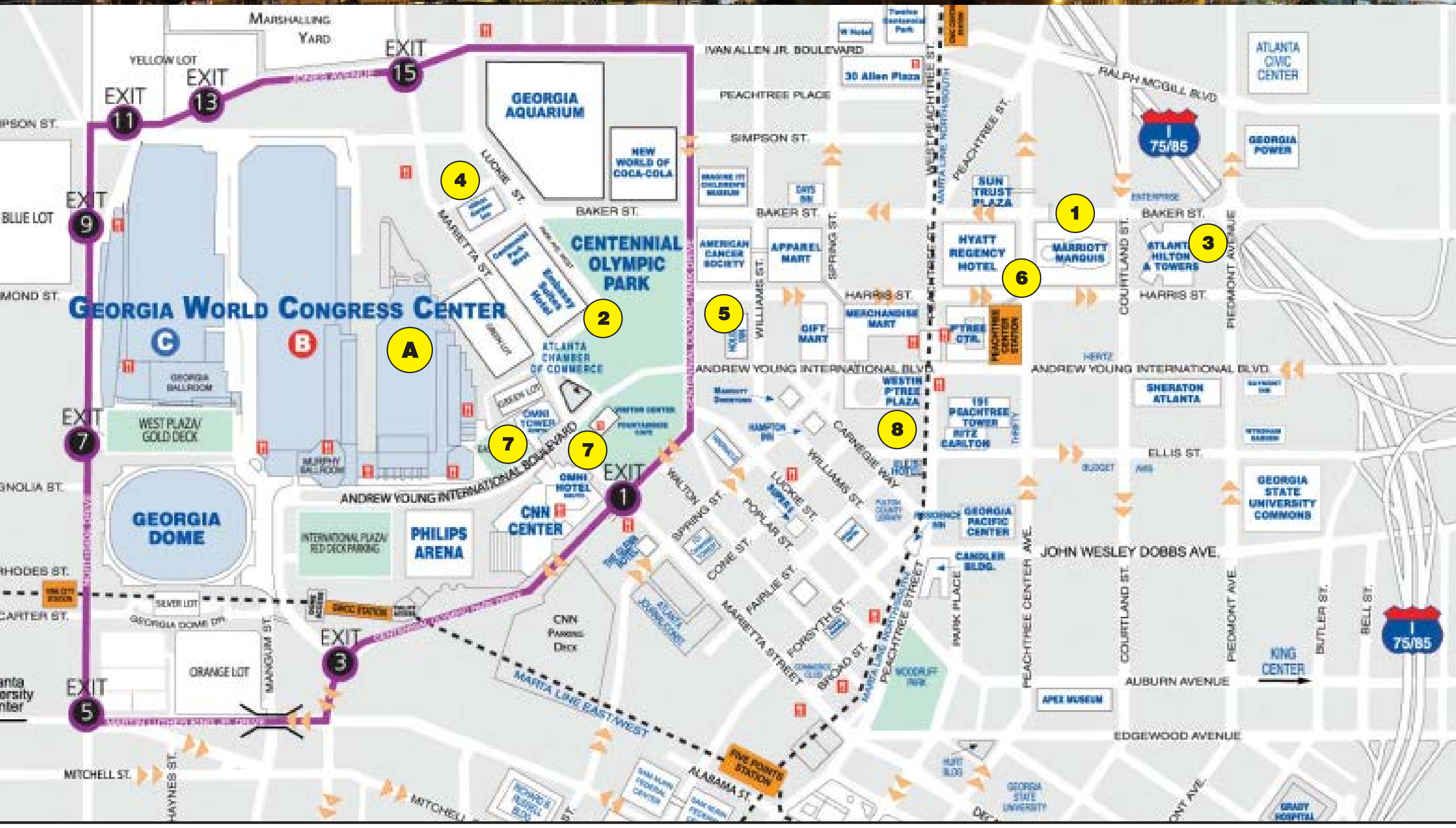
www.atlantabotanicalgarden.org

Piedmont Park

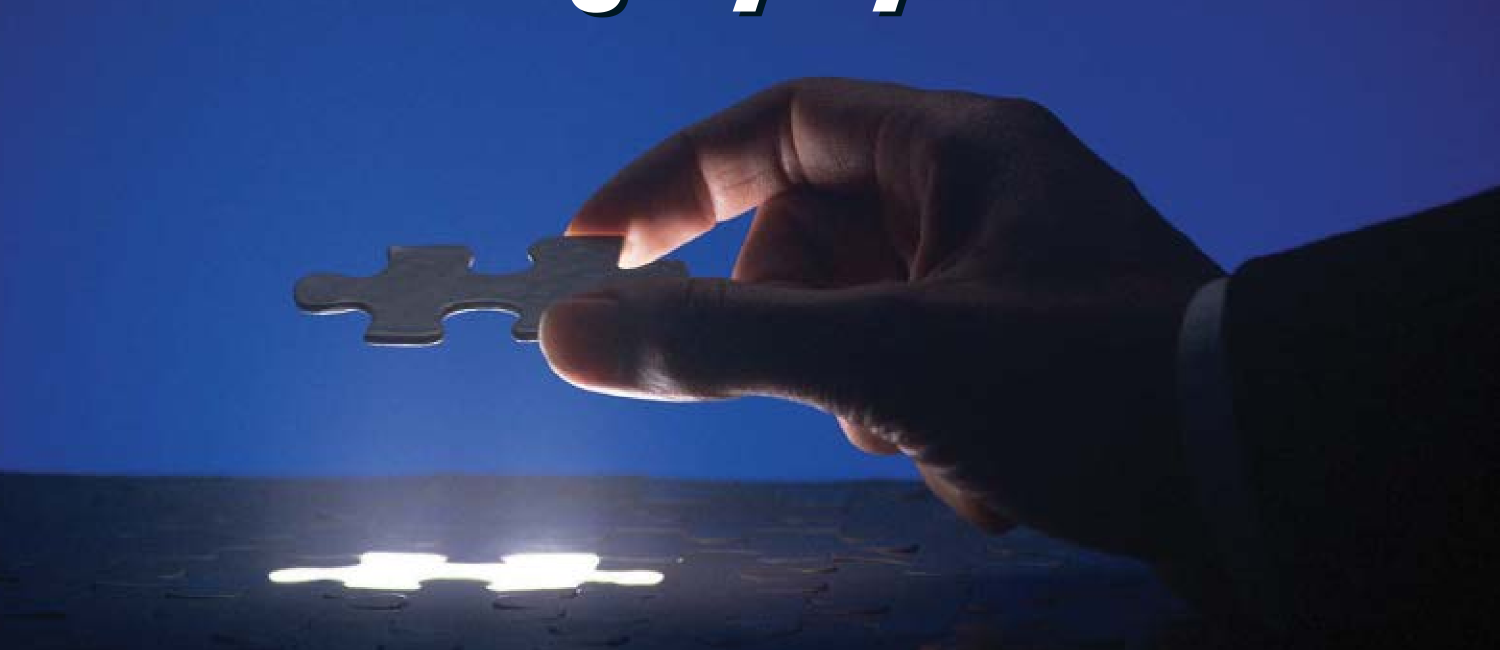
Located at 10th St. and Monroe Drive, Piedmont Park will let you stretch, walk, run and enjoy the impromptu concerts.

www.piedmontpark.org

Scott Wood
Milestone Marketing Inc.
Atlanta, GA



Infusing new technology into legacy systems.



ATLANTA IMS 2008

INTERNATIONAL MICROWAVE SYMPOSIUM
June 15–20, 2008

2008 IMS Conference Hotel Locations

1. Atlanta Marriott Marquis
2. Embassy Suites Hotel @ Centennial Olympic Park
3. Hilton Atlanta & Towers
4. Hilton Garden Inn
5. Holiday Inn Atlanta Downtown
6. Hyatt Regency
7. Omni Hotel at CNN Center – *Headquarters Hotel*
8. Westin Peachtree Plaza

A Georgia World Congress Center - Building A

Maps of Atlanta area provided courtesy of CTT, Inc. and Georgia World Congress Center

Centennial Olympic Park

This famous attraction is located on Marietta Street and International Boulevard (across the street from the Georgia World Congress Center Centennial Park) and offers walking paths, Music at Noon and the Olympic-themed fountains.

www.centennialpark.com

History

Atlanta Cyclorama

Billed as the longest running show in the United States, the Atlanta Cyclorama presents the Civil War Battle of Atlanta from a unique, rotating stage. On display since 1893, the Cyclorama is open Tuesdays through Sundays from 9 AM to 4:30 PM. The grounds also include an extensive Civil War museum. The Cyclorama is in Grant Park near Zoo Atlanta.

http://www.bcaatlanta.com

Martin Luther King, Jr. Memorial

As birthplace of Dr. King, Atlanta hosts this National Historic Site located at John Wesley Dobbs Avenue. Visitors can learn about his life and influence on others. Admission is free; open 9 to 6 daily.

www.nps.gov/malu

The Carter Center

Committed to advancing human rights and alleviating unnecessary human suffering, the Carter Center is located at 453 Freedom Parkway. Visitors can tour the gardens and visit the presidential library and museum.

www.cartercenter.org

Swan House and Atlanta History Center

This attraction is a little farther from downtown at 130 West Paces Ferry Road. The complex of living history museums, fantastic gardens and the Swan House restaurant offer a very relaxed and quiet break from the 'downtown scene.'

www.atlantahistorycenter.com

Art and Theater

The High Museum of Art

The High Museum is close by at 1280 Peachtree Street in midtown. The High enjoys a partnership with the Louvre Museum in Paris, sharing hundreds of works of art and offering visitors a chance to view world class collections, exhibits and events. Open Tuesdays through Sundays.

www.high.org

Shakespeare Tavern

Home of the Atlanta Shakespeare Company and located at 499 Peachtree Street, the New American Shakespeare Tavern is unlike other theaters. It is a place out of time with live music, period costumes, outrageous sword fights with the entire experience centered on the passion and poetry of the spoken word. Food is a British Pub Menu with a broad selection of Irish ales and premium brews. *Much Ado About Nothing* is performed in June.

www.shakespearetavern.com

Agatha's

Featuring 'Harry Plotter and the Half-Wit Princess' through June, Agatha's is home to Atlanta's original comedy, murder mystery dinner theatre. Open seven days at 161 Peachtree Center downtown. You'll laugh, you'll cry, you'll eat.

www.agathas.com

Places to Visit

Street Scenes

Every town has its funky side and Atlanta has "Little Five Points." Head shops, casual and varied dining, small and experimental theaters and street performers abound. It's a business community, a neighborhood, and possibly the coolest spot on the map between Greenwich Village and the French Quarter. Head out to the intersection of Moreland and McClendon Avenues.

www.l5p.com

Baseball

Sorry. The Atlanta Braves are playing away games in California and Texas during IMS 2008. They do return for a home stand against Seattle on Friday, June 20. You can visit Turner Stadium, affectionately known as 'The Ted,' Monday through Saturday and take in the historical exhibits, the Braves Hall of Fame and other attractions.

http://atlanta.braves.mlb.com

Laid Back

Atlanta's Virginia Highlands district offers the relaxed, alfresco dining you may be looking for after a day or two on your feet in the Convention Center. More than 40 restaurants, bistros, bars and cafes await you near the intersection of North Highland and Virginia Avenues.

www.virginahighland.com

Unplugged

For a complete change of pace, what could be more removed from a week of 'Microwave Total Emersion' than woodworking or knitting? Atlanta is home to two of the finest pilgrimage sites for dedicated followers of these popular handcrafts: Highland Woodworking and Knitch.

Nestled up in the Virginia Highlands, Highland Woodworking, located at 1045 North Highland Avenue, is the Mecca for woodworkers around the globe offering instruction, tools and supplies. When Jimmy Carter isn't shelving books at his Presidential Library, he's often seen at Highland Woodworking learning how to build chairs.

www.highlandwoodworking.com

Knitch, for serious knitters, is a one-stop, two-story education and supply center: Yarns, needles, kits, conversation and coffee. If you're traveling with a knitter to IMS 2008, Knitch is not to be missed. It's located in its own alley off St. Charles Avenue in the Virginia Highland neighborhood.

www.knitchknitting.com

IMS 2008 is coming soon. The World Congress Center is ready, and Atlanta's famous hospitality is waiting. Come as you are and welcome.

Restaurants

American

Bacchanalia
1198 Howell Mill Road
(404) 365-0410

Aria
490 East Paces Ferry Road
(404) 233-7673

Park 75
The Four Seasons Hotel at 75 14th Street
(404) 253-3840

Asher
(Roswell) 1085 Canton Street
(770) 650-9838

Food Studio
887 W Marietta Street
(404) 815-6677

Greenwoods on the Green
(Roswell) 1087 Green Street
(404) 992-5383

Hal's on Old Ivy
30 Old Ivy Road
(404) 261-0025

Thumbs Up
(Cabbagetown/Candler Park/
Inman Park)
573 Edgewood Avenue
(404) 223-0690

Murphy's
997 Virginia Avenue
(404) 872-0904

CHINESE

Chopstix
4279 Roswell Road
(404) 255-4868

Little Szechuan
5091 Buford Highway
(770) 451-0192

House of Chan
2469 Cobb Parkway
(770) 955-9444

Pung Mie
5145 Buford Highway
(770) 455-0435

Hsu's Gourmet
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(404) 523-6678

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THE ATLANTA FISH MARKET
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3G Metalworx Inc.	1052
A-Alpha Waveguide Co.	1805
Acceleware Corp.	751
Accumet Engineering Corp.	411
Actipass Co. Ltd.	539
AdTech Ceramics	2231
Advanced Control Components Inc.	1008
Advanced Microwave Components	351
Advanced Switch Technology	404
Aeroflex Inc.	1627
Aeroflex Microelectronic Solutions	1627
Aeroflex Test Solutions	1627
Aethercomm Inc.	1911
Agilent EEsof EDA	1123
Agilent Technologies	1123
AKON Inc.	812
Allrizon-TG Comm Equipment	2134
Altair Technologies Inc.	2003
AMCAD Engineering	329
American Beryllia Inc.	327
American Microwave Corp.	912
American Standard Circuits Inc.	749
American Technical Ceramics	816
Ametek HCC Industries	636
AML Communications Inc.	1148
Amplical Corp.	2235
Amplifier Solutions	651
AmpliTech Inc.	1609
Analog Devices Inc.	1743
AnaPico AG	2118
Anaren Inc.	837
Anatech Electronics Inc.	2222
Anoison Electronics	2129
Anritsu Co.	1715
Ansoft Corp.	1209
Antenna Research Associates-ARA	301
Antenna Systems & Technology	2150
Apollo Microwaves Ltd.	2035
Applied Radar Inc.	1551
Applied Specialties Inc.	1202
Applied Thin-Film Products	616
AR Modular RF	1409
AR RF/Microwave Instrumentation	1409
ARC Technologies Inc.	601
Arlon Tech. Enabling Innovation	1832
Artech House	613
ASB Inc.	502
Assemblies Inc.	2030
Astrolab Inc.	1801
ATTEN Microwave Comp. Co. Ltd.	328
Avago Technologies	509
Avnet Electronics Marketing	1131
AWR	923
AWT Co. Ltd.	953
B&Z Technologies	350
Barry Industries Inc.	805
Batten & Allen Ltd.	948
BeckElec Inc.	2145
Berlin Microwave Technologies AG	2137
Besser Associates Inc.	1006
Bliley Technologies Inc.	633
Bonding Source	2217
Boonton Electronics	1901
Brush Ceramic Products	418
C-Tech Co. Ltd.	432
CAD Design Software	314
Cadence Design Systems Inc.	2013
California Eastern Labs	1037
Cambridge University Press	605
CAP Wireless Inc.	742
CapeSym Inc.	204
Carleton University	614
Cascade Microtech	1144
Castle Microwave Ltd.	852
Centellax Inc.	1647
Century Seals Inc.	410
Ceramic Products Group	1509
Cernex Inc.	2051
Channel Microwave Corp.	1051
Charter Engineering Inc.	514
Chengdu AINFO Inc.	305
Ciao Wireless Inc.	738
ClearComm Technologies Inc.	1533
Cobham DES	1327
Coilcraft Inc.	1904
Coining Inc.	1549
Coleman Microwave Co.	2123
Colorado Microcircuits	1049
COM DEV International	904
Commercial Microwave Technology	1150
Communications & Power Industries	1936
Compac Development Corp.	2234
Compex Corp.	1833
Component Distributors Inc.	1537
COMSOL Inc.	318
Comtech PST	412
Connectronics Inc.	2008
Constant Wave Inc.	348
CoorsTek	1419
Corning Gilbert Inc.	716
Corry Micronics	2017
Crane Aerospace & Electronics	1927
CRC Press-Taylor & Francis Grp LLC	2135
Cree Inc.	1243
Cristek Interconnects Inc.	2211
Crystek Corp.	2215
CST of America Inc.	933
CTT Inc.	1231
Cuming Microwave Corp.	642
Custom Cable Assemblies Inc.	434
Custom Interconnects	1053
Custom Microwave Components Inc.	1750
Daa Sheen Technology Co. Ltd.	500
dBm	1806
Delta Electronics Mfg Corp.	943
DeWeyl Tool Co. Inc.	408
Diablo Industries Thin Film	1751
Diamond Antenna	1810
Dielectric Laboratories Inc.	1509
DiTom Microwave Inc.	1202
Dorado International Corp.	1202
Dow Key Microwave	1514
Ducommun Technologies Inc.	503
DuPont Electronic Technologies	1518
Dyconex AG	1253
Dynawave Inc.	1932
e2v	535
EADS North America Test & Services	1632
Eagle Comtronics	850
Eclipse Microwave Inc.	1202
EE-Evaluation Engineering	2153
Egide	326
Elcom Technologies Inc.	736
Electro Rent Corp.	610
ElectroMagneticWorks Inc.	1753
EM Research Inc.	2138
EM Software & Systems	324
EMAG Technologies Inc.	2029
EMC Technology Inc.	1523
EMCO Elektronik GmbH	852
Emcore (formerly Ortel)	1705
Emerson & Cuming	313
Emerson & Cuming Microwave Prod.	1113
Emerson Connectivity Solutions	1143
Empower RF Systems	2105
Endicott Interconnect Technologies	335
Endwave Corp. – Telecom Division	916
Endwave Defense & Security Division	916
Equipment Management Technology	330
ET Industries	2011
ETS-Lindgren	304
Eudyna Devices Inc.	1543
European Microwave Week	611
Excelics Semiconductor Inc.	1432
EZ Form Cable Corp.	1552
F&K Delvotec Inc.	1942
Farran Technology Ltd.	1527
FCT Electronics LP	848
The Ferrite Co. Inc.	2237
Filtel Microwave Inc.	2018
Filtran Microcircuits Inc.	737
Firan Technology Group	342
Flann Microwave Ltd.	2143
Flexco Microwave Inc.	1933
Florida RF Labs Inc.	1523
Focus Microwaves Inc.	643
Fotofab	734
Freescale Semiconductor	915

FujiFilm Dimatix Inc.	2236
G-Way Microwave/G-Wave Inc.	2232
General Dynamics Satcom Technology	638
Gerotron Communication GmbH	852
GGB Industries Inc.	950
Giga-tronics Inc.	1115
GigaLane Co. Ltd.	2037
Global Comm. Semiconductors	437
Good Will Instrument Co. Ltd.	332
WL Gore & Associates Inc.	1429
Gowanda Electronics	2032
Greenray Industries Inc.	2233
Gryphics Prod. Grp/Cascade Microtech	1144
GT Microwave Inc.	1700
Hantechnic Inc.	2116
Harbour Industries	607
Haverhill Cable & Mfg. Corp.	2234
HEI Inc.	217
Helic SA	2125
Herley Industries Inc.	1614
Herotek Inc.	1645
Hesse & Knipps Inc.	1149
High Frequency Electronics	2147
Hirai SK Corp.	312
Hittite Microwave Corp.	1345
Holzworth Instrumentation	409
HTMicrowave Co. Ltd.	1915
Huada Intl Electronics & Technology	219
HUBER+SUHNER Inc.	701
IEEE Communications Magazine	BIN
IEEE Microwave Magazine	428
IHP GmbH	306
IKE Micro	2219
IMST GmbH	1746
Infineon Technologies	1216
Innertron Inc.	308
Inphi Corp.	222
Inst. for Electronics Engineering	852
Instruments for Industry (IFI)	2007
Integra Technologies Inc.	1909
International Manufacturing Svcs.	1808
Ion Beam Milling Inc.	932
Isotec Corp.	847
ITF Co. Ltd.	632
ITT Corp. - Microwave Systems	1917
IW Inc.	908
J MicroTechnology Inc.	2142
Jacket Micro Devices Inc.	2002
Jazz Semiconductor	416
Jersey Microwave	2010
JFW Industries Inc.	1916
Johanson Manufacturing Corp.	1330
Johanson Technology Inc.	1912
Johnson	1143
Jointcom Communication Technology	431
JQL Electronics Inc.	1046
JyeBao Co. Ltd.	2104
K&L Microwave Inc.	1506
Kaben Wireless Silicon Inc.	2230
Keithley Instruments Inc.	727
Kemac Technology Inc.	2238
KJ Comtech Co. Ltd.	343
KMIC Technology Inc.	1433
KOR Electronics	2110
Krytar Inc.	543
Kyocera America Inc.	323
L-3 Comm Narda Microwave West	1600
L-3 Electron Devices	1600
L-3 Narda Microwave East	1600
Labtech Microwave	634
LadyBug Technologies	1353
Lake Shore Cryotronics Inc.	309
Lambda Americas	512
Lark Engineering Co./Baier & Baier	532
Laser Process Mfg. Inc.	1914
Laser Services Inc.	635
LeCroy Corp.	2214
Linear Photonics	501
Linearizer Technology	501
Litron Inc.	706
LNX Corp.	2151
Locus Microwave	504
Logus Microwave Corp.	507
Lorch Microwave	1529
LPKF Laser & Electronics	905
M2 Global Technology Ltd.	1707
Marubeni Chemix Corp.	207
Maury Microwave Corp.	1112
Maxtek Components Corp.	608
McGraw-Hill	2100

MECA Electronics Inc. 714
Mega Circuit Inc. .732
MegaPhase 1913
Meggitt Safety Systems Inc. 800
Merix Corp. 1702
Merrimac Industries Inc. 737
MESL Microwave Ltd. 436
Metropole Products Inc. 1202
MI Technologies .2223
MICA Microwave .516
Mician GmbH 1045
Micreo Limited 333
Micro Lambda Wireless Inc. 1009
Micro-Coax Inc. 2216
Micro-Mode Products Inc. 1752
MicroFab Inc. 2221
Microlab/FXR 1901
Micronetics Inc. 516
Micronews 331
Microphase Corp. .602
Microsemi Corp. .1426
Microsorb Technologies Inc. 339
Microtech Inc. 833
Microwave Applications Group 338
Microwave Communications Labs Inc. . .2026
Microwave Concepts Inc. 516
Microwave Development Labs Inc. 705
Microwave Dynamics 1202
Microwave Engineering Corp. 533
Microwave Engineering Europe 849

Microwave Filter Co. Inc. 2014
Microwave Innovation Group 709
Microwave Journal 617
Microwave Power Inc. 1148
Microwave Product Digest 949
Microwave Technology Inc. 1251
Microwaves & RF 2210
Mid-Atlantic RF Systems 942
Midwest Microwave 1143
Military & Aerospace Electronics . . . . .BIN
Millitech Inc. 1522
Mimix Broadband Inc. 1423
Mini-Circuits 1937
Mini-Systems Inc. 448
Mission Technology Co. (MTC) 417
MITEQ Inc. 1108
Mitsubishi Electric & Electronics 1137
Modelithics Inc. .746
Modular Components National Inc. 942
Molex 844
Momentive Performance Materials 2106
MPDevice Co. Ltd. 609
MtronPTI 2000
Municom GmbH 852
Murata Electronics 1103
NaF Technology Corp. 402
Nanjing Jiexi Technologies Co. Ltd. 300
Nanjing LOPU Co. Ltd. 315
Natel Engineering Co. Inc. 317
National Instruments 529

NDK 909
Neltec Inc. 1811
Netcom Inc. 1711
Networks International Corp. (NIC) . . .1749
New Continents Technology 2117
Ningbo Junper Comm. Tech. 215
Nitronex Corp. 2108
Noise Com 1901
NoiseWave Corp. 2235
Northeast Electronics Corp. 1048
Northrop Grumman-Velocium 1001
NOWTEL Co. Ltd. 345
NSI 2012
NTK Technologies Inc. 1843
Nuhertz Technologies LLC 947
NXP Semiconductors 523
Octagon Communications 949
OEwaves Inc. 353
OMMIC 214
ON Semiconductor 316
OPHIR RF Inc. 2019
OPTEOS Inc. 2029
Orient Microwave Corp. 1649
P/M Industries Inc. 1744
P1dB 651
Paratek Microwave Inc. 2111
Park Electrochemical 1811
Partron Co. Ltd. .2152
Pascall Electronics Ltd. 442
Passive Microwave Technology 1735

Pendulum Instruments-XL Microwave . . .344
Penn Engineering Components 406
Peregrine Semiconductor Corp. 1606
Phase Matrix Inc. .450
The Phoenix Co. of Chicago 2213
Piconics Inc. 604
Picosecond Pulse Labs 1623
Planar Electronics Technology 912
Planar Monolithics Industries Inc. 912
Plextek Ltd. 2016
Pole/Zero Corp. .1512
Polyfet RF Devices 647
Polyflon, a Crane Co. company 1931
Precision Connector Inc. 413
Precision Photo-Fab Inc. 733
Presidio Components Inc. 704
Prewell Corp. 319
Pulsar Microwave Corp. 1548
Q Microwave Inc. .446
Q3 Laboratory 513
QuartzLock 346
Quest Microwave Inc. 1735
Questech Services Corp. 433
QuinStar Technology Inc. 1905
R&D Microwaves LLC 951
R&K Co. Ltd. 1712
R-Theta Thermal Solutions Inc. 435
Radant MEMS Inc. 1550
Radiall-AEP 2131
Reactel Inc. 1722
Reinhardt Microtech AG 843
RelComm Technologies Inc. 1532
Remcom Inc. 203
Remtec Inc. 2114
Renaissance Electronics Corp. 1800
Resin Systems Corp. 710
RF Depot.Com Inc. 1202
RF Design Magazine 2210
RF Globalnet 2144
RF Industries' RF Connectors Div. 508
RF Morecom 1804
RFHIC Corp. 422
RFMD 1235/1311
RFMW Ltd. 651
RH Laboratories Inc. 952
Richardson Electronics 1626
RJR Polymers Inc. 510
RLC Electronics Inc. 415
Rogers Corp. 1437
Rohde & Schwarz Inc. 623
Rohm and Haas Electronic Materials 606
Rosenberger North America LLC 1517
Roswin Inc. 1650
Roth & Rau AG .2005
RTx Technology Co. Ltd. 1453
Sage Laboratories Inc. 715
Samsung Electro-Mechanics 1157
Sangshin Elecom Co. Ltd. 651
Santron Inc. 1042
Sawcom Tech Inc. 537
Sawnics Inc. 2109
Schleifring und Apparatebau GmbH . . .1807
Schmid & Partner Engineering AG 2206
Scientific Microwave Corp. 2049
Semflex Inc. 1143
Semi Dice Inc. 1050
Semiconductor Packaging Materials 347
SET Tech Co. Ltd. 336
Shadow Technologies Inc. 302
Shenzhen Kingsignal Cable Tech Co. . . .2133
Shenzhen Shennan Circuits Co. Ltd. 414
Shenzhen Sinte Technology Co. Ltd. 310
SHF North America Inc. 349
Shoulder Electronics Co. Ltd. 426
Sigma Systems Corp. 1815
Signatone (Lucas/Signatone) 1630
Silicon Cert Ltd. 322
Simulation Technology & Applied Res . . .430
Sinclair Manufacturing Co. 429
Skyworks Solutions Inc. 1617
Sonnet Software Inc. 1443
Soshin Electric Co. Ltd. 2148
Sources East Inc. 1350
Southwest Microwave Inc. 2043
Spectrum Control 1835
Spectrum Elektrotechnik GmbH 1735
Spectrum Microwave Inc. 1835
Spectrum Power Mgmt. Systems 1835
Spectrum Sensors & Controls 1835
Sprague-Goodman Electronics Inc. 1553

SRI Connector Gage Company 1436
SRI Hermetics Inc. 1436
SSI Cable Corp. 713
State of the Art Inc. 700
Stealth Microwave 516
Stellar Industries Corp. 2001
Stellar Microelectronics 206
StratEdge Corp. .2039
Summitek Instruments Inc. 1526
Suron ACA Ltd. .2224
SUSS Microtec Inc. 1017
SV Microwave Inc. 801
CW Swift & Associates Inc. 1733
Synergy Microwave Corp. 900
T-Tech Inc. 452
Taconic 637
Tactron Elektronik OHG 852
Talley Communications Corp. 2102
Tecdia Inc. 1848
Technical Research & Manufacturing . . .1339
Technical Services Laboratory Inc. 515
Tegam Inc. 600
Tektronix Inc. 2023
Teledyne Coax Switches 823
Teledyne Cougar Inc. 823
Teledyne KW Microwave 823
Teledyne MEC 823
Teledyne Microelectronics 823
Teledyne Microwave 823
Teledyne Relays 823
Teledyne Scientific Co. 823
Teledyne Storm Products Inc. 628
Teledyne Technologies 823
Telegartner Inc. 1452
TeleMobile Electronics 2115
Tensolite 1637
Terabeam/HXI 403
Test & Measurement World . . . . .BIN
Thales Components Corp. 809
Thunderline-Z 1143
Times Microwave Systems 1000
Toshiba America Electronic Comp. 1701
TRAK Microwave Corp. 1528
Trans-Tech Inc. .1611
Transcom Inc. 946
Trilithic Inc. 1836
TriQuint Semiconductor 1023/1027
Trompeter 1143
Tronser Inc. 804
TRS-RenTelco 2119
TRU Corp. 717
TT electronics 2227
TTE Europe 852
TTE Inc. 534
AJ Tuck Co. 1653
Tyco Electronics: Aerosp & Def Prod . . .1723
Tyco Electronics: CC&CE Products 1723
Tyco Electronics: GIC Products 1723
Tyco Electronics: M/A-COM Products . .1723
UBE Industries Ltd. 2226
UltraSource Inc. .1900
United Monolithic Semiconductors 811
Universal Microwave Corp. 528
UTE Microwave Inc. 832
Valpey Fisher Corp. 1449
Vector Fields Inc. 1850
Vectron International 1501
Versphect-Teyssier-DeGroote s.a.s 851
VIDA Products Inc. 1451
Virginia Diodes Inc. 400
Vishay Intertechnology Inc. 1013
Voltronics Corp. .1515
VTI Microwave 1748
Vubiq Inc. 311
Weinschel Associates 603
Wenzel Associates Inc. 2139
Werlatone Inc. 1648
West Bond Inc. 817
Wiley-Blackwell .1708
WIN Semiconductor Corp. 808
Winton Machine Co. 307
WIPL-D d.o.o. 853
Wireless Design & Development 2136
XMA Corp. 218
YanTat Group 2228
Yantel Corp. 745
Yixin Microwave Electronics Co. Ltd. 401
Z-Communications Inc. 1908
Zeland Software Inc. 1622
ZIFOR Enterprise Co. Ltd. 712

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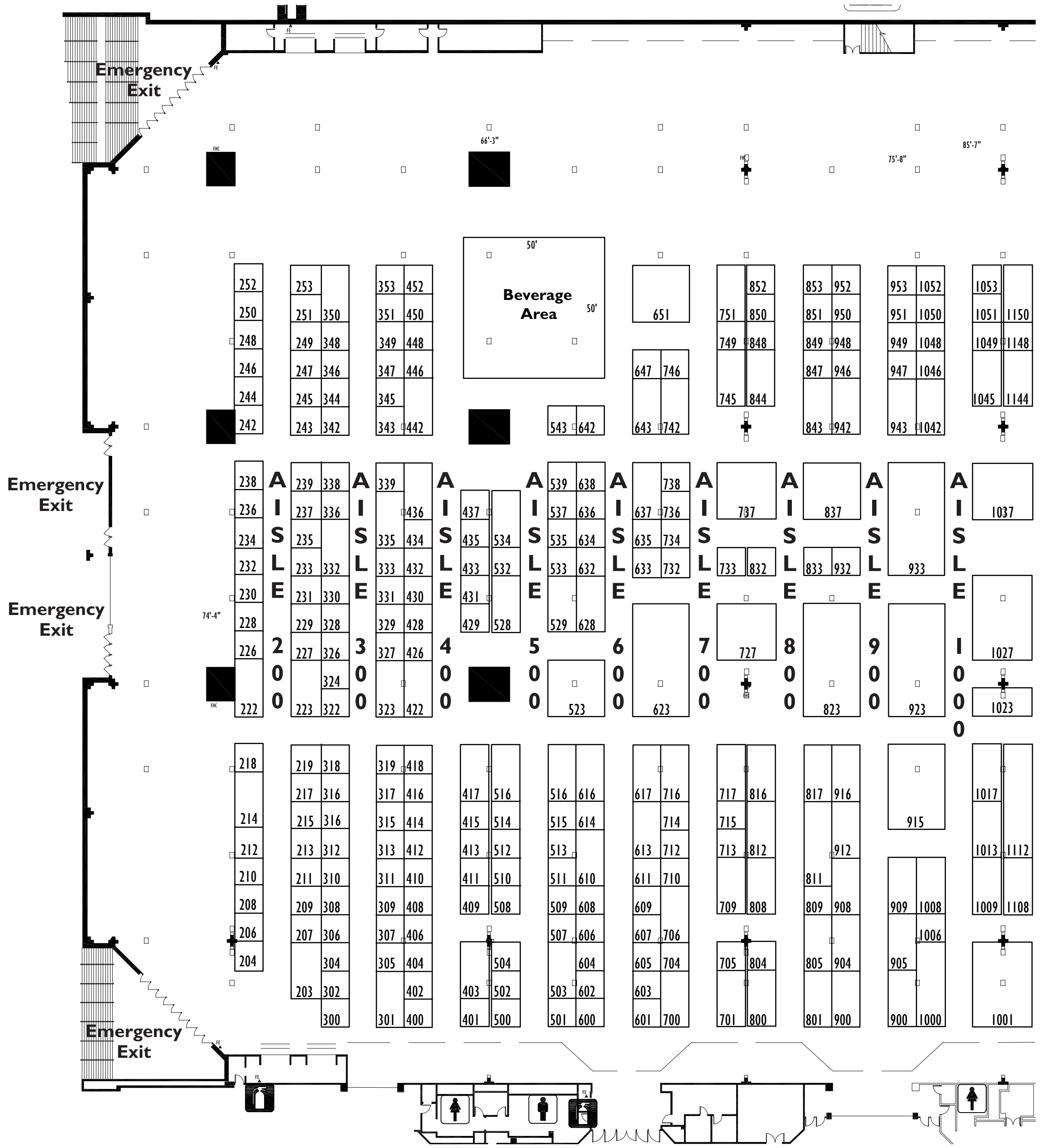

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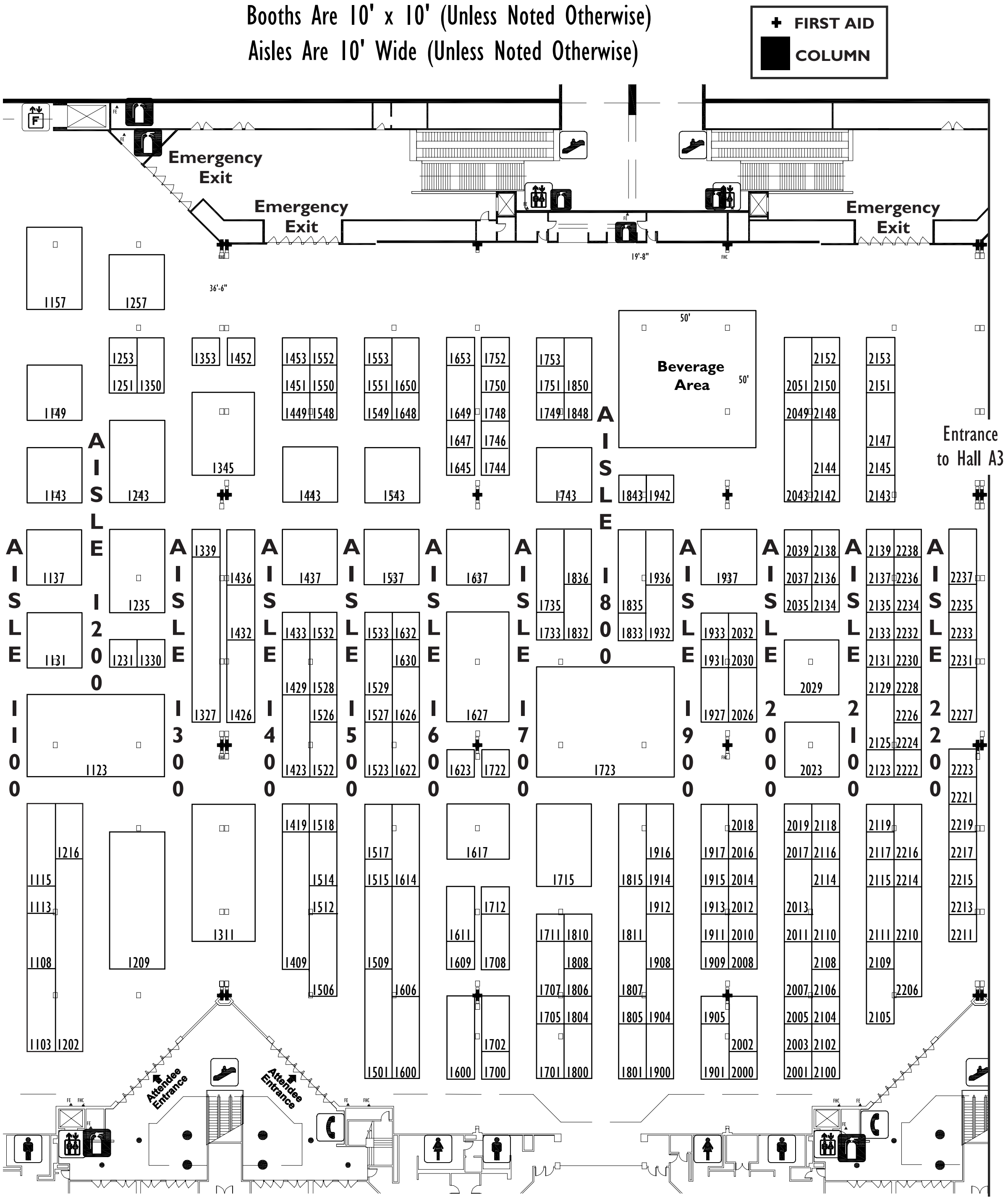


2008 IEEE MTT-S Technical Program

TUESDAY, JUNE 17, 2008
1:20 PM TO 3:00 PM

TU3A WIRELESS COMMUNICATION FRONT-END TECHNOLOGIES

Chair: Y. Ethan Wang • Co-chair: J.F. Luy

This session will address front-end technologies including software defined radio, multi-band, multi-functional transceivers. This covers system integration, design and packaging of wireless front-end.

TU3A-01: **Design of a Cell-Phone Sized, Reconfigurable, Fault-Tolerant Extravehicular Activity (EVA) Communication System for Lunar Surface Operations**
A.L. Benjamin, R. Zenick, P.J. Stephanou, J.P. Black

TU3A-02: **An Ultra-miniaturized Transceiver Module for Bluetooth Applications Using 3-D LTCC System-On-Package Technology**
Y. Cho, J. Kim, Y. Park

TU3A-03: **Design of a Simultaneous Multi-band RF Sub-sampling Receiver**
N. Behjou, M. Hegdal, T. Larsen

TU3A-04: **Ultra-Low Power High Bandwidth QPSK Modulator**
T.S. Pochiraju, V.F. Fusco

TU3A-05: **Highly-Integrated Dual-band Front-end Module for WLAN and WiMAX Applications Based on LTCC Technology**
A. Yatsenko, J. Heyen, S. Sakhnenko, B. Vorotnikov, P. Heide

TU3A-06: **Multiband Wireless Transmitter Using Nonlinear Characteristics of Power Amplifier and Harmonic-Tuning Predistorter**
K. Oh, Y. Lee, H. Ku

TU3B RF MEMS DEVICE TECHNOLOGY

Chair: D. Hyman • Co-chair: J. Robert Reid

As RF MEMS switches continue to mature new and interesting device types and measurements emerge.

TU3B-01: **A SP2T and a SP4T Switch Using Low Loss Piezoelectric MEMS**
D.J. Chung, J. Papapolymerou, R.G. Polcawich, D. Judy, J. Pulskamp

TU3B-02: **Stable Multi-Step Capacitance Control with Binary Voltage Operation at ±3 V in Integrated Piezoelectric RF MEMS Tunable Capacitors**
T. Nagano, M. Nishigaki, K. Itaya, T. Kawakubo

TU3B-03: **Microwave Intermodulation Technique for Monitoring the Mechanical Stress in RF MEMS Capacitive Switches**
C. Palego, S. Hadler, B. Baloglu, Z. Peng, J.C. Hwang, H.F. Nied, D.I. Forehand, C.L. Goldsmith

TU3B-04: **Study of Residual Charging in Dielectric Less Capacitive MEMS Switches**
D. Mardivirin, D. Bouyge, A. Crunteanu, A. Pothier, P. Blondy

TU3B-05: **A 2-Pole Digitally Tunable Filter Using Local One Bit Varactors**
M. Houssini, A. Pothier, A. Crunteanu, P. Blondy

TU3B-06: **MEMS Liquid Metal Through-wafer Microstrip to Microstrip Transition**
X. Liu, D. Peroulis, L.P.B. Katehi

TU3C HYBRID AND OPTIMIZED TIME-DOMAIN METHODS

Chair: N. Bushyager • Co-chair: S. El-Ghazaly

The papers presented in this session demonstrate the importance of using techniques suited to the phenomena under study. The methods presented focus on solving problems where existing techniques show deficiencies, or dissimilar features recommend the use of multiple techniques. Two of the papers incorporate what are traditionally separate techniques, one to combine the study of large homogenous regions with finely detailed ground planes, and another combines electromagnetic and solid state interactions.

TU3C-01: **An Efficient Unconditionally Stable Three-Dimensional LOD-FDTD Method**
Q. Liu, Z.D. Chen, W. Yin

TU3C-02: **An Efficient Method for the Coupling of a Fully-Explicit Time-Domain Solid-State Hydrodynamic Simulator with FDTD EM Solvers**
B.S. McGarvey, M.M. Tentzeris

TU3C-03: **Efficient TLM Sensitivity Analysis Exploiting Rubber Cells**
P.A. Basl, M.H. Bakr, N.K. Nikolova

TU3C-04: **Interfacing the TLM and the TWF Method using a Diakoptics Approach**
N. Fichtner, S. Wane, D. Bajon, P. Russer

TU3C-05: **The Meshless Radial Point Interpolation Method for Time-Domain Electromagnetics**
T. Kaufmann, C. Fumeaux, R. Vahldieck

TU3D ADVANCES IN HF, VHF AND UHF POWER AMPLIFIERS

Chair: A. Moussessian
Co-chair: R. Campbell

This session presents six RF power amplifier designs using a variety of semiconductor technologies including GaAs, GaN, LDMOS and SiC. The session starts with a 65 W high efficiency UHF power amplifier and moves to an 800 W amplifier for radar applications. These are followed by papers on class E and other switching mode amplifiers. The session concludes with a class S amplifier.

TU3D-01: **A 65-W High-Efficiency UHF GaN Power Amplifier**
N.D. Lopez, J. Hoversten, M. Poulton, Z. Popovic

TU3D-02: **800 W UHF SiC SIT Transistor for Radar Applications**
T. Shi, M. Mallinger, L. Leverich, J. Chang, C. Leader, M. Caballero

TU3D-03: **Series-Tuned High Efficiency RF-Power Amplifiers**
J. Vidkjaer

TU3D-04: **Design and Computer Simulation of High Efficiency Broadband Parallel-Circuit Class-E RF Power Amplifier with Reactance Compensation Technique**
K. Narendra, C. Prakash, A. Grebennikov, A. Mediano, C. Paoloni

TU3D-05: **Switching-Mode Linear RF Power Amplifier System**
B. Shi, M. Chia

TU3D-06: **An AlGaN/GaN Class-S Amplifier for RF-Communication Signals**
R. Leberer, M. Oppermann, R. Reber

TU3E Microwave Packaging and Materials

Chair: W. Heinrich • Co-chair: K. Maruhashi

This session covers various aspects of packaging, interconnects and related material issues.

TU3E-01: **A Compact Dual Band 802.11n Front-end Module for MIMO Applications Using Multi-layer Organic Technology**
S. Dalmia, L. Carastro, R. Fathima, V. Govind, J. Dekosky, S. Lapushin, R. Wu, B. Bayruns, G. White

TU3E-02: **Development of LCP Surface Mount Package with a Bandpass Feedthrough at K-band**
M.P. McGrath, K. Aihara, A. Pham, S.R. Nelson

TU3E-03: **Novel Enhanced-Thickness Magnetic Nanoparticle Thin-Films for System-On-Chip (SOC) Wireless Applications**
Y. Li, H. Doo, B. Pan, M.M. Tentzeris, Z.J. Zhang, J. Papapolymerou

TU3E-04: **Carbon Nanotube-based Polymer Composites for Microwave Applications**
S. Pacchini, T. Idda, D. Dubuc, E. Flahaut, K. Grenier

TU3E-05: **Filtering Land Pattern for Miniature Mechanical Switch Connector**
D. Lo Hine Tong, P. Minard, J. Le Bras

3:30 pm to 5:10 pm

TU4A UWB Techniques and Radar Systems

Chair: R.K. Gupta • Co-chair: H. Okazaki

This session focuses on recent innovations made in Ultra-wideband (UWB) techniques and FMCW Radar Systems. The first paper demonstrates use of UWB impulse radio (UWB-IR) architecture and development of a wavelet generator for multi-gigabit communications systems. It is followed by the introduction of a novel slot antenna using an integrated dielectric waveguide and filter assembly for automotive UWB radar applications. The third paper presents a high precision local positioning UWB radar prototype with 1 GHz bandwidth. The fourth paper shows a novel phase-noise performance analysis technique for FMCW radar distance measurements. The last paper demonstrates significant improvements in measurement using adaptive beam forming approach for the FMCW radar sensors.

TU4A-01: **A W-band Wavelet Generator using 0.13 μm InP HEMTs for Multi-gigabit Communications Based on Ultra-Wideband Impulse Radio**
Y. Nakasha, Y. Kawano, T. Suzuki, T. Ohki, T. Takahashi, K. Makiyama, T. Hirose, N. Hara

TU4A-02: **Dielectric Waveguide Slot Antenna with Integrated Filter for Automotive UWB Radar Applications**
K. Sano, K. Ito

TU4A-03: **Method for High Precision Local Positioning Radar using an Ultra Wideband Technique**
B. Waldmann, R. Weigel, P. Gulden

TU4A-04: **Performance Analysis of Cooperative FMCW Radar Distance Measurement Systems**
S. Scheiblhofer, S. Schuster, M. Jahn, R. Feger, A. Stelzer

TU4A-05: **A Four Channel 24 GHz FMCW Radar Sensor with Two-Dimensional Target Localization Capabilities**
R. Feger, A. Haderer, S. Schuster, S. Scheiblhofer, A. Stelzer

TU4B RF MEMS Tunable and Reconfigurable MEMS Circuits

Chair: D. Peroulis

Co-chair: H. Newman

The papers in this section describe advances being made in multi-switch configurations, matching networks, filters and time-delay circuits.

TU4B-01: **Monolithic Crossbar MEMS Switch Matrix**
K. Chan, M. Daneshmand, R.R. Mansour, R. Ramer

TU4B-02: **1.6–2.4 GHz RF MEMS Tunable 3-Pole Suspended Combline Filter**
I. C. Reines, A. Brown, G. Rebeiz

TU4B-03: **Low Loss Switchable Coupled Resonator Bandpass Filter**
C.Y. Ong, M. Okoniewski

TU4B-04: **Thin-Film LCP Amplitude Compensated Long Time Delay Circuit**
M.J. Chen, E. Zhang, A.H. Pham, D. Hyman

TU4B-05: **A Novel Reconfigurable Impedance Matching Network Using DGS and MEMS Switches for Millimeter-wave Applications**
S. Fouladi, A. Akhavan Fomani, R.R. Mansour

TU4C Grand-Challenge Time Domain Modeling

Chair: Z. Chen • Co-chair: A. Elsherbeni

This session addresses new challenging topics related to time domain modeling techniques for electromagnetics. The introductory two papers present an intelligent use of recent personal computer hardware technology to significantly enhance the execution speed of the finite difference time domain (FDTD) and the transmission line method (TLM). Orders of magnitude of speeding up factors are demonstrated. The following two papers provide a methodology for the simulation of moving boundaries, and the optimized updating parameters for accuracy enhancement. Next, fast schemes are presented in the last two papers where the design of periodic structures and high-frequency VLSI are well demonstrated.

TU4C-01: **Optimization and Parameter Exploration Using GPU Based FDTD Solvers**
M.J. Inman, A.Z. Elsherbeni

TU4C-02: **Massively Parallel Two-Dimensional TLM Algorithm on Graphics Processing Units**
F.V. Rossi, P. So, N. Fichtner, P. Russer

TU4C-03: **An Efficient Methodology for the Modeling of Electromagnetic Wave Phenomena in Domains with Moving Boundaries**
J.A. Russer, A.C. Cangellaris

TU4C-04: **The Optimized Weakly Conditionally Stable (WCS) FDTD Method**
I. Ahmed, E. Li, Z.D. Chen

TU4C-05: **Accelerated Time-Domain Modeling of Microstrip Based Microwave Circuit Geometries on Periodic Substrates**
D. Li, C.D. Sarris

TU4C-06: **A Fast-Marching Time-Domain Layered Finite-Element Reduction-Recovery Method for High-Frequency VLSI Design**
H. Gan, D. Jiao

TU4D Advanced Applications of Transmission Line Elements

Chair: G.E. Ponchak

Co-chair: B.E. Spielman

This session is concerned with advanced applications of transmission line elements. The first paper presents a volumetric left-handed structure while the second paper uses a left-handed phenomenon to realize RFID applications. The third paper discusses an application of periodic structure in a CMOS environment. The fourth paper demonstrates a water-based rectangular waveguide high-power switch, and the last paper uses a spur line filter structure for suppressing harmonics in a Wilkinson power divider.

TU4D-01: **Fully Printed Volumetric Negative-Refractive-Index Transmission-Line Slabs Using A Stacked Shunt-Node Topology**
J. Zhu, G.V. Eleftheriades

TU4D-02: **Performance Evaluation of Left-Handed Delay Lines for RFID Backscatter Applications**
M. Schüßler, C. Damm, M. Maasch, R. Jakoby

TU4D-03: **Millimeter-wave CMOS Digital Controlled Artificial Dielectric Differential Mode Transmission Lines for Reconfigurable ICs**
T.R. LaRocca, S. Tam, D. Huang, Q. Gu, E. Socher, W. Hant, F. Chang

TU4D-04: **A Ka-band Waveguide Water-Based Absorptive Switch with an Integrated Micropump**
C. Chen, D. Peroulis

TU4D-05: **Harmonics Suppression of a Wilkinson Power Divider Using Spurlines with Adjustable Rejection Bands**
H. Liu, R. Cao, W. Hu, M. Wu

TU4E Circuits and Techniques for GHz Transmission

Chair: E. Gebara

Co-chair: H. Boss

This session is focused on techniques to improve the signal integrity of GHz transmissions using techniques such as Duobinary and shockwave formation. Those techniques will enable an increase in throughput and reach for multi-gigabit applications. Additionally, on chip active filtering techniques are being presented which result in high Q.

This is achieved with a newly proposed Q-enhancement technique for GHz operation frequencies. This technique can be applied to a front end receiver as well a DS digital receiver in particular.

TU4E-01: **A 4.5 GHz to 5.8 GHz Tunable ΔΣ Digital Receiver with Q Enhancement**
T. Chalvatzis, S.P. Voinigescu

TU4E-02: **39.4 Gb/s Data Transmission over 24.4 meters of Coaxial Cable using Duobinary Signaling**
J.H. Sinsky, A. Konczykowska, A. Adamiecki, F. Jorge, M. Duelk

TU4E-03: **Active Silicon-Based Shockwave Formation**
J.F. Buckwalter

Wednesday, June 18, 2008
8:00 am to 9:40 am

WE1A Electromagnetic Analysis of Complex Structures

Chair: N.K. Nikolova

Co-chair: I. Wolff

In this session, complex materials and periodic microwave structures are studied. Analyses of interesting structures such as microwave furnaces and power lines for communication are also presented. The audience will get an insight into the electromagnetic theory of metamaterials, interesting techniques combining electromagnetic and thermal simulations, and new microwave components.

WE1A-01: **Electromagnetic Wave Propagation in Dispersive Negative Group Velocity Media**
S.M. Mikki, A.A. Kishk

WE1A-02: **Near-Field Focusing Plates**
A. Grbic, L. Jiang, R. Merlin

WE1A-03: **Equivalent Circuit Model to Explain Extraordinary Transmission**
F. Medina, F. Mesa, R. Marques

WE1A-04: **Propagation and Band Broadening Effect of Planar Integrated Ridged Waveguide in Multilayer Dielectric Substrates**
W. Che, C. Li, P. Russer, Y.L. Chow

WE1A-05: **Modeling of an Industrial Microwave Furnace for Metal Casting Applications**
M.H. Awida, N. Shah, B. Warren, A.E. Fathy

WE1A-06: **Investigation of Fields and Currents for Broadband over Power Line (BPL) Communications**
A. Lau, D.R. Jackson, J.T. Williams, F. Mesa, J. Bernal

WE1B Novel Low Phase Noise Techniques for VCOs and Synthesizers

Chair: D. Elad

Co-chair: Y.J. Emery Chen

This session presents papers on novel design techniques to achieve low phase noise in VCOs and synthesizers. Papers in this sesion include frequency synthesizers for UWB applications, VCOs utilizing meta material transmission lines, SiGe HBT VCOs, BJT STCPR VCOs and CMOS QVCO.

WE1B-01: **A 1.5 V 3–10 GHz 0.1 µm CMOS Frequency Synthesizer for MB-OFDM UWB Applications**
Z. Huang, F. Kuo, W. Wang, M. Chen, C. Wu

WE1B-02: **STPCR Offers Integrable Alternatives of DRO**
U.L. Rohde, A.K. Poddar

WE1B-03: **A Low-Voltage Low-Phase-Noise Bottom-Series LC QVCO using Capacitor Tapping Technique**
Y. Zhang, P. Liu, T. Luo, Y.E. Chen, D. Heo

WE1B-04: **Dual -band VCO using Composite Right-/Left-Handed Transmission Line and Tunable Negative Resistance Based on PIN Diode**
J. Choi, C. Seo

WE1B-05: **A High Sensitivity, Low Power Phase Controlled Current Source for GSamples/s Phase-Locked Loops**
T. Chien, C. Lin, D. Chang, Y. Juang, C. Huang

WE1B-06: **Low-Phase-Noise SiGe HBT VCOs using Trifilar-Transformer Feedback**
C. Meng, J. Syu, S. Tseng, Y. Chang, G. Huang

WE1C Nonlinear Measurement Techniques Using CW, Pulsed and Modulated Excitations

Chair: D. Schreurs
Co-chair: J. Martens

As practical excitations become more complex, more advanced nonlinear methods are needed. These papers tie together system and device evaluation under a variety of stimuli and help provide some methods of comparing results from different approaches.

WE1C-01: **Mixed Analog-Digital Instrumentation for Software Defined Radio Characterization**
P.M. Cruz, N.B. Carvalho, K.A. Remley, K.G. Gard

WE1C-02: **A Robust Approach for Comparison and Validation of Large Signal Measurement Systems**
T.V. Williams, O. Mojón, S. Woodington, J. Lees, M. Barciela, J. Benedikt, P.J. Tasker

WE1C-03: **Vector and Harmonic Amplitude/Phase Corrected Multi-Envelope Stimulus Response Measurements of Nonlinear Devices**
L.C. Betts

WE1C-04: **A New Method for the Design of Multi-sine Excitations for the Assessment of Non-linear Devices**
J. Su, J. Benedikt, P. Tasker

WE1C-05: **Time-Frequency Characterization of Long-Term Memory in Nonlinear Power Amplifiers**
J. Hu, K.G. Gard, N.B. Carvalho, M.B. Steer

WE1C-06: **Measurement of ACLR with High Dynamic Range**
O. Andersen, D. Wisell, N. Keskitalo

WE1D Advances in Solid-State Millimeter-wave Technology

Chair: R. Weikle
Co-chair: E. Niehenke

Modern millimeter-wave radar, communications, and imaging systems demand high-performance solid-state circuitry. Moreover, a variety of different electronic material systems continue to have significant impact on active millimeter-wave devices. This session highlights recent advances in millimeter-wave active circuits that incorporate circuit techniques such as power combining, gain peaking and integration, as well as different material technologies.

WE1D-01: **A Q-band MHEMT 100 mW MMIC Power Amplifier with 46% Power-Added Efficiency**
E.C. Niehenke, J. Whelehan, D. Xu, D. Meharry, K. Duh , P.M. Smith

WE1D-02: **A Ruggedly Packaged D-band GaAs Gunn Diode with Hot Electron Injection Suitable for Volume Manufacture**
N. Farrington, P. Norton, M. Carr, J. Sly, M. Missous

WE1D-03: **A 70 GHz Transformer-Peaking Broadband Amplifier in 0.13 μm CMOS Technology**
J. Jin, S.S. Hsu

WE1D-04: **W-band SiGe LNA using an Enhanced Unilateral Gain Peaking**
J. Alvarado Jr., K.T. Kornegay, B.P. Welch, Y.W. Wang

WE1D-05: **InP HBT Millimeter-wave Power Amplifier Implemented using Planar Radial Power Combiner**
T. O'Sullivan, M. Urteaga, R. Pierson, P.M. Asbeck

WE1D-06: **Low Cost Modular Integrated Horn Antenna Array Using Heterojunction Barrier Diode Detectors**
H. Kazemi, C.N. Nguyen, B. Brar, G. Rabeiz, G. Nagy, L.K. Tran, A.C. Young

WE1E New Benchmarks in Power Amplifiers

Chair: J. Schellenberg • Co-chair: J. Komiak

In this session high power amplifiers that have established new benchmarks in power, bandwidth, and efficiency are described. Gallium Nitride shows its emerging presence with 400 W at S-band and a second paper describes a broadband 10 W VHF to S-band PA. A third paper describes an internally matched 100 W device with a PAE of 50% at C-band. At X-band an internally matched HFET at 14 W has achieved 50% PAE. Finally, TWTAs are reported at K-/Ka-band with CW power of up to 200 W and 60% efficiency.

WE1E-01: **Wideband 400 W Pulsed Power GaN HEMT Amplifiers**
K. Krishnamurthy, J. Martin, B. Landberg, R. Vetury, M.J. Poulton

WE1E-02: **A High Efficiency Broadband Monolithic Gallium Nitride Distributed Power Amplifier**
C. Xie, J. Pavio, D.A. Griffey, A. Hanson, S. Singhal

WE1E-03: **Over 57% Efficiency C-band GaN HEMT High Power Amplifier with Internal Harmonic Manipulation Circuits**
H. Otsuka, K. Yamanaka, H. Noto, Y. Tsuyama, S. Chaki, A. Inoue, M. Miyazaki

WE1E-04: **X-band 14 W High Efficiency Internally-Matched HFET**
K. Mori, J. Nishihara, H. Utsumi, H. Takeda, A. Inoue, M. Miyazaki

WE1E-05: **High Power and Efficiency Space Traveling Wave Tube Amplifiers with Reduced Size and Mass for NASA Missions**
R.N. Simons, J.D. Wilson, D.A. Force

9:30 AM TO 11:30 AM

WEDNESDAY INTERACTIVE FORUM I

WEP1A Transmission Line Elements

WEP1A-01: **Inkjet Printing of Passive Microwave Circuitry**
O.A. Azucena, J. Kubby, D. Scarbrough, C.L. Goldsmith

WEP1A-02: **An Ultra-wideband Microstrip-to-CPW Transition**
Y. Kim, K.W. Kim, Y. Cho

WEP1B Planar Passive Filters and Multiplexers

WEP1B-01: **A Parameter Extraction Method for Microwave Direct-Coupled-Resonator Filters with the Consideration of Component Losses**
H. Lee, C. Tsai

WEP1C Non-Planar Passive Filters and Multiplexers

WEP1C-01: **Spurious Suppression of Dielectric Filters in Practical Wireless Systems**
H. Salehi, R.K. Reddy, T. Lukkarila, S. Amir

WEP1C-02: Highly Integrated Triplexers for WiMAX Applications
D. Kim, D. Kim, J. Ryu, J. Kim

WEP1C-03: Enhanced Prediction of Multipaction Breakdown in Passive Waveguide Components Including Space Charge Effects
S. Anza, C. Vicente, D. Raboso, J. Gil, B. Gimeno, V.E. Boria

WEP1D Active and Integrated Filters

WEP1D-01: Frequency Agile Bandstop Filter (FABSF)
A. Roussel, C.W. Nicholls, J.S. Wight

WEP1D-02: Tunable Band Stop Filters Based on Metal-Insulator Transition in Vanadium Dioxide Thin Films
J. Givernaud, C. Champeaux, A. Catherinot, A. Pothier, P. Blondy, A. Crunteanu

WEP1D-03: Left-Handed Band Pass Filter Realized by Coupled Negative Order Resonators
T. Ishizaki, M. Tamura, C.A. Allen, T. Itoh

WEP1D-04: Low Profile LTCC Balanced Filter Based on a Lumped Elements Balun for WiMAX Applications
S. Sakhnenko, D. Orlenko, K. Markov, A. Yatsenko, B. Vorotnikov, G. Sevskiy, P. Heide

WEP1D-05: BST Varactor Tuned Bandstop Filter with Slotted Ground Structure
Y. Chun, J. Hong, P. Bao, T.J. Jackson, M.J. Lancaster

WEP1D-06: Ultra Compact Band Pass Filters Implemented Through Complementary Spiral Resonators (CSRs)
M. Gil, J. Bonache, F. Martín

WEP1E PA Devices and PAs

This session covers high efficiency, adaptive, and high frequency power amplifiers. Waveform engineering techniques will also be presented.

WEP1E-01: A Novel 2–12 GHz 14 dBm High Efficiency Power Distributed Amplifier for Ultra-Wideband-Applications Using a Low-Cost SiGe BiCMOS Technology
B. Sewiolo, R. Weigel

WEP1E-02: A High Power and High Efficiency 20 GHz InP HBT Monolithic Power Amplifier for Phased Array Applications
M.V. Aust, A.K. Sharma, A.L. Gutierrez-Aitken

WEP1E-03: Broadband Hybrid Flip-Chip 6–18 GHz AlGaN/GaN HEMT Amplifiers
S. Piotrowicz, R. Aubry, E. Chartier, O. Jardel, J.C. Jacquet, E. Morvan, B. Grimbert, G. Lecoustre, S.L. Delage, J. Obregon, D. Floriot

WEP1E-04: Directional Dual Band Distributed Power Amplifier with Composite Left-/Right-handed Transmission Lines
C. Xie

WEP1E-05: A Low-loss, Wideband Combiner for Power Amplification at Ka-band Frequencies
H. Grubinger, H. Barth, R. Vahldieck

WEP1E-06: Systematic Waveform Engineering Enabling High Efficiency Modes of Operation in Si LDMOS at both L-band and S-band Frequencies
A. Sheikh, C. Roff, J. Benedikt, P.J. Tasker, B. Noori, P. Aaen, J. Wood

WEP1E-07: Highly Efficient Operation Modes in GaN Power Transistors Delivering Upwards of 81% Efficiency and 12 W Output Power
P. Wright, A. Sheikh, C. Roff, P.J. Tasker, J. Benedikt

WEP1E-08: A Tunable Matching Network for Power Amplifier Efficiency Enhancement and Distortion Reduction
J. Fu, A. Mortazawi

WEP1F Radars and Broadband Communication Systems

WEP1F-01: Antenna and Flip-chip Circuit Board Design for a 24 GHz Short-range Radar Transceiver
M. Notten, H. Veenstra, E. van der Heijden, G. Dolmans, F. Jansen

WEP1F-02: 3-Dimensional Ultra-Wideband Monopulse-based Direction Finding
M.D. Blech, M.O. Benzinger, T.F. Eibert

WEP1F-03: Resolution Improvement for UWB Wallscanning Radar Applications
S. Hantscher, C.G. Diskus

WEP1F-04: 60 GHz Single-Chip 90 nm CMOS Radio with Integrated Signal Processor
S. Sarkar, P. Sen, B.G. Perumana, D. Yeh, D. Dawn, S. Pinel, J. Laskar

WEP1F-05: Cancellation of Unwanted Motion in a Handheld Doppler Radar used for Non-Contact Life Sign Monitoring
I. Mostafanezhad, O. Boric-Lubecke, V. Lubecke, A. Host-Madsen

WEP1G Wireless and Cellular Communication Systems

WEP1G-01: Half-Mode Substrate Integrated Waveguide Six-Port Front-End Circuits for Direct-Conversion Transceiver Design
Y. Ding, K. Wu

WEP1G-02: Design and Performance of a Single Band 1 × 2 RF Front End Module for Mobile WiMAX Applications
C.K. Mmasi, R. Wu, V. Govind, S. Dalmia, G. White

WEP1G-03: **Novel Double Pole Double Throw Switchplexer that Simplifies Dual-band WLAN and MIMO Front-End Module Designs**
C.P. Huang, W. Vaillancourt, A. Bruce, L. Thavone, C. Masse, M. Doherty

WEP1G-04: **Experimental Study of the Effects of RF Front-end Imperfection on the MIMO Transmitter Performance**
S. Bassam, M. Helaoui, S. Boumaiza, F.M. Ghannouchi

WEP1G-05: **Cancellation Techniques for LO Leakage and DC Offset in Direct Conversion Systems**
S. Yamada, O. Boric-Lubecke, V.M. Lubecke

WEP1H Semsprs and Sensor Systesms

WEP1H-01: **Microwave Mass Flow Sensor for Process Monitoring Applications**
A. Penirschke, A. Rijiranuwat, R. Jakoby

WEP1H-02: **A Micromachined Airflow Sensor-based on RF Evanescent-Mode Cavity Resonator**
Y. Zhao, S. Kim, Y. Li, B. Pan, X. Wu, M.M. Tentzeris, J. Papapolymerou, M.G. Allen

WEP1H-03: **Pressure Micro-Sensor based on Radio-Frequency Transducer**
M.M. Jatlaoui, P. Pons, H. Aubert

10:10 am to 11:50 am

WE2A Theory and Applications of Metamaterials

Chair: J. Machac • Co-chair: D.R. Jackson

This session presents analysis and design for various metamaterial structures, including those composed of split-ring resonators, dielectric, and metallic elements. Novel applications such as metamaterial antennas on conformal surfaces are investigated. Novel effects including near-field focusing are studied, and practical devices such as integrated sensors are realized.

WE2A-01: **Revising the Equivalent Circuit Models of Resonant-Type Metamaterial Transmission Lines**
F. Aznar, M. Gil, J. Bonache, F. Martin

WE2A-02: **Coupling of Split Ring Resonators in a Mu-negative Volumetric Metamaterial**
J. Machac, J. Zehentner, M. Blaha

WE2A-03: **Dispersion Engineered Metamaterial-based Transmission Line for Conformal Surface Application**
M. R. Hashemi, T. Itoh

WE2A-04: **2.5 D Stacked Composite Right-/Left-Handed Metamaterial Structures Using Dielectric Resonators and Parallel Mesh Plates**
T. Ueda, N. Michishita, A. Lai, M. Akiyama, T. Itoh

WE2A-05: **A 3D Isotropic Left-Handed Metamaterial Composed of Wired Metallic Spheres**
A. Sanada

WE2A-06: **A Correlator Sensor Chip Based on the Integration of Metamaterials and Photonic Crystals**
C. Lin, I. Mirza, S. Shi, D.W. Prather

WE2B Advances in High Frequency Signal Sources

Chair: H.J. Kuno
Co-chair: P. Shastry

This session summarizes advances in signal sources at K-band and above. Papers presented include wideband VCO, FMCW radar using digital PLS, K-band SiGe synthesizer IC, LTCC VCO, InGaP/GaAs HBT and CMOS VCO.

WE2B-01: **A Novel Ring-based Triple-Push 0.2–34 GHz VCO in 0.13 μm CMOS Technology**
C.C. Li, C.C. Chen, B.J. Huang, P.C. Huang, K.Y. Lin, H. Wang

WE2B-02: **A 77 GHz FMCW Radar using a Digital Phase-Locked Synthesizer**
C. Wagner, R. Feger, A. Haderer, A. Fischer, A. Stelzer, H. Jäger

WE2B-03: **A Single SiGe Chip Fractional-N 275 MHz…20 GHz PLL with Integrated 20 GHz VCO**
R. Follmann, D. Kother, T. Kohl, M. Engels, T. Podrebersek, V. Heyer, K. Schmalz, F. Herzel, W. Winkler, S. Osmany, U. Jagdhold

WE2B-04: **Vertically Integrated Voltage-Controlled Oscillator in LTCC at K-band**
T. Baras, A.F. Jacob

WE2B-05: **A K-band Quadrature VCO based on Asymmetric Coupled Transmission Lines**
C. Kim, J. Yang, D.W. Kim, S. Hong

WE2B-06: **27 GHz Low Phase-Noise CMOS Standing-Wave Oscillator for Millimeter-wave Applications**
T. Huang, P. You

WE2C Linear Network Measurement

Chair: A. Ferrero • Co-chair: L. Hayden

This session will present the latest developments in linear microwave measurements from novel VNAs up to de-embedding and substrate testing.

WE2C-01: **On-Wafer Single Contact Quadrature Accuracy Measurement Using Receiver Mode in Four-Port Vector Network Analyzer**
Y. Chang, Y. Hsu, S. Lin, Y. Juang, H. Chiou

WE2C-02: **Low-cost High-resolution Handheld VNA Using RF Interferometry**
K. Will, T. Meyer, A. Omar

WE2C-03: Ultra Wide-band Four-Port Reflectometer Using Only Two Quadratic Detectors
K. Haddadi, M. Wang, D. Glay, T. Lasri

WE2C-04: A Simple Through-only De-embedding Method for On-wafer S-parameter Measurements up to 110 GHz
H. Ito, K. Masu

WE2C-05: A Low Cost Method for Testing Integrated RF Substrates
A. Goyal, M. Swaminathan

WE2D Advanced Techniques for Sub-mmwave Generation, Amplification and Frequency Conversion

Chair: D. Choudhury
Co-chair: J. Cunningham

Sub-mmwave generation, amplification and frequency conversion technologies are under-developed compared with their lower frequency counterparts. Emerging market opportunities in the security, communications, and medical sectors are driving active and passive device technologies to terahertz frequencies. This session concentrates on recent advances in devices and circuits for sub-mm operation, including tunable sources, InP HEMT and DHBT-based MMICs.

WE2D-01: High Power Tunable THz Generation Based on Photoconductive Antenna Arrays
M. Jarrahi, T.H. Lee

WE2D-02: A 330 GHz MMIC Oscillator Module
V. Radisic, L. Samoska, W. Deal, X. Mei, W. Yoshida, P. Liu, J. Uyeda, A. Fung, T. Gaier, R. Lai

WE2D-03: A Balanced Sub-millimeter Wave Power Amplifier
W.R. Deal, X. Mei, V. Radisic, B. Bayuk, A. Fung, W. Yoshida, P. Liu, J. Uyeda, L. Samoska, T. Gaier, R. Lai

WE2D-04: 250 nm InP DHBT Monolithic Amplifiers with 4.8 dB Gain at 324 GHz
J. Hacker, M. Urteaga, D. Mensa, R. Pierson, M. Jones, Z. Griffith, M. Rodwell

WE2D-05: A G-band (140–220 GHz) Microstrip MMIC Mixer Operating in Both Resistive and Drain-Pumped Mode
S.E. Gunnarsson, N. Wadefalk, I. Angelov, H. Zirath, I. Kallfass, A. Leuther

WE2E Linearity Advancement of Power Amplifiers

Chair: P.J. Tasker • Co-chair: B. Kim

This session covers advances in power amplifier linearity techniques. Two papers focus on optimizing aspects of base-band terminations covering key considerations with respect to EER application and larger than expected bandwidth observations. The other three papers address the hot topic of improving the linearity of Doherty amplifiers without compromising efficiency.

WE2E-01: Envelope Injection Consideration of High Power Hybrid EER Transmitter for IEEE 802.16e Mobile WiMAX Application
I. Kim, J. Moon, J. Kim, J. Kim, C. Seo, K. Sun, C. Ahn, B. Kim

WE2E-02: Reduction of Electrical Baseband Memory Effect in High-Power LDMOS Devices using Optimum Termination for IMD3 and IMD5 using Active Load-Pull
A. Alghanim, J. Lees, T. Williams, J. Benedikt, P. Tasker

WE2E-03: Complexity Reduced Odd-Order Memory Polynomial Pre-distorter for 400 W Multi-Carrier Doherty Amplifier Linearization
N. Messaoudi, M.C. Fares, S. Boumaiza, J. Wood

WE2E-04: A Doherty Power Amplifier with Extended Resonance Power Divider for Linearity Improvement
M. Nick, A. Mortazawi

WE2E-05: Linearity-Optimized Power Tracking GaN HEMT Doherty Amplifier Using Derivative Superposition Technique for Repeater Systems
Y. Lee, M. Lee, Y. Jeong

1:20 PM TO 3:00 PM

WE3A Planar Filter I

Chair: C. Wang
Co-chair: K. Zaki

This session reports on the state-of-the-art in planar microwave filter development. Topics of interest include compact ultra-wideband filters and balanced filters.

WE3A-01: A Multi-Resolution Channel-Select Filter with Ultra-Wide Frequency Coverage
M. Koochakzadeh, A. Abbaspour-Tamijani

WE3A-02: A Novel Compact Ultra-Wideband Bandpass Filter using Microstrip Stub-Loaded Dual-Mode Resonator Couples
Z. Ma, W. He, C. Chen, Y. Kobayashi, T. Anada

WE3A-03: Planar Quintuple-Mode Resonator Bandpass Filters with Sharp Transition and Wide Stopband
Y. Chiou, Y. Lee, J. Kuo, C. Chen

WE3A-04: Rectangular Stubs in Microstrip or Stripline Using V-lines
R. Levy

WE3A-05: New Differential PSL Coupled Resonator Filters
S.F. Peik, F. Langner

WE3B Low Noise Devices and Circuits

Chair: P. Smith

Co-chair: M. Pospieszalski

This session presents exciting advances in a wide range of device and circuit technologies. We begin with state-of-the-art MMIC performance demonstrated at 180 GHz using 35 nm InP HEMTs. Next, Q-band MHEMT LNAs with excellent broadband performance are presented. The following two papers address the low noise properties of devices over temperature. First, cryogenic measurements and modeling of SiGe HBTs over the range of 15–300° K are given. Second, the noise properties of GaN HEMTs at elevated temperatures are reported for the first time. The final paper of the session describes a DC–40 GHz active traveling wave power divider.

WE3B-01: **Low Noise Amplifier for 180 GHz Frequency Band**
P. Kangaslahti, D. Pukala, T. Gaier, W. Deal, X. Mei, R. Lai

WE3B-02: **Q-band Low Noise Amplifiers Using a 0.15 μm MHEMT Process for Broadband Communication and Radio Astronomy Applications**
S. Weng, C. Lin, H. Chang, C. Chiong

WE3B-03: **Experimental Cryogenic Modeling and Noise of SiGe HBTs**
J.C. Bardin, S. Weinreb

WE3B-04: **Thermal Characterization of the Intrinsic Noise Parameters for AlGaN/GaN HEMTs**
M. Thorsell, K. Andersson, M. Fagerlind, M. Südow, P. Nilsson, N. Rorsman

WE3B-05: **DC to 40 GHz MMIC Traveling Wave Power Splitter for Airborne Systems**
R.S. N'Gongo, K.Y. Varma, P. Ratna, V. Kirty

WE3C Nonlinear Device Modeling

Chair: W. Struble • Co-chair: M. Rudolph

The nonlinear device modeling session this year includes compact models of PIN diodes, LDMOS transistors, and hetero junction: bipolar transistors. Topics range from physical, thermal, to transit-time effects.

WE3C-01: **Modeling Fast Switching Speed PIN Diodes for RF and Microwave Applications**
R.H. Caverly, A.M. Reif

WE3C-02: **A Nonlinear Electro-Thermal Model for High Power RF LDMOS Transistors**
D. Bridges, J. Wood, M. Guyonnet, P.H. Aaen

WE3C-03: **A Scalable Compact Model for III-V Heterojunction Bipolar Transistors**
S.R. Nedeljkovic, J.R. McMacken, J.M. Gering, D. Halchin

WE3C-04: **Large-Signal Hybrid Compact/Behavioral HBT Model for III-V Technology Power Amplifiers**
T.S. Nielsen, S. Nedeljkovic, D. Halchin

WE3C-05: **Limitations of Current Compact Transit-Time Models for III-V-Based HBTs**
M. Rudolph

WE3D RF Over Fiber Links and Components

Chair: R. Reano

Co-chair: C. Scholz

This session presents advances in microwave photonic links and components. 10 Gb/s data transmission at 33 GHz and a record high IP3 of a UTC photodiode are reported. Recent radio over fiber demonstrations are also presented, including a multi-band system.

WE3D-01: **Performance Evaluation of Multiband Radio-over-Fiber for WLAN, Gigabit Ethernet and UWB**
M. Yee, Y. Guo, V. Pham, L. Ong

WE3D-02: **MultiGbit/s Transmission over a Fiber Optic mm Wave Link**
I. Gonzalez Insua, K. Kojucharow, C.G. Schaffer

WE3D-03: **High-Power Modified Uni-Traveling Carrier Photodiode with > 50 dBm Third Order Intercept Point**
A. Beling, H. Pan, H. Chen, J.C. Campbell

WE3D-04: **Radio-Over-Fiber Systems for WLAN Based on CMOS-Compatible Si Avalanche Photodetectors**
H. Kang, M. Lee, W. Choi

WE3D-05: **A Broadband High Dynamic Range Analog Photonic Link using Push-Pull Directly-Modulated Semiconductor Lasers**
D.A. Marpaung, C.G. Roeloffzen, W.C. van Etten

WE3E Frequency Domain Techniques

Chair: L. Perregrini • Co-chair: A. Beyer

Three papers in this session deal with the problem of extracting equivalent parametric circuit models by means of full wave frequency domain techniques. These models can be useful for the optimization of complex structures by using standard circuit analysis techniques. Another paper will present a novel approach to setup absorbing boundary conditions in conjunction with the use of the method of moments. Finally, the last paper treats the evaluation response sensitivity in the FEM analysis of a component, when varying the port characteristics.

WE3E-01: **A Derived Circuit Model for Spiral Inductors on Lossy Silicon Substrate**
K. Yang, H. Hu, K.L. Wu, W.Y. Yin, J.F. Mao

WE3E-02: **Modeling of Losses in Substrate Integrated Waveguide by Boundary Integral-Resonant Mode Expansion Method**
M. Bozzi, L. Perregrini, K. Wu

WE3E-03: **Electromagnetic Macro-modeling of 3D High Density Trenched Silicon Capacitors for Wafer-Level-Packaging**
S. Wane, V. Muhlhaus, J. Rautio

WE3E-04: **A Novel Boundary Element Method with Surface Conductive Absorbers for 3-D Analysis of Nanophotonics**
L. Zhang, J. Lee, A. Farjadpour, J.K. White, S.G. Johnson

WE3E-05: **Sensitivity Analysis of S-parameters Including Port Variations Using the Transfinite Element Method**
L. Vardapetyan, J. Manges, Z. Cendes

3:30 PM TO 5:10 PM

WE4A Planar Filter II

Chair: J. Pond

Co-chair: R. Mansour

The session deals with realization of miniature microstrip filters as well as the realization of a filter with improved spurious performance. A paper is also included on the use of the non-resonating nodes concept in planar filters.

WE4A-01: **Parallel-Coupled Microstrip Filters with Periodic Floating-Conductors on Coupled-Edges for Spurious Suppression**
T. Yamaguchi, T. Fujii, T. Kawai, I. Ohta

WE4A-02: **A Miniaturized Microstrip Ring Resonator Lowpass Filter with Sharp Attenuation**
T. Wuren, I. Sakagami, M. Fujii, M. Tahara

WE4A-03: **Design of Dual- and Triple-Passband Bandpass Filters with Interdigital Resonators**
C. Tang, L. Lu, C. Shen, J. Wu

WE4A-04: **Design Procedure of Low Cost Substrate Microstrip Filters based on Nonresonating Nodes**
S. Cogollos, V. Boria, R.J. Cameron, R.R. Mansour

WE4A-05: **Improvement of Stopband Performance in Parallel-Coupled Bandpass Filters using Quasi-Lumped Elements**
V. Zhurbenko, V. Krozer, P. Meincke

WE4B High Performance Frequency Conversion and Control Integrated Circuits

Chair: D.H. Heo

Co-chair: J.S. Rieh

This session highlights two switch papers, a mixer paper and a frequency divider paper. These ICs represent significant contribution to the industry in terms of performance and design approach.

WE4B-01: **A Q-band Low Loss Reduced-size Filter-Integrated SPDT Switch using 0.15 μm MHEMT Technology**
J. Lee, R. Lai, K. Lin, C. Chiong, H. Wang

WE4B-02: **3 W SPDT Antenna Switch Design Using Standard 0.18 μm CMOS Process**
M. Ahn, C. Lee, B. Kim, J. Laskar

WE4B-03: **A 60 dB Harmonic Mixing Reduction Mixer for Wideband Applications**
C. Li, P. Huang

WE4B-04: **A V-band Wide Locking Range CMOS Frequency Divider**
T. Luo, Y.E. Chen, D. Heo

WE4C Tags and Sensors

Chair: A. Jenkins

Co-chair: H. Kondoh

This session will review both RFID concepts and sensors for physical measurement systems, with particular emphasis on addressing system architecture and tag realizations for RFID applications that improve the tag read-range under various deployment scenarios.

WE4C-01: **Complex Signal Demodulation and Random Body Movement Cancellation Techniques for Non-contact Vital Sign Detection**
C. Li, J. Lin

WE4C-02: **Regenerative Backscatter Transponder using the Switched Injection-Locked Oscillator Concept**
M. Vossiek, T. Schäfer, D. Becker

WE4C-03: **A Smart Beam Steering RFID Interrogator for Passive Tags in Item Level Tagging Applications**
M.Y. Chia, K.C. Ang, K. Chee, S. Leong

WE4C-04: **A Dual-Resonant Microstrip-Based UHF RFID "Cargo" Tag**
S.R. Aroor, D.D. Deavours

WE4C-05: **Miniaturized Patch Antenna for the Radio Frequency Identification of Metallic Objects**
A. Ghiotto, S.F. Cantalice, T. Vuong, A. Pouzin, G. Fontgalland, S. Tedjini

WE4D Microwave Photonic Technologies and Systems

Chair: D. Jaeger • Co-chair: E. Rezek

This session includes papers describing microwave signal techniques, a photonic instantaneous frequency measurement scheme, an optical packing routing method, and a fiber-fed 60 GHz self-heterodyne system.

WE4D-01: **Fiber-Fed 60 GHz Self-Heterodyne Systems using Self-Oscillating Harmonic Optoelectronic Mixers Based on CMOS-Compatible APDs**
M. Lee, H. Kang, K. Lee, W. Choi

WE4D-02: **New Label Processing for Routing Optical Packets**
G. Kovacs, T. Berceli, J. Capmany, B. Ortega, D. Pastor, A. Martinez, G. Puerto, T. Banky, M. Csörnyei, M.D. Manzanedo

WE4D-03: **Pure 2.5 Gb/s 16 QAM Signal Generation with Photonic Vector Modulator**
J.L. Corral, R. Sambaraju, M.A. Piqueras, V. Polo

WE4D-04: **Photonic Instantaneous Frequency Measurement using Non-Linear Optical Mixing**
N. Sarkhosh, H. Emami, L.A. Bui, A. Mitchell

WE4D-05: Microwave Signal Generation using Self-Heterodyning of a Fast Wavelength Switching SG-DBR Laser
M.A. Bernacil, S. O'Connor, B. Maher, A. Dekelaita, D. Derickson

WE4E Linear Device Modeling

Chair: P.H. Aaen • Co-chair: M. Megahed

The linear device modeling session presents new advancements in active and passive modeling techniques. This session includes recent developments for the extraction of extrinsic components for high-power transistor modeling. A novel algorithm for passivity verification and enforcement on macro models of microwave devices will be presented. The session closes with a paper on enhancements of the space mapping surrogate model through support vector regression.

WE4E-01: An Extrinsic Component Parameter Extraction Method for High Power RF LDMOS Transistors
J. Wood, D. Lamey, M. Guyonnet, D. Chan, D. Bridges, N. Monsauret, P.H. Aaen

WE4E-02: A Novel Passivity Verification and Enforcement Algorithm for Macromodels of Microwave Devices
C. Walkey, D.W. Paul, M.S. Nakhla, R. Achar, A. Weisshaar

WE4E-03: Support-Vector-Regression-based Output Space-Mapping for Microwave Device Modeling
S. Koziel, J.W. Bandler

2:00 PM TO 4:00 PM

WEDNESDAY INTERACTIVE FORUM II

WEP2A Passive Circuit Elements

WEP2A-01: Notes on Bandpass Filters Whose Inter-Resonator Coupling Coefficients are Linear Functions of Frequency
S. Amari, M. Bekheit, F. Seyfert

WEP2A-02: Miniaturized Ultra-Wideband Self-Complementary Antennas Using Shunted Spiral Inductors
A. Saitou, Y. Ohhashi, K. Honjo, K. Takahashi

WEP2A-03: A Miniature Lumped Element LTCC Bandpass Filter with High Stopband Attenuation for GPS Applications
G.M. Brzezina, L. Roy

WEP2A-04: A New Ultra Wideband Directional Coupler Based on a Combination between CB-CPW and Microstrip Technologies
M. Nedil, T.A. Denidni

WEP2A-05: Designs of Dual-band Wilkinson Power Dividers with Flexible Frequency Ratios
H. Zhang, H. Xin

WEP2A-06: A Novel Planar Dual-band Branch Line Coupler Using Defect Ground Structure
C. You, X. Zhu

WEP2A-07: Accurate and Efficient Design Approach of Substrate Integrated Waveguide Filter Using Numerical TRL Calibration Technique
X. Chen, K. Wu

WEP2A-08: A Ka-band Multilayer LTCC 4-pole Bandpass Filter using Dual-mode Cavity Resonators
K. Ahn, I. Yom

WEP2A-09: Small Form-Factor Integrated Balun with Complex Impedance Matching
K. Liu, R. Emigh, R. Frye

WEP2A-10: A Planar Ultra-Wideband Balanced Doubler
Y. Kim, K.W. Kim, Y. Cho

WEP2A-11: High Performance Bandstop Filter Design and Investigation using Physical Model for WiMAX Measurement Equipment
K. Ma, R.M. Jayasuriya, K. Chan

WEP2B Ferroelectric Ferrite and Acoustic Wave Components

WEP2B-01: A Circuit Model for Nonlinear Simulation of Radio-Frequency Filters Employing Bulk Acoustic Wave Resonators
M. Ueda, M. Iwaki, T. Nishihara, Y. Satoh, K. Hashimoto

WEP2B-02: Surface Acoustic Wave Filter in High Frequency with Narrow Bandwidth and Excellent Temperature Characteristic
T. Murata, M. Kadota, T. Nakao, K. Matsuda

WEP2B-03: Third Order Intermodulation Distortion in Film Bulk Acoustic Resonators at Resonance and Antiresonance
E. Rocas, C. Collado, J. Mateu, H. Campanella, J.M. O'Callaghan

WEP2B-04: Strontium Titanate DC Electric Field Switchable and Tunable Bulk Acoustic Wave Solidly Mounted Resonator
G.N. Saddik, D.S. Boesch, S. Stemmer, R.A. York

WEP2C MEMS Components and Technologies

WEP2C-01: Continuously Tunable RF-MEMS Varactor for High Power Applications
S. Leidich, S. Kurth, T. Gessner

WEP2C-02: A 40–50 GHz Diplexer Realized with Three Dimensional Copper Micromachining
J.R. Reid, D. Hanna, R.T. Webster

WEP2C-03: Effect of Dielectric Film Thickness on Dielectric Charging of RF MEMS Capacitive Switches
R.A. Daigler, G. Papaioannou, E. Papandreou, J. Papapolymerou

WEP2C-04: Improved Distributed MEMS Matching Network for Low Frequency Applications Using a Slow-Wave Structure
F. Domingue, A.B. Kouki, R.R. Mansour

WEP2C-05: High-Q RF MEMS Capacitor with Digital/Analog Tuning Capabilities
A. Grichener, B. Lakshminarayanan, G.M. Rebeiz

WEP2D Semiconductor Devices and Monolithic IC Technologies

WEP2D-01: Intergate-Channel-Connected Multi-Gate PHEMT Devices for Antenna Switch Applications
S. Koya, T. Ogawa, H. Takazawa, A. Nakajima, S. Osakabe, Y. Shigeno, S. Takatani

WEP2D-02: An Efficient Technique for Designing Balanced Vector Modulators with Low Insertion Loss
Y. Hou, X. Sun, L. Li

WEP2D-03: A Monolithic, 1000 W SPDT Switch
T.E. Boles, J. Brogle, A. Rozbicki

WEP2D-04: A Low Phase-Shift Temperature Compensation Attenuator with Variable-Q FET Resonators
M. Hangai, H. Asao, M. Hieda, H. Takeda, M. Yamaguchi, M. Miyazaki

WEP2D-05: A K-band AlGaN/GaN-based MMIC Amplifier with Microstrip Lines on Sapphire
T. Murata, M. Kuroda, S. Nagai, M. Nishijima, H. Ishida, M. Yanagihara, T. Ueda, H. Sakai, T. Tanaka, M. Li

WEP2E Packaging, Interconnects, MCMs and Hybrid Manufacturing

WEP2E-01: Wideband Electrical Modeling of Large Three-Dimensional Interconnects using Accelerated Generation of Partial Impedances with Cylindrical Conduction Mode Basis Functions
K. Han, M. Swaminathan, E. Engin

WEP2E-02: Utilizing Infrared for Improved Channel Temperature Prediction
A. Darwish, A. Bayba, H.A. Hung

WEP2E-03: Design, Integration and Characterization of a Novel Paper-based Wireless Sensor Module
R. Vyas, A. Rida, L. Yang, M.M. Tentzeris

WEP2F Biological Effects and Medical Applications

WEP2F-01: Miniature Antenna for RF Telemetry through Ocular Tissue
E.Y. Chow, C. Yang, A. Chlebowski, W.J. Chappell, P.P. Irazoqui

WEP2F-02: A Tapered Microstrip Patch Antenna Array for Microwave Breast Imaging
J.P. Stang, W.T. Joines

WEP2G Smart Antennas, Spatial Power Combining and Phased Arrays

WEP2G-01: Integrated Mixer Based on Composite Right-/Left-handed Leaky-wave Antenna
Y. Kim, E. Kim, A. Lai, D.S. Goshi, T. Itoh

WEP2G-02: Blind Source Separation of Human Body Motion using Direct Conversion Doppler Radar
A. Vergara, N. Petrochilos, O. Boric-Lubecke, V. Lubecke

WEP2G-03: A Self-Steering Array Using Power Detection and Phase Shifting
J.M. Akagi, A. Zamora, M.K. Watanabe, W.A. Shiroma

Thursday, June 19, 2008
8:00 am to 9:40 am

TH1A Filter Theory and New Concepts

Chair: G. Macchiarella
Co-chair: H. Yao

This session presents the recent development of filter theory and new design concepts. It attempts to take the advantage of losses and multiple passes to enhance filter characteristics.

TH1A-01: Novel Waveguide Pseudo-Elliptic Filters using Slant Ridge Resonators
S. Bastioli, L. Marcaccioli, R. Sorrentino

TH1A-02: Design of a Coaxial Resonator Filter with Nonuniform Dissipation
Z. Zakaria, I.C. Hunter, A.C. Guyette

TH1A-03: Generalized Lossy Microwave Filter Coupling Matrix Synthesis and Design
V. Miraftab, M. Yu

TH1A-04: Longitudinal Dual-Mode Filters in Rectangular Waveguide
J.A. Ruiz-Cruz, Y. Zhang, J.R. Montejo-Garai, J.M. Rebollar, K.A. Zaki

TH1A-05: Enhanced Topology for the Design of Bandpass Elliptic Filters Employing Inductive Windows and Dielectric Objects
M. MartInez-Mendoza, F.J. Perez-Soler, J.S. Gomez-Diaz, F. Quesada-Pereira, A. Alvarez-Melcon, R. Cameron

TH1A-06: A Novel Low-loss Integrated 60 GHz Cavity Filter with Source-Load Coupling using Surface Micromachining Technology
B. Pan, Y. Li, M.M. Tentzeris, J. Papapolymerou

TH1B High Power Amplifiers for Infrastructure Applications

Chair: A. Platzker • Co-chair: J. Heaton

Four leading technologies for high power applications are presented in this session. Novel stacked PHEMT and balun technologies yield a 10 W ultra broadband PA, and a 28 V InGaP HBT process has been used to realize a 40 W high linearity 900 MHz PA. An 85 W 62% efficient PA at 2.14 GHz is realized in a 48 V GaN process. 150 W and 400 W 50% efficient highly linear base station PAs are reported in LDMOS.

TH1B-01: 10 W Ultra-Broadband Power Amplifier
A.K. Ezzeddine, H.C. Huang

TH1B-02: High Linearity 40 W, 28 V InGaP/GaAs HBT
W. Ma, X. Sun, P. Hu, J. Yao, B. Lin, H. Chau, L. Liu, C. Lee

TH1B-03: Characterization and Thermal Analysis of a 48 V GaN HFET Device Technology for Wireless Infrastructure Applications
B. Green, H. Henry, J. Selbee, F. Clayton, K. Moore, M.C. deBaca, J. Abdou, C. Liu, O. Hartin, D. Hill, M. Miller

TH1B-04: A 2-stage 150 W 2.2 GHz Dual Path LDMOS RF Power Amplifier for High Efficiency Applications
C. Cassan, J. Jones, O. Lembeye

TH1B-05: Asymmetrical Doherty for 3G Base Stations Based on Dedicated Transistors including Integrated Bias
J. Bouny

TH1C Dual -band Passive Components

Chair: M. Salazar-Palma • Co-chair: M. Abouzahra

Modern wireless communication systems often operate in multiple frequency bands. This session presents dual band power combiners/dividers, couplers, baluns and filters together with a dual behavior resonator. Some of the devices employ metamaterial structures.

TH1C-01: Compact Single and Dual Band Zero-degree Metamaterial N-way Radial Power Combiner/Divider
A. Dupuy, A. Gummalla, M. Achour, G. Poilasne

TH1C-02: Dual-band Y-Junction Power Dividers Implemented Through Artificial Lines Based on Complementary Resonators
G. Siso, J. Bonache, F. Martín

TH1C-03: A Compact Dual-band Metamaterial-based Rat-Race Coupler for a MIMO System Application
P. Chi, C. Lee, T. Itoh

TH1C-04: Miniaturized DBR Filter: Formulation and Performances Improvement
H. Issa, J. Duchamp, P. Ferrari

TH1C-05: Dual-band Bandpass Filter and Diplexer Based on Double-Sided Parallel-Strip Line
J. Chen, Q. Xue

TH1C-06: Dual-band Marchand Baluns
W.M. Fathelbab

TH1D Microwave and Millimeter-wave Phased Array and Applications

Chair: N. Buris • Co-chair: C.A. Balanis

This session addresses novel designs and techniques in the microwave and millimeter-wave regions. Applications include wireless sensor networks, broadband receiver systems, novel modularized butler matrices, low-cost architectures and coupled phased-lock loops for beam steering.

TH1D-01: A Feedback-based Distributed Phased Array Technique and its Application to 60 GHz Wireless Sensor Network
M. Seo, M. Rodwell, U. Madhow

TH1D-02: **A Tunable Concurrent 6–18 GHz Phased-Array System in CMOS**
H. Wang, S. Jeon, Y. Wang, F. Bohn, A. Natarajan, A. Babakhani, A. Hajimiri

TH1D-03: **A Novel Modularized Folded Highly Compact LTCC Butler Matrix**
G. Tudosie, R. Vahldieck, A.C. Lu

TH1D-04: **Architecture for Low Cost Electronically Steered Phased Arrays**
M. Sanchez-Barbetty, R.W. Jackson

TH1D-05: **An Electronically Scanned Array with 180° Scanning Range Using Coupled Phase-Locked Loops**
S. Yan, T. Chu

TH1D-06: **Millimeter-wave Substrate Integrated Waveguide Multi-beam Antenna Based on the Modified R-KR Lens**
Y. Cheng, W. Hong

TH1E History of MIC/MMIC Inventions – I

Chair: G.D. Vendelin • Co-chair: R. Pengelly

This session will review the history of the development of MIC/MMIC circuits, which occurred at Texas Instruments 1964–1970 due to the MERA (Microwave Electronic Radar Applications) Program, which was a contract between TI and Wright Patterson Air Force Base to develop an X-band solid-state radar. Many of the people who performed this work will give their recollections of the design of this benchmark system, including Tom Hyltin, the program manager.

TH1E-01: **Five Years at Texas Instruments: 1963–1968**
G.D. Vendelin

TH1E-02: **COMPACT-Microwave Circuit Optimization through Commercial Timesharing**
L. Besser

TH1E-03: **Applied High Frequency Electromagnetic Analysis – A Historical Perspective**
J. Rautio

TH1E-04: **The MERA Program, a MMIC Pioneer**
T. Hyltin

TH1E-05: **Microwave Power Generation at 9 GHz in Hybrid Microwave Integrated Circuits**
B.T. Vincent, Jr.

9:30 AM TO 11:30 AM

THURSDAY INTERACTIVE FORUM I

THP1A Field Analysis and Guided Waves

THP1A-01: **Source Stirring Technology for Automotive Antenna Measurement**
M. Albrecht, J. Luy, P. Russer

THP1A-02: **On the Slow Wave Behaviour of the Shielded Mushroom Structure**
F. Elek, G.V. Eleftheriades

THP1A-03: **Far Field Measurement on a Ka-band Substrate-integrated Waveguide Antenna Array with Polarization Multiplexing**
K. Kuhlmann, K. Rezer, A.F. Jacob

THP1A-04: **Dielectric Resonance in Composites Filled with Metal-coated Microspheres**
J. Liu, N. Bowler

THP1B Frequency-domain Techniques

THP1B-01: **Complex-Domain Mapping for Evaluating Troublesome Integrals in Fast Full-Wave Integral Equation Solvers**
J. Lee, J. White

THP1B-02: **Evaluation of Electrical Properties for Complex Mixtures with a Periodic Technique**
H. Wu, D. Wu, J. Chen, R. Liu

THP1C Time-domain Techniques

THP1C-01: **Analyzing Broad-band Electromagnetics Problems with Commercial Software-Time Domain versus Frequency Domain**
E.L. Holzman, W.S. Nelson, B.C. Swift, J.R. Willhite, S. Hegde

THP1C-02: **An FDTD-Based Tool for Simulation of Nonlinear Interactions of Guided Waves**
A. Marandi, P.P. So, T.E. Darcie

THP1C-03: **Optimisation of the Homogenization of Tissues using the Adjoint Method and the FDTD**
J. Silly-Carette, D. Lautru, A. Gati, M. Wong, J. Wiart, V. Fouad Hanna

THP1C-04: **A General Method for Introducing Subgrids into High-Order FDTD: Formulation and Microwave Applications**
R.B. Armenta, C.D. Sarris

THP1C-05: **An Accurate and Stable Fourth Order Finite Difference Time Domain Method**
J.L. Wilson, C. Wang, S. Yang, A.E. Fathy, Y.W. Kang

THP1D CAD Algorithms and Techniques

THP1D-01: **Perfectly Calibrated Internal Ports in EM Analysis of Planar Circuits**
J.C. Rautio

THP1D-02: **Space Mapping with Distributed Fine Model Evaluation for Optimization of Microwave Structures and Devices**
S. Koziel, J.W. Bandler

THP1D-03: **Topology Optimization Applied to the Design of a Dual-mode Filter Including a Dielectric Resonator**
H. Khalil, N. Delhote, S. Bila, M. Aubourg, S. Verdeyme, J. Puech, L. Lapierre, C. Delage, T. Chartier

THP1D-04: **Modeling Device Manufacturing Uncertainty in Electromagnetic Simulations**

L.R. de Menezes, A.O. Paredes, H. Abdalla Jr., G.A. Borges

THP1D-05: Modeling of Arbitrary-Order Mutual Coupling
L. Han, K. Wu

THP1D-06: Time Domain Sensitivity of Non Linear Circuits via Wavelet Transform
S. Barmada, A. Musolino, M. Raugi, M. Tucci

THP1D-07: RF Design Methodology for Design-Cycle-Time Reduction using Parameterization of Embedded Passives on Multilayer Organic Substrates
S. Min, C. Seo, A.M. Yepes, C. Ward, S. Dalmia, G. White, M. Swaminathan

THP1D-08: Scalable Parallel Matrix Solver for Steady State Analysis of Large Nonlinear Circuits
N. Soveiko, M. Nakhla, R. Achar, E. Gad

THP1E Linear Device Modeling

THP1E-01: Extraction of an Extrinsic Parasitic Network for Accurate mm-Wave FET Scalable Modeling on the Basis of Full-Wave EM Simulation
D. Resca, A. Raffo, A. Santarelli, G. Vannini, F. Filicori

THP1E-02: A New Method for Determining the Gate Resistance and Inductance of GaN HEMTs Based on the Extrema Points of Z11 Curves
J.A. Reynoso-Hernández, J.E. Zuniga-Juarez, A. Zarate-de Landa

THP1F Nonlinear Device Modeling

THP1F-01: A Scalable High Power Nonlinear HBT Model for a 28 V HVHBT
X. Zhang, F. Chau, B. Lin, X. Sun, W. Ma, P. Hu, J. Yao, C. Lee

THP1F-02: RF Large-Signal Model for SiO_2/AlGaN/GaN MOSFETs
J. Deng, W. Wang, S. Halder, W.R. Curtice, J.C. Hwang, V. Adivarahan, A. Khan

THP1F-03: A New Empirical Model for the Characterization of Low-Frequency Dispersive Effects in FET Electron Devices Accounting for Thermal Influence on the Trapping State
A. Raffo, V. Vadalà, G. Vannini, A. Santarelli

THP1F-04: Harmonic Balance Simulation of a New Physics Based Model of the AlGaN/GaN HFET
H. Yin, D. Hou, G.L. Bilbro, R.J. Trew

THP1G Nonlinear Circuit Analysis and System Simulation

THP1G-01: A Piecewise Transistor-Level Simulation Technique for the Steady State and Phase Noise Analysis of Integer N PLLs
B. Wang, E. Ngoya

THP1G-02: Evaluation of Nonlinear Distortion in ADCs Using Multisines
P.M. Cruz, N.B. Carvalho, K.A. Remley

THP1G-03: An Orthogonal Lookup-table Decomposition for Accurate IMD Prediction in Power Amplifier with Memory
C. Quindroit, E. Ngoya, A. Bennadji, J. Nabus

THP1G-04: Comparison of Evaluation Criteria for Power Amplifier Behavioral Modeling
P.N. Landin, M. Isaksson, P. Händel

THP1G-05: Low-Pass Equivalent Feedback Topology for Power Amplifier Modeling
T.R. Cunha, J.C. Pedro, E.G. Lima

THP1G-06: Analysis and Reduction of the Oscillator Phase Noise from the Variance of the Phase Deviations, Determined with Harmonic Balance
S. Sancho, F. Ramirez, A. Suarez

THP1G-07: A Novel Measurement-based Method Enabling Rapid Extraction of an RF Waveform Look-up Table-based Behavioral Model
S.P. Woodington, T. Williams, H. Qi, D. Williams, L. Pattison, A. Patterson, J. Lees, J. Benedikt, P. Tasker

THP1H Microwave Photonics

THP1H-01: Phase Modulated Fiber-optic Link with High Dynamic Range
Y. Li, P. Herczfeld, A. Rosen

10:10 AM to 11:50 AM

TH2A Filter Realization Techniques

Chair: M. Yu • Co-chair: V.E. Boria

This session presents the recent development of filter realization techniques. It attempts to minimize filter volume and introduce new fabrication techniques.

TH2A-01: New Concepts for Dielectric Multi-Mode Resonators with Branches
M. Höft

TH2A-02: Multilayer Folded-Waveguide Dual-band Filter.
S.K. Alotaibi, J. Hong, Z. Hao

TH2A-03: Theoretical Investigation of Microwave Breakdown Ignition in OMUX Filters: A 3D Numerical Modeling Approach
K. Frigui, D. Baillargeat, S. Verdeyme, S. Bila, A. Catherinot, J. Puech, D. Pacaud, J.J. Herren

TH2A-04: Sequential Tuning of Coupled Resonator Filters Using Hilbert Transform Derived Relative Group Delay
N. Zahirovic, R.R. Mansour

TH2A-05: Innovative Manufacturing Technology for RF Passive Devices Combining Electroforming and CFRP Application
S. Liberatoscioli, M. Mattes, M. Guglielmi, D. Schmitt, C. Ernst

TH2A-06: Size-Reduced Tunable Hairpin Bandpass Filter using Aperture Coupling with Enhanced Selectivity and Constant Bandwidth
H. Moon, S. Choi, Y. Cho, S. Yun

TH2B Advanced High Efficiency Power Amplifier Concepts

Chair: A.V. Pham
Co-chair: L. de Vreede

In this session various efficiency enhancement techniques will be covered, ranging from switch mode, to adaptive load modulation. We start with 90% efficient GaAs-HBT and GaN HEMT amplifiers for software defined radio and followed by an all-digital CMOS approach to serve ZigBee applications. New approaches are tested for their functionality using extensions to traditional LINC and Doherty Amplifier concepts. The session is completed with a discussion of a novel sequential power amplifier.

TH2B-01: Switch-Mode Amplifier ICs with over 90% Efficiency for Class-S PAs using GaAs-HBTs and GaN-HEMTs
C. Meliani, J. Flucke, A. Wentzel, J. Wurfl, W. Heinrich, G. Tränkle

TH2B-02: An All-Digital CMOS 915 MHz ISM Band 802.15.4/ZigBee Transmitter with a Noise Spreading Direct Quantization Algorithm
J. Rode, T. Hung, P. Asbeck

TH2B-03: A Highly Efficient Chireix Amplifier Using Adaptive Power Combining
J. Qureshi, R. Lui, A.J.M. de Graaw, M.P. van der Heijden, J. Gajadharsing, L.C. de Vreede, A.J. de Graauw

TH2B-04: A Novel Doherty Amplifier for Enhanced Load Modulation and Higher Bandwidth
M. Sarkeshi, O.B. Leong

TH2B-05: Design and Performance of Sequential Power Amplifiers
T. Lehmann, R. Knoechel

TH2C Passive Semiconductor Microwave Components

Chair: P. Russer • Co-chair: M. Salazar-Palma

For monolithic integrated microwave and millimeter-wave circuits passive distributed planar and three-dimensional lumped and distributed circuit structures are of great importance. This session deals with spiral inductors, transmission line resonators, filters, tuners and directional couplers. Emphasis is put on silicon CMOS technology.

TH2C-01: A CMOS 3 dB Directional Coupler Using Edge-Coupled Meandered Synthetic Transmission Lines
M. Chiang, H. Wu, C.C. Tzuang

TH2C-02: A 60 GHz High-Q Tapered Transmission Line Resonator in 90 nm CMOS
C. Marcu, A.M. Niknejad

TH2C-03: A Reconfigurable MEMS-less CMOS Tuner for Software Defined Radio
L. Rabieirad, S. Mohammadi

TH2C-04: Three-Stage Bandpass Filters Implemented in Silicon IPD Technology Using Magnetic Coupling between Resonators
R.C. Frye, K. Liu, Y. Lin

TH2C-05: Dummy Fill Insertion Considering the Effect on High-Frequency Characteristics of Spiral Inductors
A. Tsuchiya, H. Onodera

TH2D Retrodirective Phased Arrays and Smart Antennas

Chair: C. Rodenbeck
Co-chair: K. Tomiyasu

Presenting new concepts and techniques for retro-directive scanning and smart antennas. Recent achievements include PLL-based phase control, conformal retro-directive arrays, and low-cost hardware implementations.

TH2D-01: Quadrant Switching PLL Phase Conjugator for Retrodirective Antenna Applications
N.B. Buchanan, V.F. Fusco

TH2D-02: A Sparse Conformal Retrodirective Array for UAV Application
J.S. Sun, D.S. Goshi, T. Itoh

TH2D-03: A Planar Circular Phase Conjugated Array with Full Scanning Range
L. Chiu, Q. Xue, C. Chan

TH2D-04: A 2.4 GHz 1-Dimensional Array Antenna Driven by Vector Modulators
N. Tohme, J. Paillot, D. Cordeau, S. Cauet, Y. Mahe, P. Ribardiere

TH2D-05: CRLH Leaky-Wave Real-Time Spectrum Analyzer (RTSA) with Unrestricted Time-Frequency Resolution
S. Gupta, C. Caloz, S. Abielmona

TH2D-06: Self-Phasing Receive Array for RF-Sensing and Tracking Applications
R.N. Pang, M.K. Watanabe, W.A. Shiroma

TH2E History of MIC/MMIC Inventions – II

Chair: G.D. Vendelin
Co-chair: R. Pengelly

This session will review the history of the development of MIC/MMIC circuits, which occurred at Texas Instruments 1964–1970 due to the MERA (Microwave Electronic Radar Applications) Program, which was a contract between TI and Wright Patterson Air Force Base to develop an X-band solid-state radar. Many of the people who performed this work will give their recollections of the design of this benchmark system, including Tom Hyltin, the program manager.

TH2E-01: The Development of a Solid State Transceiver for an Active Element Ground Based L-band Phased Array Radar
R.W. Sudbury

TH2E-02: **Development of Silicon-based Millimeter-wave Monolithic Integrated Circuits at National Taiwan University**
H. Wang

TH2E-03: **Early MMIC Developments at Texas Instruments**
G. Brehm

TH2E-04: **Early GaAs FET Monolithic Microwave Integrated Circuit Developments for Radar Applications at Plessey, UK**
R. Pengelly

1:20 PM TO 3:00 PM

TH3A Microacoustic Frontend Technologies

Chair: C. Ruppel • Co-chair: R. Weigel

In this session novel developments and future trends in the design of microwave acoustic components are addressed. The session starts with novel WCDMA duplexers, proceeds with ultra miniature ISM filters, FBAR oscillators, and highly stable SAW filters, and concludes with a new measurement technique for both SAW and BAW devices.

TH3A-01: **BAW/SAW/IPD Hybrid Type Duplexer with Rx Balanced Output for WCDMA Band I**
T. Nishihara, M. Iwaki, G. Endo, X. Mi, S. Taniguchi, M. Ueda, Y. Satoh

TH3A-02: **Selection of Micro-Acoustic Technologies for the Realization of Single-ended/Balanced WCDMA Duplexers**
T. Metzger, M. Maier, H. Klamm, Z. Kovats, D. Ritter, G. Maurer, P. Selmeier

TH3A-03: **An Ultra-Miniature, Low Cost Single Ended to Differential Filter for ISM Band Applications**
S.R. Gilbert, R. Parker, M.K. Small, U.B. Koelle, J.D. Larson III, R.C. Ruby

TH3A-04: **A 2 GHz Oscillator using a Monolithically Integrated AlN TFBAR**
M. Norling, J. Enlund, I. Katardjiev, S. Gevorgian

TH3A-05: **Miniature Surface Acoustic Wave Devices with Excellent Temperature Stability using High Density Metal Electrodes and SiO_2 Film**
M. Kadota, T. Nakao, K. Nishiyama, S. Kido, M. Kato, R. Omote, H. Yonekura, N. Takada, R. Kita, Y. Nakai, D. Yamamoto

TH3A-06: **A Fast Scanning Laser Probe Based on Sagnac Interferometer for RF Surface and Bulk Acoustic Wave Devices**
K. Hashimoto, K. Kashiwa, T. Omori, M. Yamaguchi, O. Takano, S. Meguro, K. Akahane

TH3B Power Amplifier Design Techniques for Millimeter-wave and Multi-band Applications

Chair: C.H. Lee • Co-chair: D. Dawn

This session focuses on the integrated power amplifiers for the millimeter-wave from 35 GHz to 100 GHz and on multi-band applications with various device technologies and reconfigurable design techniques.

TH3B-01: **35 dBm, 35 GHz Power Amplifier MMICs using 6 inch GaAs pHEMT Commercial Technology**
S.J. Mahon, A. Dadello, A.P. Fattorini, A. Bessemoulin, J.T. Harvey

TH3B-02: **17 dB Gain CMOS Power Amplifier at 60 GHz**
D. Dawn, S. Sarkar, P. Sen, B. Perumana, D. Yeh, S. Pinel, J. Laskar

TH3B-03: Q-, V-, and W-band Power Amplifiers Utilizing Coupled Lines for Impedance Matching
M. Abbasi, H. Zirath, I. Angelov

TH3B-04: A Novel Reconfigurable Quad-band Power Amplifier with Reconfigurable Biasing Network and LTCC Substrates
A. Fukuda, H. Okazaki, S. Narahashi

TH3B-05: A Variable Supply, 2.3–2.7 GHz Linear Power Amplifier Module for IEEE 802.16e and LTE Applications using E-mode PHEMT Technology
Y.H. Chow, C.K. Yong, J. Lee, H.K. Lee, J. Rajendran, S.H. Khoo, M.L. Soo, C.F. Chan

TH3B-06: A 2.4 GHz HBT Power Amplifier Using an On-Chip Transformer as an Output Matching Network
H. Seol, C. Park, D. Lee, M. Park, S. Hong

TH3C Innovative Substrate Techniques for Passive Integration

Chair: N. Kingsley • Co-chair: J. Taub

Recent advancements in innovative substrate techniques are presented in this session. These technologies utilize organic substrates or metallic structures to implement power dividers, couplers, filters, and wide-band waveguide corners. The intention is to realize compact, low-loss techniques for passive integration. These technologies are beneficial for a variety of applications, including system-on-packages and multilayer devices.

TH3C-01: Broadband Half-Mode Substrate Integrated Waveguide (HMSIW) Wilkinson Power Divider
Z. Zhang, K. Wu

TH3C-02: Substrate Integrated Waveguide Power Divider Based on Multimode Interference Imaging
N. Yang, C. Caloz, K. Wu

TH3C-03: A Compact Multilayered Magic-T in Microstrip Form and its Application to Microwave Sampler
T. Ma, C. Chou

TH3C-04: Ultra Slow-Wave Periodic Transmission Line Using 3D Substrate Metallization
Y. Zhang, H. Yang

TH3C-05: A Compact Highly-Selective Filter Inspired by Negative-Refractive-Index Transmission Lines
R. Islam, G.V. Eleftheriades

TH3C-06: Compact H-Plane Waveguide Corners with Very Wide Bandwidth
S. Matsumoto, M. Ohshima, K. Fukata, T. Kawai, I. Ohta, M. Kishihara, K. Iio, T. Kashiwa

TH3D Biological Effects and Medical Applications

Chair: M.R. Tofighi • Co-chair: A. Rosen

This year, accepted papers cover broad interests in the use of microwave technology in medical applications. The papers were selected from traditional areas that range from microwave biological tissue characterization to the relatively new areas of microwave human cell characterization and biomedical implants. Interest in the field of implanted sensors has grown, and the subject is also discussed in this year's session. Implanted microwave sensors, based on wireless communication and backscattering principles, require efficient antennas in small biocompatible packages. As in the past, many presenters will be attending this session from all over the world, something that underscores the ongoing dynamic research in the area of microwave in medicine.

TH3D-01: On Design of a Low Power Wireless Hearing Aid Communication System
G.S. Shaker, M. Nezhad-Ahmadi, S. Safavi-Naeini, G. Weale

TH3D-02: **Electrical Properties of Nude Rat Skin and Design of Implantable Antennas for Wireless Data Telemetry**
T. Karacolak, E. Topsakal

TH3D-03: **Label Free Biosensors for Human Cell Characterization using Radio and Microwave Frequencies**
C. Dalmay, A. Pothier, P. Blondy, F. Lalloue, M. Jauberteau

TH3D-04: **High Frequency Wideband Permittivity Measurements of Biological Substances Using Coplanar Waveguides and Application to Cell Suspensions**
S. Seo, T. Stintzing, I. Block, D. Pavlidis, M. Rieke, P.G. Layer

TH3D-05: **Two Frequency Radar Sensors for Non-contact Vital Signal Monitor**
J. Oum, D. Kim, S. Hong

TH3D-06: **A Novel Liquid Antenna for Wearable Bio-monitoring Applications**
A. Traille, L. Yang, A. Rida, M.M. Tentzeris

TH3E Nonlinear Circuit Analysis and System Simulation

Chair: J.C. Pedro

Co-chair: V. Rizzoli

The session introduces a wealth of innovative techniques for nonlinear circuit, component, and system modeling, simulation, and design. The topics covered range from power-amplifier behavioral modeling to microwave link analysis under realistic propagation conditions.

TH3E-01: **A CAD Procedure for MIMO Link Estimation by the Combination of Nonlinear, Electromagnetic and Propagation Analysis Techniques**
V. Rizzoli, A. Costanzo, P. Spadoni, F. Donzelli, D. Masotti, E.M. Vitucci

TH3E-02: **Quantifying Distortion of RF Power Amplifiers for Estimation of Predistorter Performance**
P.J. Draxler, A. Zhu, J.J. Yan, P. Kolinko, D.F. Kimball, P.M. Asbeck

TH3E-03: **A Linearized Polar Transmitter for Wireless Applications**
P.M. Cabral, J.C. Pedro, J.A. Garcia, L. Cabria

TH3E-04: **Mismatch Detection and Compensation Algorithm with the Closed Form Solution for the LINC System Implementation**
S. Myoung, I. Lee, K. Lim, J. Yook, J. Laskar

TH3E-05: **Implementation of a Volterra Behavioral Model for System Simulation**
S.A. Maas, J.C. Pedro

TH3E-06: **Nonlinear Analysis and Design of Frequency Selective Limiters Based on Parametric Circuits**
F. Ramirez, R. Melville, A. Suarez, J.S. Kenney

2:00 PM TO 4:00 PM

THURSDAY INTERACTIVE FORUM II

THP2A Signal Generation

THP2A-01: **Microwave Pulse Generation using the Bragg Cutoff of a Nonlinear Transmission Line**
K.G. Lyon, E.C. Kan

THP2A-02: **An Eight-Phase Voltage-controlled Oscillator with Reflection-Type Modulators in 0.18 μm CMOS Technology**
C. Lin, H. Chang

THP2A-03: **Low Phase Noise VCO using Microstrip Square Open Loop Multiple Split Ring Resonator**
J. Choi, C. Seo

THP2B Frequency Conversion and Control

THP2B-01: **High Power AlGaN/GaN Ku -band MMIC SPDT Switch and Design Consideration**
B.Y. Ma, K.S. Boutros, J.B. Hacker, G. Nagy

THP2B-02: **A 14–23 GHz CMOS MMIC Distributed Doubler with a 22 dB Fundamental Rejection**
K. Lin, J. Huang, J. Kuo, C. Lin, H. Wang

THP2B-03: **A 60 GHz Single-balance Gate-pumped Down-conversion Mixer with Reduced-size Rat-race Hybrid on 130 nm CMOS Process**
C. Lien, P. Wu, K. Lin, H. Wang

THP2B-04: **An Even Harmonic Image Rejection Mixer using an Eight-Phase Polyphase Filter**
M. Shimozawa, K. Nakajima, H. Ueda, T. Tadokoro, N. Suematsu

THP2B-05: **An Ultra Low Power Analog Frequency Divider**
P. Sun, J. Jung, Y. Kim, D. Heo

THP2C HF/VHF/UHF Technologies and Applications

THP2C-01: **A Novel Adaptive LDMOS Power Amplifier with Constant Efficiency for Wide Dynamic Power Levels Control**
K. Narendra, A. Mediano, C. Paoloni, E. Limiti

THP2C-02: **Long Life Microwave Electrodeless Lamps for Projection Display and General Lighting Applications**
M. DeVincentis, G. Hollingsworth, R. Gilliard

THP2C-03: **Underwater Motion and Physiological Sensing using UHF Doppler Radar**
N. Hafner, W. Massagram, V.M. Lubecke, O. Boric-Lubecke

THP2D High-power Amplifiers

THP2D-01: **Characterization of Switch Mode LDMOS and GaN Power Amplifiers for Optimal Use in Polar Transmitter Architectures**
H.M. Nemati, C. Fager, U. Gustavsson, R. Jos, H. Zirath

THP2D-02: **A 120 W, Two-Stage, LDMOS Power Amplifier IC at 1.8 GHz for GSM/EDGE Applications**
L. Zhao, G. Bigny, J. Jones

THP2D-03: **Digital Baseband Injection Techniques to Reduce Spectral Regrowth in Power Amplifier**
M. Xiao, P. Gardner

THP2D-04: **Wide Bandwidth Adaptive Digital Predistortion of Power Amplifiers using Reduced Order Memory Correction**
R.N. Braithwaite

THP2D-05: **Novel Approach for Static Nonlinear Behavior Identification in RF Power Amplifiers Exhibiting Memory Effects**
O. Hammi, S. Carichner, B. Vassilakis, F.M. Ghannouchi

THP2E-01: **A Miniature LNA-Filter GPS Receiver Front-end Module Combining FBAR and E-mode pHEMT Technology**
Y.H. Chow, H.T. Tan, S.C. Low, M. Mutanizam, T.W. Lee, C.C. Lim, S.H. Khoo, Y.Y. Liew, W.K. Kim

THP2F-01: **Gunn Oscillator Modeling and Second Harmonic Output Power Optimization at 76 GHz**
T. Kiuru, A.M. Safwat, J. Mallat, A.V. Räisänen

THP2F-02: **Application of Terahertz Imaging to Osteoarthritis**
E. Pickwell-MacPherson, W.C. Kan, W. Lee, V.P. Wallace, W.H. Cheung

THP2F-03: **Full Coverage Millimeter-wave Primary Noise Standards for 18–170 GHz**
D.R. Vizard, P. Foster, B. Lunn, S. Cherry

THP2F-04: **A 60 GHz High Isolation SPDT MMIC Switch Using Shunt PHEMT Resonator**
Y. Tsukahara, H. Amasuga, S. Goto, T. Oku, T. Ishikawa

THP2F-05: **A Heterostructure Barrier Charge Swing Device for Frequency Multiplication at 306 GHz**
B.I. Nicolae, M. Ruf, J. Schür, L. Schmidt, H.L. Hartnagel

THP2F-06: **Ka-band Surface-Mount Directional Coupler Fabricated using Micro-Rectangular Coaxial Transmission Lines**
K.J. Vanhille, J. Rollin, S. Rondineau, J.W. O'Brien, J.L. Wood, Z. Popovic

THP2F-07: **A W-band Quasi-optical Doppler Radar for Detection of Very Slow-Moving Targets**
J.Y. Suen, R.S. Singh, Z.D. Taylor, E.R. Brown

THP2F-08: **A CMOS-Compatible Schottky-Barrier Diode Detector for 60 GHz Amplitude-Shift Keying (ASK) Systems**
M. Ko, H. Kang, W. Choi

THP2F-09: **Average Capacity of Wireless Optical Communication Systems over Gamma Gamma Atmospheric Turbulence Channels**
H.E. Nistazakis, G.S. Tombras, A.D. Tsigopoulos, E.A. Karagianni, M.E. Fafalios

THP2G-01: **Signal Integrity in Reflection-Limited Channels**
J.F. Buckwalter

THP2H-01: **On the Cyclostationary Properties of the 1/f Noise of Microwave Semiconductor Devices**
A.A. Lisboa de Souza, J. Nallatamby, M. Prigent, J. Obregon

THP2H-02: **Mapping of Passive Intermodulation Products on Microstrip Lines**
A.P. Shitvov, D. Zelenchuk, A.G. Schuchinsky, V.F. Fusco

THP2H-03: **Measurement of Polarized Nano-Material (PNM) for Microwave Application**
W. Chen, Z. Zhang, Z. Feng, Y. Chen, K. Jiang, S. Fan, M. Iskander

THP2H-04: **Characterization of Galileo Signal Correlation Losses Caused by Non Linear Power Amplification with Memory**
G. Nanfack Nkondem, J. Santiago, G. Neveux, D. Barataud, J. Collantes, J. Portilla, J. Nebus, A. Mallet

THP2H-05: **Microwave Properties of Platinum Nanoparticle Films**
A. Sulaimalebbe, A. Porch, G. Attard

THP2H-06: **Vector Near-Field Measurement System Using an Electro-Optic Microcavity and Electrical Downconversion**
D. Lee, J. Kang, C. Chen, J.F. Whitaker

3:30 PM TO 5:10 PM

TH4A Ferrites and Ferroelectrics

Chair: S. Gevorgian • Co-chair: S. Stitzer

Microwave ferroelectric materials have voltage controllable permittivity that is primarily used in realizing tunable reactance. The first four papers in this session explore applications of ferroelectric-based tunable capacitors. The first paper presents integrated broadband tunable filters with one filter operating from 230 to 400 MHz with an instantaneous bandwidth of 10% or less. The second paper describes a tunable matching network operating from 1.5 to 2 GHz with an impedance matching ratio of 4. Suppression of harmonic generation in a ferroelectric-based tunable antenna is described in the third paper. A reduced size power divider is realized using tunable lumped capacitors to provide tunable optimum performance. The last two papers address current topics in ferrite technology. The first of these uses flexible composite ferrite-based material to miniaturize flexible RF tags. The last paper of the session addresses nonlinear characterization of ferrites.

TH4A-01: **Broadband Tunable Filters Using High Q Passive Tunable ICs**
M. Nguyen, W.D. Yan, E.P. Horne

TH4A-02: **A Ferroelectric-based Impedance Tuner for Adaptive Matching Applications**
J. Fu, X.A. Zhu, J.D. Phillips, A. Mortazawi

TH4A-03: **Suppression on Harmonic Radiation of Tunable PIFA by Ferroelectric Varactor Loading**
Y. Zheng, A. Hristov, A. Giere, R. Jakoby

TH4A-04: **A Novel Flexible Magnetic Composite Material for RFID, Wearable RF and Bio-monitoring Applications**
L. Yang, L. Martin, D. Staiculescu, C.P. Wong, M.M. Tentzeris

TH4A-05: **A Tunable and Reduced Size Power Divider using Ferroelectric Thin-Film Varactors**
E. Lourandakis, M. Schmidt, A. Leidl, S. Seitz, R. Weigel

TH4A-06: **Intermodulation Distortion Evaluation of Ferrite Element by Two-tone Method**
T. Miura, L.E. Davis

TH4B Advanced Techniques for CAD

Chair: A. Sharma

Co-chair: A. Cangellaris

Advanced design optimization techniques using rigorous analytical and numerical procedures are presented. Space mapping, EM sensitivity, and neural network techniques provide robust practical solutions for microwave design.

TH4B-01: **Rigorous Computer-Aided Design of Coaxial/Circular Antennas with Semi-Spherical Dielectric Layers**
C. Tomassoni, M. Mongiardo, P. Russer, R. Sorrentino

TH4B-02: **Efficient Electromagnetic Optimization Using Self-adjoint Jacobian Computation Based on a Central-node FDFD Method**
X. Zhu, A. Hasib, N.K. Nikolova, M.H. Bakr

TH4B-03: **A General EM-based Design Procedure for Single-Layer Substrate Integrated Waveguide Interconnects with Microstrip Transitions**
J.E. Rayas-Sanchez, V. Gutierrez-Ayala

TH4B-04: **Adaptive Space Mapping with Convergence Enhancement for Optimization of Microwave Structures and Devices**
S. Koziel, J.W. Bandler, Q.S. Cheng

TH4B-05: **Tuning Space Mapping: A Novel Technique for Engineering Design Optimization**
J. Meng, S. Koziel, J.W. Bandler, M.H. Bakr, Q.S. Cheng

TH4B-06: **Robust Training of Microwave Neural Network Models Using Combined Global/Local Optimization Techniques**
H. Ninomiya, S. Wan, H. Kabir, X. Zhang, Q. Zhang

TH4C Novel Passive Components

Chair: I. Bahl • Co-chair: J. Owens

This session deals with novel passive components developed using single and multilayer fabrication technologies. These include new switching structure using, branch-line hybrids, H-plane probe based power divider, compensated coupler, dual-function dielectric resonator, selectivity enhanced resonator and electronic all tunable resonator.

TH4C-01: **A New Switching Structure using Branch-Line Hybrid Couplers for Time Division Duplex System**
K. Kim, D. Ahn

TH4C-02: **A Waveguide-based Power Divider using H-plane Probes Short-circuited with Substrate Metallization Patterns**
M. Abe, Y. Tahara, N. Yoneda, H. Oh-hashi

TH4C-03: **Complex Compensation of Coupled Line Structures in Inhomogeneous Media**
J. Muller, A.F. Jacob

TH4C-04: **Dual Function of a Dielectric Resonator: A High-Q Resonator and a Low-Q Radiator**
L.K. Hady, D. Kajfez, A.A. Kishk

TH4C-05: **The Compound Resonator Approach: Parity Control and Selectivity Enhancement in N-Resonator Planar Systems**
T. Caillet, D. Bajon, S. Wane, R. Plana

TH4C-06: **A High-Q Electronically Tunable Evanescent-Mode Double-Ridged Rectangular Waveguide Resonator**
A.L. Amadjikpè, J. Papapolymerou

TH4D Tunable and Active Filters

Chair: Y. Kotsuka • Co-chair: P. Blondy

Advances in tunable and active filters are being driven by the demands for software defined systems. This session presents a fascinating view of these activities with the papers on wide variety of topics. These includes ultra wide band frequency tuning, switchable/reconfigurable, millimeter-wave, active and super-regenerative ultra-wide-band filters.

TH4D-01: **Multi-scale Tunable Filter Covering a Frequency Range of 6.5:1**
M. Koochakzadeh, A. Abbaspour-Tamijani

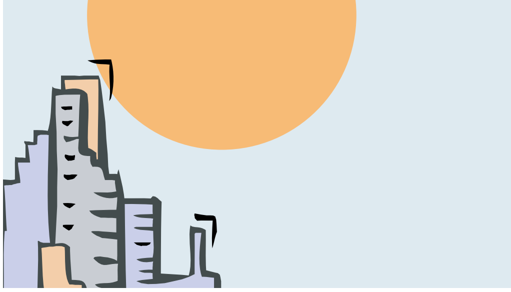
TH4D-02: **Manifold-Coupled Switched Filter Bank Implementing Filters with Embedded Switches**
P.D. Laforge, R.R. Mansour, M. Yu

TH4D-03: **Miniaturized Reconfigurable Filter Using PIN Diode for UWB Applications**
M. Karim, Y. Guo, Z.N. Chen, L.C. Ong

TH4D-04: **Tunable RF Bandpass Filter with Variable Resonator Coupling**
J.C. Estes

TH4D-05: **Novel Tunable Hexaferrite Bandpass Filter Based on Rectangular Waveguide Coupled Shielded Coplanar Transmission Lines**
M. Sterns, D. Schneiderbanger, R. Rehner, S. Martius, L. Schmidt

TH4D-06: **A 3.7 mW Zero dB Fully Integrated Active Bandpass Filter at Ka-band in 0.18 μm CMOS**
M. Chiang, H. Wu, C.C. Tzuang



TH4D-07: **Low Power Complementary-Colpitts Self-Quenched Super-regenerative Ultra-Wideband (UWB) Bandpass Filter in CMOS Technology**
M. Anis, R. Tielert, N. Wehn

TH4E Novel Monolithic Circuit Elements and IC Technology

Chair: Z. Bardai • Co-chair: T. Tokumitsu

This session will cover advances in monolithic circuit elements and designs. The papers will include discussions in the areas of nanoionics, SiGe-transceivers, monolithic millimeter-wave amplifiers, HEMT-HBT technology integration as well as balanced active inductor and an interesting realization of a low temperature variable inductor in porous anodic alumina.

TH4E-01: **A Novel Nanoionics-based Switch for Microwave Applications**
J.A. Nessel, R.Q. Lee, C.H. Mueller, M.N. Kozicki

TH4E-02: **Low Temperature Variable Inductor Using Porous Anodic Alumina**
T.B. Oogarah, M. Daneshmand, R.R. Mansour, S. Chang

TH4E-03: **High Quality-Factor and Inductance of Symmetric Differential-Pair Structure Active Inductor using a Feedback Resistance Design**
K. Hwang, C. Cho, J. Lee, J. Kim

TH4E-04: **Monolithic Millimeter-wave Distributed Amplifiers using AlGaN/GaN HEMTs**
R. Santhakumar, Y. Pei, U.K. Mishra, R.A. York

TH4E-05: **A Mixed HEMT-HBT MMIC Technology using MBE Regrowth**
E.T. Kunkee, S. Consolazio, J. Barner, T. Retelny, G. Dietz, E. Bogus, A. Cavus, J. Chen, J. Uyeda, R. Hsing, P. Chin, A. Ahkiyat, D. Chua, R. Clark, R. Haubenstricker, M. Johnson, T. Nguyen, P. Sahm, E. Zelias, R. Lai

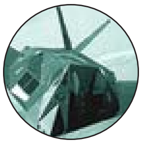
TH4E-06: **ASK and Pi/4-QPSK Dual Mode SiGe-MMIC Transceiver for 5.8 GHz DSRC Terminals having Stabilized Amplifier Chain**
S. Shinjo, K. Tsutsumi, K. Mori, H. Okada, M. Inoue, N. Suematsu

ARFTG 71ST Microwave Measurement Conference

Network Analysis – 50 Years On

Friday, June 20, 2008 • Omni Hotel

8:00 AM–9:40 AM	Technical Session 1
9:40 AM–10:20 AM	Interactive Forum
10:20 AM–12:00 NOON	Technical Session 2
1:30 PM–2:45 PM	Technical Session 3
2:45 PM–3:15 PM	Interactive Forum
3:15 PM–4:40 PM	Technical Session 4



Northrop Grumman Bids for Army Integrated Air and Missile Defense System

Northrop Grumman Corp. submitted its bid for the prime role in the US Army's Integrated Air and Missile Defense Battle Command System (IBCS) competition. Due to be awarded in August 2008, the contract is considered the first step towards an integrated air and missile defense capability for the Army and a joint capability for the nation.

Under IBCS, the winning team will establish a network-centric system-of-systems solution for integrating sensors, shooters and battle management, command, control, communications and intelligence systems for Army air and missile defense. The newly integrated system will allow warfighters to take advantage of expanded sensor and weapon systems combinations via an integrated fire control network.

"Our team has listened closely to the customer's needs and has developed an open architecture approach that connects Army systems with joint systems, allowing the services to operate as one integrated force in the future," said Larry Dodgen, vice president and deputy general manager of Missile Defense Division for Northrop Grumman's Mission Systems sector. "We are leveraging our team's collective expertise in command and control and air and missile defense to deliver a transformational system that will meet tomorrow's needs and give the warfighter the ultimate defensive advantage on the field."

Northrop Grumman is leading a team that includes the Boeing Co., Lockheed Martin Corp., Harris Corp., Shafer Corp., Torch Systems LLC, Numerica Corp., Applied Data Trends, COLSA Corp., Space and Missile Defense Technologies LLC, CohesionForce Inc., Millennium Engineering and Integration Co., RhinoCorps Ltd. Co. and Tobyhanna Army Depot. The program is being managed by the Integrated Air and Missile Defense Program Office, Program Executive Office for Missile and Space in Huntsville, AL.

US Army Deploys Harris Broadband Ethernet Radios

Harris Corp., an international communications and information technology company, has announced the deployment of its RF-7800W high-capacity line-of-sight radio by the 2-25th Stryker Brigade Combat Team (SBCT) of the US Army's 25th Infantry Division. The RF-7800W delivers expanded high-bandwidth secure communications to the battlefield.

The 2-25th SBCT is using Harris RF-7800W radios to provide wireless backbone connections between battalion and brigade command posts and their company outposts and joint security stations. The SBCT has effectively integrated the radios into the Joint Network Transport Capability-Spiral (JNTC-S), a key component of the Army's battlefield communications solution. Secure wide area network (WAN) connectivity through Harris RF-7800W radios enables the maneuver company commander to rapidly synchronize military intelligence systems with brigade, division and national level databases. WAN connectivity also provides a common operational picture and situational awareness of defined areas of responsibility and facilitates operational planning and command and control with higher headquarters.

"Harris radios provide commanders at company outposts and joint security stations with digital high-speed secure connectivity, enabling real-time intelligence and situational awareness," said Lt. Col. Rob Fisher of the 2-25th Stryker Brigade Combat Team. "This helps the commander see and understand his operating environment, the enemy threat and ultimately make informed decisions that will save lives."

The radios are part of Harris Corp.'s expanding line of high-capacity tactical radio systems, which deliver a robust tactical network and enable critical applications such as real-time video transmission, situational awareness traffic and military voice and data exchange. Designed for network-centric operations, the radios securely transfer encrypted Internet Protocol (IP) traffic over distances of greater than 50 km under clear line-of-sight conditions in fixed point-to-point and 20 km in point-to-multipoint configurations. The RF-7800W provides voice and data transmissions with very low latency and supports power-over-Ethernet for limited cabling and easy deployment.

"The RF-7800W expands Harris Corp.'s tactical radio leadership into high data-rate communications systems," said George Helm, vice president and general manager, US Government Products, Harris RF communications. "The RF-7800W provides deployed forces with the high-speed, low-latency data capability needed to exchange voice, video, imagery, intelligence and situational awareness data. This information, delivered in real time, enables improved decision-making and allows commanders to act and respond within the enemy's decision cycle."

Modernized GPS Satellite Begins Operations

A combined US Air Force/Lockheed Martin team has completed a rapid on-orbit deployment of the modernized Global Positioning System Block IIR (GPS IIR-M) satellite launched on March 15 from Cape Canaveral. The spacecraft, which includes new features that enhance operations and navigation signal performance, has been declared operational for military and civilian navigation users worldwide.

Lockheed Martin's operations team assisted the Air Force Space Command's 2nd Space Operations Squadron (2 SOPS) and its Reserve associate unit 19 SOPS based at

Schriever Air Force Base, CO, with the launch and early orbit maneuvers. The record on-orbit deployment and checkout of all spacecraft systems and subsequent payload initialization was completed in just over nine days, allowing 2 SOPS to set the spacecraft healthy for users around the globe.

The satellite declared operational represents the third successful deployment of a GPS IIR-M satellite in less than six months and is one of the final three Block IIR-M satellites planned for launch in 2008 to sustain and improve the GPS constellation. The next GPS mission will feature an IIR-M spacecraft with a demonstration payload that will temporarily transmit the third new civil signal, known as L5. The launch, designated GPS IIR-20M, is scheduled for June 30, from Cape Canaveral.

"The successful launch and operational turnover of this modernized IIR satellite is a profound testament to the close collaboration and partnership between the Lockheed Martin and Air Force team," said Don DeGryse, Lockheed Martin's vice president of Navigation Systems. "We take great pride in providing world class, high performance GPS spacecraft at rapid cycle times and look forward to achieving mission success on the next modernizes spacecraft launch, which will feature a demonstration payload for the new civil signal."

The satellite, designated GPS IIR-19M, is the sixth in a line of eight GPS IIR satellites that Lockheed Martin Navigation Systems, Valley Forge, PA, has modernized for its customer, the Global Positioning Systems Wing, Space and Missile Systems Center, Los Angeles, CA.

Each IIR-M satellite includes a modernized antenna panel that provides increased signal power to receivers on the ground, two new military signals for improved accuracy, enhanced encryption and anti-jamming capabilities for the military, and a second civil signal that will provide users with an open access signal on a different frequency.

The Global Positioning System enables properly equipped users to determine precise time and velocity and worldwide latitude, longitude and altitude to within a few meters. Air Force Space Command's 2nd Space Operations Squadron (2 SOPS) manages and operates the GPS constellation for both civil and military users.

Lockheed Martin is also leading a team which includes ITT and General Dynamics in the competition to build the US Air Force's next-generation Global Positioning System, GPS Block III. The next-generation program will improve position, navigation and timing services for the warfighter and civil users worldwide and provide advanced anti-jam capabilities yielding improved system security, accuracy and reliability. A multi-billion dollar development contract is scheduled to be awarded by the Global Positioning System Wing, Space and Missile Systems Center, Los Angeles Air Force Base, CA, in early 2008. ■

Conformity For ELVA-1 in Russia

ELVA-1 Millimetre Wave Division has received Certificates of Conformity from the Russian Federation's Ministry of Information Technologies and Communications (MITC) for its wireless communications technologies PPC-80/70 and PPC-95/92 digital radio links, providing data transmission up to 1250 Gbps.

As the company continues to expand its presence in broadband markets throughout the world, the Russian certification makes it the first manufacturer to be able to offer certified 71 to 76 GHz, 81 to 86 GHz and 92 to 95 GHz gigabit wireless links to customers in the Russian Federation. This puts the company in a strong position to be a major participant in the large and rapidly developing Russian wireless communications market.

The certification process was detailed and lengthy. First, ELVA-1 had to obtain development and manufacturing permits, and then assist in creating new Russian equipment regulations for these high frequency, high data capacity radio bands. For certification, their equipment was subjected to stringent performance testing.

As a result the company now has all necessary certifications for worldwide acceptance by government technical agencies: American (FCC), European (ECC) and Russian (MITC) for its PPC-1000, PPC-80/70 and PPC95/92 radio links, providing wireless connectivity at 100 Mbps Fast Ethernet, 155 Mbps STM-1 and 1250 Mbps Gigabit Ethernet capacities.

Indra Gains Pleidaes Space Contract

In a contract with the Spanish Ministry of Defence worth €13.7 M, to be concluded in three years, Indra will develop, integrate and implement the ground segment of the Pleidaes Space Programme, a French constellation of high-resolution optical satellites for Earth observation.

The systems to be implemented by Indra will allow the Spanish Army to make wide use of the information supplied by civil and military satellites involved in this space programme promoted by France, of which Spain owns a three percent stake. The first satellite is expected to enter orbit by the end of 2009 and the next one in 2011.

The company will design, develop and start up the necessary systems for satellite imagery collection, the treatment for final products and the programme to request information from the satellites. The system will be located in the airspace systems centre for observation (CESAEROB) at the air force base in Torrejón, Spain.

The satellites will be able to catch images at submetrical level. Once both satellites of the constellation are into operational service, building 3D imagery with a higher performance and enhanced quality will be possible. This will be a qualitative leap for the Spanish Army. Observation of the Earth and cartography will be more efficient, using these images as a means for taking measurements for tactical and intelligence affairs.

Motorola to Create Two Companies

Motorola's Board of Directors has commenced a process to create two independent, publicly-traded companies. The move follows evaluation of the structural and strategic realignment of the company's businesses and represents affirmative steps to position its Mobile Devices and Broadband & Mobility Solutions businesses for success, while creating value for all Motorola shareholders.

Based on current plans, the creation of the two standalone businesses is expected to take the form of a tax-free distribution to Motorola's shareholders, subject to further financial, tax and legal analysis, resulting in shareholders holding shares of two independent and publicly-traded companies.

The Mobile Devices business is an industry leader in multi-mode, multi-band communications products and technologies, while the Broadband & Mobility Solutions business includes Motorola's Enterprise Mobility, Government and Public Safety, and Home and Networks businesses. The company expects that the separation of its businesses, if consummated, would take place in 2009.

TNO and SINTEF Strengthen Collaboration

Research organizations TNO (the Netherlands) and SINTEF (Norway) have signed a Memorandum of Understanding (MoU) to develop and market their joint services in a number of fields of technology. The agreement was signed by Tini Colijn, member of the TNO Board of Management, and Unni M. Steinsmo, president and CEO of SINTEF.

SINTEF, the largest independent research organization in Scandinavia, employs some 2000 professionals, had a turnover of €300 M in 2007, and generates new knowledge and solutions for customers and society, based on research and development in technology, the natural sciences, medicine and the social sciences. The Netherlands Organisation for Applied Scientific Research (TNO) employs some 4300 professionals, had a consolidated turnover of €579 M in 2007, and is a prominent, independent knowledge company whose expertise and research contributes significantly to the competitiveness of businesses and organisations, to the economy and to the quality of life as a whole.

Both parties rank among the largest contract research organizations in Europe, and have a long and successful experience of research collaboration in different fields of technology. By signing this MoU, both parties express their commitment to strengthen and increase their collaboration.

ANSYS to Acquire Ansoft

ANSYS and Ansoft Corp. have signed a definitive agreement whereby ANSYS will acquire Ansoft for a purchase price of approximately $832 M in a mix of cash and ANSYS common stock. Under the terms of the agreement, which was unanimously approved by the Boards of Directors of both companies, Ansoft stockholders will receive $16.25 in cash and 0.431882 shares of ANSYS common stock for each outstanding Ansoft share.

The transaction is subject to customary closing conditions, regulatory approvals and approval by the Ansoft stockholders. Once the transaction has been completed Ansoft stockholders will own approximately 12 percent of the combined company on a pro forma basis, Ansoft will become a wholly-owned subsidiary of ANSYS and its common stock will cease trading on NASDAQ.

ANSYS is a global innovator of simulation software and technologies designed to optimize product development processes. The acquisition of Ansoft is the company's first foray into the broader EDA software industry and is expected to enhance the breadth, functionality, usability and interoperability of the combined ANSYS portfolio of engineering simulation solutions. The combination is expected to increase operational efficiency and lower design and engineering costs for customers, and accelerate development and delivery of new and innovative products to the marketplace.

The complementary combination of both companies' software products and services is expected to give ANSYS one of the most complete, independent engineering simulation software offerings in the industry, reaffirming and strengthening its commitment to open interface and flexible simulation solutions that are primarily driven by customer demand, flexibility and choice. With over 40 direct sales offices and 21 development centres on three continents, the combined company will employ approximately 1700 people. ■

Softening Demand Dampens 2008 Semiconductor Outlook

Where the semiconductor market was characterized by excess capacity and high demand, 2008 will be characterized by better capacity balance, but softening demand, reports In-Stat. The net result is forecasted revenue growth in 2008 of only 2.4 percent, the high-tech market research firm says. The computer segment, whose share has been trending downward since 2000, is expected to remain the largest segment by a wide margin, although, by 2012, its share is forecast to be well below the 50 percent + levels of the 1990s.

"Declining MPU prices have joined DRAM price gyrations as a significant factor in computer segment annual growth," says Jim McGregor, In-Stat research director and principal analyst.

Recent research by In-Stat found the following:

- Worldwide semiconductor revenue is expected to grow to $261.9 B in 2008.
- The consumer segment will lead 2008 growth at 5.9 percent.
- Semiconductor revenue growth is forecast to be 7.4 percent in 2009, followed by 9.7 and 11.6 percent in 2010 and 2011, respectively.

The research, "Global Semiconductor End-use Forecast – Market Diversity, It's a Good Thing" and "Global Semiconductor Product Market Forecast – If It's Not One Thing It's Another," cover the worldwide market for semiconductors. The complementary reports can be purchased separately or as part of a discounted research package.

Nearly One Billion Bluetooth-enabled Devices to Ship in Asia in 2013

While Bluetooth has been in the market for almost a decade, it has not proliferated widely in Asia. In terms of consumer awareness, this region still lags behind others. However, the picture is changing, especially when it comes to cellular handsets, and a new study from ABI Research indicates that Bluetooth-enabled equipment shipments in Asia will reach 982 million units in 2013, representing a compound annual growth of 30 percent over 2006 shipments.

"One of the biggest barriers for consumers is cost," says senior analyst Andy Bae. "Consumers in Asia believe that the Bluetooth headset is comparatively expensive; they also seem to underestimate its voice quality." Bluetooth has achieved its greatest penetration to date in mobile handsets, as mobile operators have demanded continuous support from manufacturers. In South Korea, the penetration rate in mobile phones reached 51 percent in 2007. Bae adds, "Streaming music services over mobile networks, such as Japan's Chaku Uta, will be key drivers of Bluetooth inclusion in cellular handsets."

The positive uptake in the cellular sector also produces a ripple effect for other devices. With increasing consumer awareness, notebook manufacturers now consider Bluetooth to be an ideal medium for exchanging files and data with peripherals and devices such as printers and digital cameras. Bluetooth will still face challenges from competing short-range wireless technologies. In Asia, there are home-grown technologies to deliver music, voice and video within a small radius. These include Binary CDMA, Wireless USB and Giga-Fi, which are all discussed in the ABI Research study, in order to compare their market position and technical features with Bluetooth. "These technologies may have superior transmission capabilities," notes Bae. "But there is no other technology as well suited as Bluetooth for the transmission of audio services—nor does any other technology maintain the same price points or the same well-established market position." The new report, "Bluetooth: Opportunities in Asia," offers a comprehensive assessment of the current and future market environment for Bluetooth-enabled devices in Asia. It examines personal area network (PAN) environment applications, discusses competing technologies developed in Asia, profiles market players and provides forecasts through 2013.

Networking Connections Go from Nice-to-have to Necessary in Consumer Electronics

According to ABI Research, in coming years home network connections will no longer be an optional feature for many consumer electronic products, as digital content, social networking and IP services delivered through embedded network connections will be demanded by consumers in the devices they buy. The leading device categories for embedded networking in consumer electronics will shift from the early market leaders—game consoles—to TVs and DVD players. ABI Research forecasts the number for networked TV shipments alone to grow to 60 million total units shipped by 2012, from just 3.6 million in 2008.

"While many TV manufacturers have been evaluating the integration of networking features into devices for some time, only recently have manufacturers such as LG, Sony and HP begun to ship products en masse with embedded networking," says research director Mike Wolf. "While Japan has had networked TVs for some time, other regions are beginning to receive such merchandise too, as TV manufacturers begin to see the value of future-proofing their products with IP connections." While portable devices such as portable media players and game consoles will have mostly wireless networking connections such as Wi-Fi, fixed devices such as TVs, set-top boxes and other device categories will have a mix of both Wi-Fi and Ethernet connections. Overall, Wi-Fi media connections will lead, however, with total Wi-Fi enabled consumer electronics reaching 329 million shipments by 2012. "Networking connections have gone from being 'nice-to-have' to 'necessary' for some categories of devices such as portable media players and gaming consoles," concludes Wolf. "We expect that as more devices get tied to content services, other categories will follow the same route and we are already beginning to see this today." ABI Research's recent study, "Home Networking and Digital Home Network Market Analysis," examines all segments of the home networking and networked entertainment market.

Space Systems/Loral Satellite Successfully Launched

Space Systems/Loral (SS/L), a subsidiary of Loral Space and Communications and the world's leading provider of high-power commercial satellites, announced that the satellite that it built for ICO Global Communications (Holdings) Ltd., was successfully launched aboard an Atlas V rocket from Cape Canaveral, FL. The satellite is the first to use Ground Based Beam Forming (GBBF) technology and is the largest commercial satellite ever launched. It successfully deployed its solar arrays several hours after separation and will begin firing its thrusters in order to maneuver into geosynchronous orbit.

ICO G1 will be used to provide fully interactive mobile video, navigation and emergency assistance service, known as ICO mim™ (mobile interactive media), throughout the US including Alaska and Hawaii, Puerto Rico and the US Virgin Islands.

"We are very excited to see the successful launch of ICO G1," said John Celli, president and chief operating officer of Space Systems/Loral. "Space Systems/Loral has a history of working with companies on the cutting edge of new technologies. I believe that this launch marks the beginning of a new era of unimpeded mobility."

ICO G1 is the biggest commercial launched to date, measuring more than 27 feet tall and weighing 15,000 pounds at launch. Deployed, its solar array span more than 100 feet across and it has a 12 meter unfurlable reflector, which will open up like an umbrella when the satellite reaches its final orbit.

Space Systems/Loral is now maneuvering the spacecraft into its operational slot by managing thruster firing from its Mission Control Center in Palo Alto, CA. The spacecraft has a planned mission life of 15 years and is designed based on SS/L's 1300 space-proven platform, which provides the flexibility to support a broad range of applications and technology advances. ■

INDUSTRY NEWS

■ **ANSYS Inc.**, a global innovator of simulation software and technologies designed to optimize product development processes, and **Ansoft Corp.**, a global provider of Electronic Design Automation (EDA) software, announced that they signed a definitive agreement whereby ANSYS will acquire Ansoft for a purchase price of approximately $832 M in a mix of cash and ANSYS common stock. The strategic, complementary business combination of ANSYS and Ansoft will create the leading provider of 'best-in-class' simulation capabilities, with combined trailing 12-month revenues of $485 M. When completed, ANSYS currently anticipates that the transaction will be modestly accretive to non-GAAP earnings per share in its first full year of combined operations.

■ **KOR Electronics** announced it has purchased the Government Solutions subsidiary, **Paragon Dynamics Inc.** (PDI), from **Zanett Inc.** for cash. Pagemill Partners served as exclusive financial advisor to KOR Electronics. KOR Electronics is an aerospace defense technology company providing domestic and international customers with advanced military electronics equipment and system solutions. PDI has been a wholly owned subsidiary of Zanett Government Solutions. Based in Aurora, CO, with offices in California and Washington, DC, PDI provides systems, software and mission engineering solutions to a variety of Intelligence Agencies, Department of Defense (DoD) and aerospace clients.

■ **Cadence Design Systems Inc.**, a leader in global electronic design innovation, announced that it has acquired **Chip Estimate Corp.**, a leader in delivering IC planning and enterprise-level IP reuse management solutions. Founded in 2003, Chip Estimate products enable electronics design teams to predict the die size, yield, power consumption, performance and cost of chips based on almost any design architecture, IP and silicon process node options. Terms of the agreement were not disclosed.

■ **Park Electrochemical Corp.** announced that its new wholly owned subsidiary, **Park Aerospace Structures Corp.**, has purchased substantially all the assets and business of **Nova Composites Inc.** located in Lynnwood, WA. Nova Composites designs and manufactures aircraft composite structures and the tooling for such structures. These composite structures are manufactured with carbon, fiberglass and other reinforcements impregnated with formulated resins. Park paid approximately $4.5 M for the Nova Composites business at the closing of the acquisition, and will, depending on the achievement of certain "earn-out" objectives, pay up to an additional $5.5 M for the business over the next five years.

■ **Namics Corp.** and **Diemat Inc.** announced the completion of a merger agreement to combine each company's services and products to better serve the global electronics marketplace. The agreement provides new opportunities for customers to benefit from expanded capabilities, complimentary technologies and expanded product lines. Diemat will maintain its brand identity and will continue to operate with the involvement and technical guidance of its founder Ray Dietz who has over 40 years of experience in the electronic materials industry. Namics will support the technology, manufacturing and marketing efforts as Diemat continues to grow.

■ **Keithley Instruments Inc.**, a leader in solutions for emerging measurement needs, announced a partnership with **Stratosphere Solutions Inc.**, Sunnyvale, CA, a provider of innovative parametric yield improvement solutions for integrated circuit manufacturers. Keithley's partnership with Stratosphere Solutions will address advanced process development and monitoring using an array test element group (TEG) technology.

■ **Nokia Siemens Networks** is teaming up with **Symmetricom** to offer operators a solution to the challenge of keeping network bandwidth capacity up to pace with the ever-increasing demand from data applications. The two companies are to introduce the industry's first open standard Timing over Packet solution to synchronize base stations over the packet-based backhaul networks vital to sustaining profitability.

■ **Arcadian Networks**, a wireless communications carrier serving energy companies with dispersed assets (electric, gas and water utilities, and oil and gas companies), announced that it has entered into a business partnership with **FreeWave Technologies** in order to enhance and diversify its existing wireless communications platform.

■ **Endicott Interconnect Technologies Inc.** (EI) announced that it has entered into a sales and manufacturing agreement with **Unimicron Technology Corp.**, Taiwan, to produce CoreEZ™ organic substrates at one of their facilities. Under terms of the agreement, EI, a design manufacturer, maintains control of the design and technical support worldwide for the CoreEZ product line. Unimicron will be the high volume manufacturer of CoreEZ products per EI's specifications and requirements. Sales of CoreEZ products will be jointly handled by the two companies.

■ **Shared Spectrum Co.** (SSC) has entered into an agreement with **Harris Corp.** to conduct a joint feasibility study of SSC's dynamic spectrum access (DSA) technology that will lead to the near-term integration of SSC's cognitive radio software in field-ready Harris Falcon® III military radios. Acting as prime, SSC will work with Harris to integrate and evaluate software developed by SSC to determine the operating requirements for deploying DSA-enabled radios in frequency-hostile environments.

■ **Merrimac Industries Inc.** announced that it has entered into a Memorandum of Understanding (MOU) with **Nitronex Corp.** to develop new highly integrated power amplifiers using Merrimac's proprietary Multi-Mix® multilayer circuit technology and high power gallium nitride (GaN) transistor technology from Nitronex. GaN device technology is highly sought as a higher-power replacement for GaAs and LDMOS device technology in communications equipment. The discrete transistors are ideal for high power transmitter amplifiers in third-generation (3G) and fourth-generation (4G) wireless communications systems as well as emerging broadband WiMAX base stations. Nitronex has developed and qualified a GaN on Silicon process to service the needs of both commercial users in the wireless infrastructure industry and military users involved in communications, electronic warfare and radar systems.

■ **Park Electrochemical Corp.** announced that it has changed the name of its business unit and subsidiary located in Waterbury, CT from **Nelcote Inc.** to **Park Advanced Composite Materials Inc.** This business unit will continue to manufacture advanced composite materials (the Nelcote® product line) principally for the aerospace markets. The company's recently opened advanced composite materials "Pioneer Plant" located on Pioneer Road in Jurong, Singapore, and the company's new advanced composite materials development and manufacturing facility currently under construction at the Newton City-County Airport at Newton, KS, will also manufacture advanced composite materials principally for the aerospace markets.

■ **Skyworks Solutions Inc.**, an innovator of high performance analog and mixed signal semiconductors enabling mobile connectivity, announced that it has received LG Electronics' 2007 Best Supplier Award. The award is based on technology, quality, product reliability and on-time delivery. LG leverages Skyworks' front-end solutions for a variety of mobile handsets sold worldwide spanning all key air interfaces including CDMA, GSM and, increasingly, EDGE and WCDMA for 3G multimode applications.

■ **New Era Electronics Ltd.** (NEE), a leader in volume production of microwave printed circuit boards, was honored by *Forbes Asia* as one of the top 200 publicly traded companies in Asia, with sales of less than one billion USD, for consistent sales and profit growth in the previous 12-month period. *Forbes Asia* annually selects top performing companies from all publicly traded companies in Asia with sales less than one billion US dollars. Those companies that exhibit consistent track records of sustained growth and profitability, as well as knowledgeable management and sound business models are chosen each year for inclusion in the list.

■ **MtronPTI**, a producer of frequency control and filter products for military and aerospace applications, announced that it has passed the Defense Supply Center Columbus (DSCC) certification process for MIL-PRF-55310. MtronPTI has a wide array of oscillator products designed for high reliability and harsh duty applications, and this latest capability further enhances the suite of products and services that MtronPTI provides to military, aerospace and avionic customers.

■ **Flex Interconnect Technologies** (FIT), a leader in design, manufacture and assembly of flexible printed circuits, announced that its Quality Management System is certified to AS9100 revision B standards. The AS9100 revision B is a standard developed by International Aerospace Quality Group (IAQC). The certification of Flex Interconnect Technologies was granted after an audit by Intertek Systems, one of the most reputed Registrars of Aerospace standards. Flex Interconnect Technologies passed the audit with a perfect 100 percent score.

CONTRACTS

■ **Comtech Telecommunications Corp.** announced that its Tempe, Arizona-based subsidiary, **Comtech EF Data Corp.**, received a $1.2 M order from a United States government agency for satellite communications equipment. The equipment will support the build out of a new satellite communications network.

■ **Herley Industries Inc.** announced that its Herley New England division in Woburn, MA, has received an additional award of approximately $1.2 M from a major US defense contractor for the manufacture of complex Integrated Microwave Assemblies (IMA) for an electronic attack aircraft for the US Navy. Herley announced a $9.8 M contract in February for this customer. The additional award brings the total value of the contract to $11 M, the largest award ever received by the Woburn division.

■ **Elcom Technologies Inc.** announced the receipt of a new contract for $1 M from a major United States Aerospace-Defense military contractor, for a high performance VME-based synthesized RF source and synthesized broadband downconverter. Elcom was initially selected due to its ability to integrate synthesizer and tuner in a VME package. This recurring contract will require support through 2009.

■ **RF Industries Ltd.** announced that its Bioconnect division has received new purchase orders for $423,000, consisting of a $247,000 contract from a major customer for a complex 24-lead connector and a separate $176,000 contract from a new customer for a single lead product utilizing a female DIN connector.

■ **Tektronix Inc.**, a worldwide provider of test, measurement and monitoring instrumentation, announced that Murray Associates, registered as Spybusters LLC, has selected a Tektronix Real-time Spectrum Analyzer (RTSA) with DPX™ live RF display technology to help the security consultancy identify wireless eavesdropping devices that may be located in clients' facilities including boardrooms and security trading floors. The RTSA instrument enables the firm to quickly and efficiently spot sophisticated listening devices, even in challenging environments where there are many competing signals.

■ **Agilent Technologies Inc.** announced that **Finisar**, a global leader in fiber optic solutions for high speed networks, has selected Agilent's Advanced Design System (ADS) software to support the development of its optics products designed for the telecom market. Agilent's ADS software platform includes the Signal Integrity Design Suite and the Ptolemy system simulator.

FINANCIAL NEWS

■ **Tyco Electronics Ltd.** announced that its Board of Directors has authorized the company to pursue the divestiture of its Radio Frequency Components and Subsystem business. This business represented approximately $500 M of the Wireless Systems segment's total sales of $887 M in fiscal 2007. The remaining portion of the Wireless Systems segment—Public Safety/Land Mobile Radio Systems and Products—is not included in the planned divestiture. The divestiture is part of Tyco Electronics' previously-announced plan to divest or exit non-strategic businesses.

■ **Superconductor Technologies Inc.** reports sales of $4.9 M for the fourth quarter ended December 31, 2007, compared to $5.3 M for the same period in 2006. Net loss for the quarter was $2.2 M ($0.17 per diluted share), compared to $1.6 M ($0.13 per diluted share) for the fourth quarter of last year.

■ **RF Industries Ltd.** reports sales of $3.8 M for the first quarter ended January 31, 2008, compared to $3.2 M for the same period in 2007. Net income for the quarter was $182,000 ($0.05 per diluted share), compared to $33,000 ($0.01 per diluted share) for the first quarter of last year.

■ **Provigent**, a leading provider of System-on-a-Chip (SoC) solutions for the broadband wireless transmission market, announced that it has increased fourth round funding to $20 M. Stata Venture Partners investment in the fourth round increased from $1 M to $4 M. In addition to Stata Venture Partners, Provigent's technology investors include: Sequoia Capital, Pitango Venture Capital, Globespan Capital Partners, Ascend Technology Ventures, Magma Venture Partners, Delta Ventures and Dr. Andrew Viterbi, co-founder of QUALCOMM.

NEW MARKET ENTRY

■ **CADEKA Microcircuits**, the industry's newest analog supplier, introduces 10 new high performance amplifiers. Although the company name is new, the unique strength of CADEKA's experienced analog designers and engineers began in the late 1980s. CADEKA's engineering staff began working together at Comlinear Corp., former supplier of industry leading high performance amplifier products. This is where the team discovered their passion for amplifiers and analog technology. Since those early years at Comlinear, the team's experience grew through three separate company transitions, including assignments at National Semiconductor, Kota Microcircuits, and most recently, Fairchild Semiconductor.

PERSONNEL

■ Vectron International announced the strategic realignment of its business to sharpen the focus on its Industrial, Military and Space (IMS) Business Unit. As part of this increased focus, Vectron appointed **Gregory Smolka** to serve in the new role of vice president of the IMS business unit. In this role, Smolka will be responsible for managing the IMS Business Unit and growing Vectron's strong market positions in test and measurement, medical imaging, process control and other industrial applications while reinforcing the company's leadership position in defense and space markets. Prior to joining Vectron, Smolka served as the vice president of sales and marketing at Axsun Technologies.

▲ Cliff Yoshida

■ ClearComm Technologies LLC, a designer and manufacturer of RF and microwave filter products for the military, commercial and wireless markets, announced the appointment of **Cliff Yoshida** to the position of business development director. Yoshida brings more than 30 years of management, sales, marketing, business development and engineering experience in the RF/microwave industry to the ClearComm sales team. Prior to joining ClearComm, he held various management positions within the industry, including domestic strategic account manager, international sales manager and engineering manager.

■ Continental Microwave, a division of Cobham Defense Electronic Systems, is expanding its antenna design capabilities with the addition of two new engineers. **Wendell Brokaw** will be leading the antenna engineering and development team as director of antenna engineering. Brokaw was employed by Harris Corp. as principal investigator/analyst designing several innovative antenna systems and more recently at Sciperio Inc. as a senior research scientist working on electronic steerable arrays. **Brian St. Hilaire** has also joined the antenna team as senior antenna engineer. His work experience comes from M/A-COM, Varian and as an educator at the University of New Hampshire.

▲ Bob Pemberton

■ KOR Electronics announced that **Bob Pemberton** has joined the company as director of sales. He will be based in the company's Texas office and reports directly to Rich Beeber, vice president of advanced development. In his role as sales director, Pemberton oversees KOR Electronics' sales activities with major prime contractors and European customers. Prior to joining KOR Electronics, Pemberton was the director of microwave sales for Crane Aerospace & Electronics. He comes to KOR Electronics with over 25 years of experience in the microwave industry.

▲ Craig Taylor

■ NDK announced that **Craig Taylor** has joined the company as GM of business and application development. Taylor will bring over 20 years of successful technical and marketing experience to aid NDK's customers. He will be working directly with OEMs on their next generation products. By nature, quartz-based frequency control components carry one of the longest lead times to develop.

▲ *Daniel Casacci*

■ Multisorb Technologies announced the appointment of **Daniel Casacci** to the position of business development leader for the electronics market. In this role, Casacci will oversee market development for the company's portfolio of technologies that manage moisture, oxygen, hydrocarbons and other volatiles to protect sensitive electronic products against degradation, and improve product reliability and performance. Casacci brings 19 years of experience in the electronics market to the company.

▲ *Bud Osthaus*

■ AR RF/Microwave Instrumentation announced the appointment of **Bud Osthaus** as microwave design specialist. Osthaus brings 30 years of microelectronics experience to the company. He began his career as a designer with Microcom Corp. and later worked in process engineering for a variety of technology companies. Prior to joining AR, he was with Merrimac Industries, where he established a full-service microelectronic prototype facility. In AR's quest to create state of the art, highly reliable RF and millimeter-wave microelectronic products, Osthaus will be developing assembly processes and equipment. His experience in military and high volume commercial electronics manufacturing will play a key role in keeping AR at the forefront of technology in a global market.

REP APPOINTMENTS

■ **Anritsu Co.** and **RFMW Ltd.** announced an Americas distribution agreement. Under terms of the agreement, RFMW will market and sell Anritsu's high performance, high frequency coaxial connectors and components used in communications and test instrument applications.

■ **Microsorb Technologies**, a manufacturer of microwave absorbers and dielectric materials, has appointed **Sertech** to cover greater Philadelphia, Delaware and southern New Jersey. **E.G. Holmes & Associates Inc.** will represent Florida and **Data Marketing Associates** will handle Texas, Oklahoma and Louisiana.

WEB SITE

■ **Strand Marketing** has launched a new web site at www.strandmarketing.com. Based in Newburyport, MA, Strand provides integrated marketing communications for regional and international high-tech companies, ranging from RF/microwave to biotech. The new site offers the unique opportunity to browse the agency's extensive creative portfolio by toggling between a client- or a project-based tour. Choosing the client-based option, visitors can read and learn about the agency's current client-base, including specific company challenges and the corresponding, custom-fit marketing solutions.

THE BATTLE BETWEEN HF AND UHF RFID

It is undeniable that RFID tags reign over the bar coding technologies and other optically read technologies due to its contactless nature, larger memory capacity and ability to allow energy to penetrate certain goods that are hidden or covered with substances such as snow, fog, ice, dirt, paint or crusted grime. In this article, the frequencies used in different RFID systems are compared. The frequencies can be divided into low frequency (LF), high frequency (HF), ultra high frequency (UHF) and microwave. The two most popular frequencies used in today's applications are HF and UHF. HF refers to the frequency 13.56 MHz, while UHF refers to the frequency range from 860 to 956 MHz in the radio spectrum. Which is the better one?

In the 21st century, RFID woke up from its hibernating stage and started making a great impact in the many applications of our lives. The ability of RFID to receive, modify and pass on information, and store large memories regarding any object embedded with a transponder brings a whole new dimension to various applications such as security systems, vehicles, personnel access control, asset tracking (baggage, ship container and animal tracking), production control, sports timing and document authentication. There has been much discussion about the potential of RFID as an important identification tool, especially in the retail market.

In the pharmaceutical industries, losses arising from the counterfeiting of drugs and overstocked or outdated products makes an RFID system a more sought after automatic identification system. Several surveys were done by the World Health Organisation (WHO), Industrial Surveys and USNPC:[1]

- 30 percent of pharmaceuticals in the developing world and 6 to 10 percent in the developed world are counterfeit (WHO)
- Up to 25 percent of a physician's time is spent filling in forms, computer entry and data searching (Industrial Surveys)
- Non-compliance with medication in the US causes 125,000 deaths yearly and 11 percent of hospital admissions (USNPC)
- Preventable medical errors in the US cause between 44,000 and 98,000 people to die yearly (USNPC)

Recently, much of the focus has been on UHF passive tags compared to the more established HF (13.56 MHz) and LF (125 to 134.2 kHz) technologies. The 860 to 956 MHz range of UHF has attracted most of the R&D investments. All of these are probably due to the Wal-Mart RFID mandate to their suppliers to follow suit using the UHF band for case-level and pallet-level supply-chain tracking. Wal-Mart, together with Gillette and Proctor & Gamble, believe that UHF is more suitable for supply chain management at the pallet and to some degree at the case level be-

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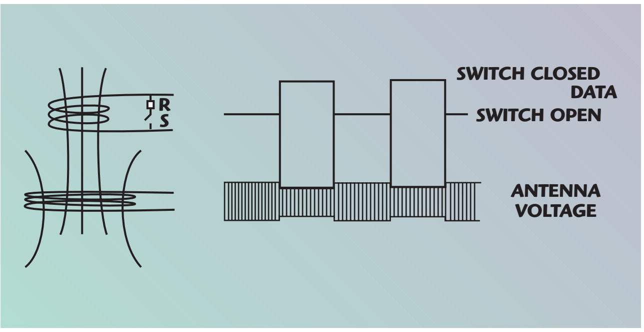
cause of the longer read range. In support of this mandate, the industry introduced in December 2004 its first global UHF RFID tag standard, known as EPC (Electronic Product Code) Gen 2 (Generation Two) ratified by EPCGlobal. Not until last year did manufacturers start developing tag and reader technology incorporating the new standard. In addition, EPCGlobal is also turning its attention to the continuing development of existing EPC standards for HF (13.56 MHz) technology. They are now focused on creating an EPCGlobal Gen 2 standard for HF bands for healthcare applications.[2] So far, established global standards developed by ISO/IEC for HF in item-level tracking includes the ISO/IEC 18000-3 and ISO/IEC 15693.[3] It is the author's opinion that with all the events that are ongoing now, HF, by far, is a better option when it comes to item-level tracking and other tagging usage.

COMPARISON OF HF AND UHF

Communication Systems

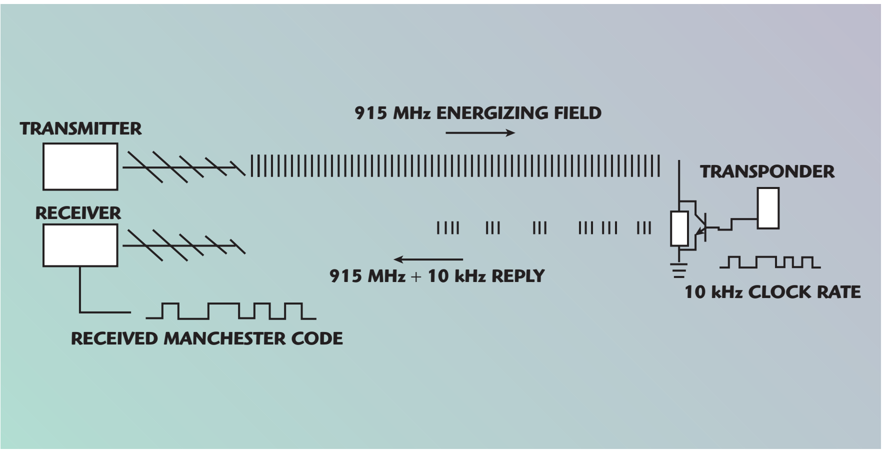
HF and UHF can be significantly distinguished when wireless communication methods between the reader and the tag are examined. HF systems use the magnetic field whereas UHF systems use the electric field to transmit power and data.

In HF systems, the magnetic field powers up an RFID tag through inductive coupling of two resonant circuits tuned at frequencies as close as possible. A magnetic field is created as a result of electrical current flow in a closed loop of the reader's antenna, often made of electrically conductive material such as copper. The reader emits the magnetic field and when a transponder passes by, the magnetic field induces an electric current flowing on the antenna of an RFID tag. The induced electric current is then used to power the RFID tag's circuitry (passive tags) and begins to transmit its on-chip stored data. The signal generated by the reader usually provides timing information as well as enough energy to power the tag. The tag sends the data back to the reader by modulating the amplitude, frequency or phase, in accordance with the data carrying bit stream. ***Figure 1*** shows amplitude shift keying (ASK) modulation. Data can also be modulated onto a sub-carrier. Higher frequency sub-carriers are generally used for higher data rates.



▲ *Fig. 1 Load modulation.[4]*

In UHF systems, the electric field powers up the tag passing within the energy field. The power of the electric field is used for the RFID tag's circuitry in a similar way to HF tags, but through capacitive coupling instead of inductive coupling. UHF systems use backscatter modulation to communicate the data from the tag to the reader (see ***Figure 2***). The term backscatter refers to the portion of the transmitted signal that is reflected back 180 degrees opposite the direction of the incident signal, as opposed to random scattering that is lost in space.[5] In this method, the tag communicates with the reader by modulating the received signal and radiating it back to the reader. This scheme is fundamentally different than the inductive coupling method used in HF systems.



▲ *Fig. 2 Backscatter modulation.[4]*

Performance Degradations from Metals and Liquids

HF has longer wavelengths, which means they are less susceptible to absorption by liquids and are able to penetrate into them. UHF's shorter wavelengths are more susceptible to absorption by liquids. Therefore, in practical applications, HF tags are better suited for liquid-bearing products. UHF tags can be made to work, but they have to compromise with their read range, which will result in the read range drastically reduced.

Metallic environments, however, can affect all RFID frequencies. Radio frequency signals can not penetrate through metal. When metals are close to the reader's or the tag's antenna, the characteristics of the system are changed. Metal changes the inductance of the antenna on HF and UHF tags by basically re-tuning its resonant frequency, reducing the overall read range. The energy can also be reflected by the metal, disabling full penetration into it. However, HF tags are less susceptible to metal degradation, compared to UHF tags.

Fishnet vs. Swiss Cheese Analogy

The intensity of the electric field in UHF systems is not as well defined as the magnetic field for a specific read zone because they are affected by areas known as field nulls. This happens when item-level tags are in close physical proximity to one another or having materials with high permittivity, such as liquids, or high reflectivity, such as metals.

An analogy[3] illustrates the difference between HF and UHF tags for item and pallet identification. For example, imagine the HF signal resonating as a fine fishnet wrapping around the tagged packages, and the UHF signal as a piece of Swiss cheese wrapping around the same tagged packages. The Swiss cheese, representing the field null phenomenon, requires the use of alternative techniques to compensate for these holes. The HF "fishnet" interrogating signal captures all of the tags, including those on items packed closer to the center of the package, while the UHF "Swiss cheese" misses many tags that may be positioned in the inner portion of a package because they fell into these field nulls.

The field nulls require the use of a more complex signaling scheme, involving a common technique known as frequency hopping. Due to frequency hopping's longer read range, UHF technology may be more suitable for reading case and pallet tags from portal or conveyor antennas. HF technology's shorter read range allows for well-defined read zones that can facilitate small shelf and item-level applications.

Read Range

Although it was mentioned earlier that HF's magnetic read zone is well defined, the magnetic field in HF systems has a relative strength that falls off quickly as a function of distance from the antenna, resulting in a short read range of typically up to 1 m for passive tags.[6] In comparison, the electric field used in UHF systems has a relative strength that extends much further, enabling a read range of up to 10 m for passive tags.[6] UHF may win over HF in this context, but it has to contend with its own limitations and challenges. For example, the read range for UHF is only achievable up to 33 cm in Europe due to current power restrictions in those countries.[6] Moreover, a longer read distance becomes a disadvantage in applications such as banking and access control.

Anti-collision and Simultaneous Reading of Tags

The current trend is toward passive tags having a built-in anti-collision feature that enables multiple simultaneous reading of tags with greater than 90-percent accuracy at a rate of up to 1000 tags/sec.[3] In pharmaceutical applications, anti-collision allows for all 100 individually tagged bottles in a package to be identified and read instantaneously without opening the package or using a handheld reader to scan each item. The anti-collision (simultaneous reads) feature implementation in UHF is achieved using a protocol based on bit broadcasting as opposed to HF protocol that operates based on the time slot concept. This allows for a higher number of tags to be read simultaneously in the UHF range, typically 200 tags as opposed to 50 tags with HF systems. However, the retuning phenomenon and the nature of RFID frequency physics, locating a tagged item within a small read area—containing multiple tagged items—can be easier with HF due to field patterns and relative tag signals.

Memory and Data Storage

Tags come in many memory sizes and capacities depending on the application and manufacturer. Several HF tags offer storage capabilities from 96 bits up to 8K bytes of memory.[3] UHF products have lower tag memory sizes. Most currently manufactured UHF tags do not have user memory and only carry a 96 bit serial number.

Tag Size and Form Factor

In comparison to the passive tag sizes of the two frequencies, UHF offers a smaller tag compared to HF.[3] In the pharmaceutical application perspective, it is ideal to use smaller tags for bottles, vials and tubes. However, blister-packs and multiple unit-dose packages may need larger, self-stick, flexible tags that can be laminated to paperboard, paper, plastic or other materials. Where a foil seal is required, a small stand-off that creates an air gap may be used to insulate the tag from the disruptive properties of metal. HF tags have shown satisfactory effectiveness and are well suited due to their form-factor adaptability. The form-factor adaptability has the ability to withstand liquid, pressure and temperature changes. Passive UHF tag implementations are still in their infancy, so it is unclear exactly what issues are yet to be encountered.

Global Standards and Power Requirements

Government bodies in various regions of the world regulate the bands of the radio-frequency spectrum. The HF (13.56 MHz) occupies an international, scientific and medical (ISM) band, which is available worldwide. In December 2002, Japan's approval to harmonize the HF frequency led to the synchronization of power levels across the world.[7] Unfortunately, the bandwidth of the UHF frequency (860 to 960 MHz) varies from region to region.[8] The US has specified 902 to 928 MHz, while the European Union has specific 865 to 868 MHz for RFID applications. In Asia, Japan has specified 952 to 954 MHz, while in Malaysia it is 912 to 923 MHz. Only just recently, China has approved the bandwidth in the 840.25 to 844.75 MHz and 920.25 to 924.75 MHz ranges.[9] This variation in frequency allocation requires that manufacturers produce country- or region-specific tags and readers, causing a potential disconnect for companies attempting to create a globally flawless international supply chain. To solve this, the standards organizations, such as EPCGlobal, started working with governments to harmonize UHF frequencies. EPCGlobal's new Gen 2 standard allows for frequencies and power levels that comply with regional regulations while maintaining global readability. However, China has yet to follow any standards on UHF RFID and is reluctant to recognize the EPCGlobal standard compared to the well known ISO standards. In fact, the World Trade Organization (WTO) does not recognize EPCGlobal as the official RFID standards body.[10] This is a big issue to UHF supply chain users because 70 percent of Wal-Mart products are manufactured in China.[11]

Europe's ETSI EN 300-220 regulations impose some limitations to the usage of the UHF band. Although the power restriction of 500 mW ERP limitation has since been improved to 2 W ERP in the 869 MHz band, even with this new power level, the continued restriction on signal modulation between the tag and the reader leads to inequality in performance between US and European systems.

Another limitation is the bandwidth restriction. This bandwidth restriction results in the inability to frequency-hop the reader and also imposes a limitation on the tag anti-collision arbitration speed. The power restriction impairs the achievable reading distance while the lack of frequency hopping causes tag visibility and reading robustness to be less than optimum.[7] Currently, European transmission channels are restricted to a maximum of 200 kHz in bandwidth, versus 500 kHz in North America.[9] These factors show that HF could be a global solution, compared to UHF.

Cost

UHF tags cost less compared to HF due to lower memory capacity and simpler manufacturing process. However, the cost of UHF readers is expensive. In 2005, the price of these readers ranged from $2500 to $3000.[12] More recently reader prices have fallen; however, it is still expensive for companies planning to implement RFID on a large scale. The main reason for the cost is the limited availability of customized components and that there is little IC integration due to the low volume of production. However, ABI Research has predicted that prices of UHF readers are expected to continue to decrease.

As for the HF tags, the cost is relatively low. It is because the antenna for a HF tag is small enough that it can be produced by printing it onto a substrate, using conductive ink and then affixing the chip. The cost for HF tags or what are also known as INLAYS is approximately $0.70 to $0.80 CDN.[5] As demand increases, prices should drop significantly.

Further research by companies such as PolyIC[13] is aimed at reducing the cost of the HF tag using printed circuits. They have already succeeded in producing a functioning polymer-based 8-bit RFID tag which operates at 13.56 MHz. Other companies working on printed electronics for RFID include ORFID Corp.[14]

ADVANTAGE OF HF OVER UHF

In terms of the maturity of technology, established standards and market presence, HF is far ahead of UHF. HF has been commercially available since 1995. The frequency has long been supported by two standards of the International Organization for Standardization, ISO 14443 and 15693, which define contactless smart cards. On the other hand, UHF only achieved ISO's imprimatur in an amendment to the 180000-6 item-management standard approved in July 2006.[15] Since the introduction of the global ISO/IEC 15693 standard in 1999, manufacturers have been producing hundreds of millions of HF tags and there are efforts of data protocol sharing and the necessary infrastructure to apply RFID in various sectors and applications. More than 100 companies supplying chips, inlays, labels, readers, antennas, printers and software currently support the ISO/IEC 15693 standard.[7] HF technology has been commercially used in markets such as library systems, petrol kiosk systems, authentication of sporting event tickets, access control systems, textile rental and industrial laundry, in addition to research areas, such as locating tissue samples and tracking pathology samples[7] with an extremely high success rate.

The RFID chip also found great importance in document authentication such as the e-passport. When queried, the embedded chip will deliver the information of the bearer. Since HF does not work over larger distances, it is safer to utilise it in e-passports as to avoid unauthorised reading from afar. When the readers are placed near the tag, they would be fairly difficult to hide thus making it almost impossible to envision a terrorist's ability to track people's details as they emerge from customs.

In food and pharmaceutical industries, UHF's longer read range advantage may seem to be a better choice for this application. In fact, UHF passive tags are being used as a standard for tracing food products. However, these tags may face a problem when in the presence of water or metal. This will lead to incorrect readings of data. Plans to improve the UHF system in this context are underway, but HF (13.56 MHz) and microwave (2.45 GHz) systems may prove to be quite promising. Password protected HF tags that have extended range reaching up to ten meters are among the new advances, making them more marketable in tracking applications.[16] At the Smart Labels USA Conference in 2006, Alastair McArthur of Tagsys[17] supported this fact. He believes that 13.56 MHz is the most suitable operating frequency for item-level tagging because UHF, while offering good range and therefore the choice for pallets and cases, can be unreliable where metal and fluids are present as these substances will reflect the RF field, causing blindspots in the reader's field.

ODIN Technologies,[18] a consulting and testing company specializing in RFID applications, performed a head-to-head comparison of the two technologies for tagging item-level pharmaceuticals. The testing, sponsored by Unisys Corp.,[1] was performed under "as deployed" conditions, such as would be found in an actual tagging/verification process at a pharmaceuticals manufacturer. Of the eight criteria on which the testing was based, HF won five outright; UHF won two, and one was a tie. HF proved to be the ideal frequency for item-level tagging, especially where water and form factor of the tag is a concern in pharmaceutical applications. ***Figure 3*** shows the comparison between the two frequencies.

Environmental condition is another factor that supports HF usage over UHF. HF's inductive coupling re-

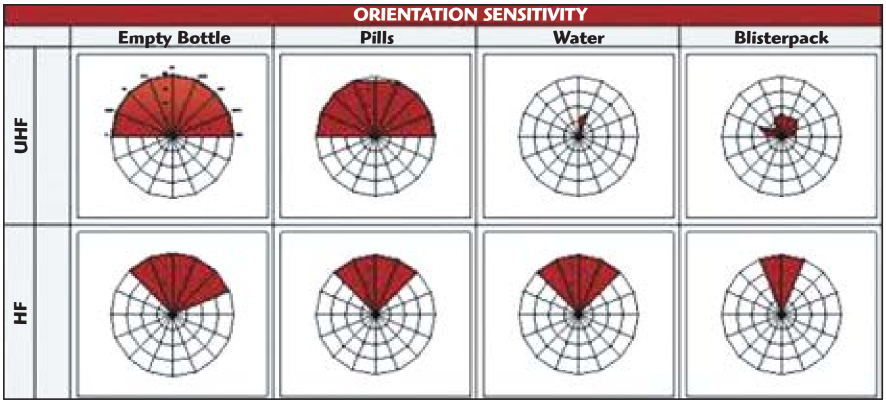


Fig. 3 The perimeter scales are read-angle; the concentric scales are a percentage of successful reads at each angle with zero at the center (ODIN Technologies).[18,19]

duces potential wireless interference issues because no real power is being radiated. In other words, HF has an excellent immunity to environmental noise and electromagnetic interference (EMI). UHF's far-field technology radiates real power, and its higher signal strength makes it more prone to EMI. Thus, the US Food and Drug Administration (FDA) shows great concern over the EMI caused by RFID usage in hospitals. The solution would be to use the HF RFID. They have met the electromagnetic radiation limits of 3 V/m, as shown in ***Table 1***, indicating that EMI would not interfere with critical medical devices. For years, HF tags have been used in hospitals.

In addition to that, Italy, Turkey and France's 865.6 to 867.6 MHz frequency range conflicts with the band allocated to the tactical relays for military applications.[8] This means that the UHF RFID systems may cause interference on military applications and telecommunication devices. Research[20] shows that there is such a risk. ***Tables 2*** and ***3*** show the very significant interference between a transmitting RFID system and a receiving military telecommunication

TABLE I

ELECTROMAGNETIC RADIATION LIMITS[7]

Classification Residential:	Signal Strength (V/m)	
Rural	up to 3	Frequency and source dependent, with condition for the proximity of local radio transmitters. If transmitters exceed conditions (power, distance), then field strengths could be higher.
Urban	up to 10	
Commercial	up to 10	
Light industrial	up to 3	
Heavy industrial	up to 30	
Traffic	up to 30	
Dedicated communications center	up to 1	
Hospital	up to 3	

1. Medical devices ad EMI: the FDA's perspective 1/2000
http://www.fda.gov/cdrh/emc/persp.html

TABLE II

INTERFERENCE RANGE BETWEEN A TRANSMITTING RFID SYSTEM AND A RECEIVING MILITARY TELECOMMUNICATION DEVICE PLACED IN LINE OF SIGHT[20]

RFID System ERP	Interference Range (km)
2 W	57
500 mW	28
100 mW	13

TABLE III

INTERFERENCE RANGE WITH THE RFID SYSTEM SITUATED INDOOR (10 dB ATTENUATION)[20]

RFID System ERP	Interference Range (km)
2 W	18
500 mW	19
100 mW	4

TABLE IV

INTERFERENCE RANGE BETWEEN RFID SYSTEMS AND GENERIC MILITARY DEVICES[20]

RFID System ERP	Interference Range (km)
2 W	< 1 m (0.8 m)
500 mW	< 1 m (0.4 m)
100 mW	< 1 m (0.2 m)

TABLE V
COMPARISON OF HF AND UHF RFID SYSTEM

	HF	UHF
Communication method	inductive coupling	propagating electromagnetic waves
Read range	~ 1 m	• 4 to 5 m (for unlicensed readers) • 10 m (for site license in the US) • 33 cm to 2 m (in Europe with power emissions from 0.5 to 2 W)
Memory size	larger	smaller
Tag size	bigger	smaller
Cost	comparatively cheap	cheap
Standards	ISO/IEC 18000-3, Auto ID HF class 1, ISO 15693, ISO 14443 (A/B)	ISO/IEC 18000-6, Auto ID class 0, class 1, EPC Gen 2
Ability to read near liquid and metal	better	worse
Immunity to environmental noise and electromagnetic interference (EMI)	good	bad

device placed in line of sight and another out of line of sight. The European improved power level of 2 W proved to be more harmful. However, there is no risk that a RFID system could cause destructive interference to a generic military device, as shown in ***Table 4***. ***Table 5*** shows the summary of comparison between the HF and UHF RFID systems as previously explained in detail.

CONCLUSION

There is not a single, universal RFID frequency that is capable of working in all applications. Different RFID technologies will be complementing each other, each used in applications that most suit its characteristics. For example, UHF is best used in logistics, baggage tagging and case-pallet tracking where longer read range is needed, whereas HF is best used in item-level tagging and in areas where liquid and metals are involved.

Some UHF users had been discussing using a hybrid solution known as the NearField UHF tag[21] to address the concern over the vicinity reading of the item-level tagging in the near future. However, two-in-one NearField/FarField UHF tags are usually too big for many items. Futhermore, UHF tags for pallets, cases and air baggage will always need to come in many variations to be effective.

For the time being, HF is still the best suited technology in most commercially growing applications because of the reasons stated in this article. The current market shows that 13.56 MHz has been the choice for many item-level applications where its range is adequate. Although Wal-Mart mandates UHF for item-level drugs, there are many leading drug companies, libraries and laundries that fit HF RFID on their items. The most significant disadvantage of UHF is where tags are exposed to environmentally challenged conditions, where liquid or metal are present that very commonly occurs in shipping of goods, and even airline baggage tagging in which UHF dominates. HF may fail in the read range category but it is a somewhat better choice between the LF and UHF, providing the best compromise between the advantages and disadvantages. ■

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AN IMPROVED BSIM4 MODEL FOR 0.13 μM RF CMOS USING A SIMPLE LOSSY SUBSTRATE EXTRACTION METHOD

An improved BSIM4 large-signal model for a 0.13 μm RF CMOS transistor with lossy substrate description is presented in this article. To accurately accomplish the CMOS model for microwave circuit designs, the RLC networks representing the parasitic effects of layout and lossy substrate were added into the BSIM4 model. With the proposed simple extraction method for a lossy substrate, the lossy substrate networks can be constructed without any complicated calculations and curve-fitting procedures. A 0.13 μm gate-length NMOS transistor was measured and extracted through the extraction method in this work. According to the experimental results, good agreement has been realized between measured and modeled results up to 40 GHz in terms of device DC I-V, S-parameters, low-frequency noise and power characteristics.

In order to improve the simulation accuracy of microwave circuit designs, an accurate active device model plays an important role for circuit simulations. According to previous studies, the BSIM models can precisely predict the characteristics of deep submicron MOSFETs at operation frequencies below 1 GHz for digital and analog circuit designs.[1] However, it cannot completely describe device behaviors at operation frequencies above several gigahertz, particularly the nonlinear behaviors and parasitic effects.[2] To develop a complete MOSFET RF large-signal model, an extended RLC network representing the parasitic effects of layout and the lossy substrate must be added into the standard BSIM model for obtaining more accurate modeled results.[3–5] In case these parasitic effects are not taken into account in a RF model, the fitting results will be only limited to several gigahertz, especially on S-parameters and power characteristics.

As to the extraction for parasitic resistances/inductances at each terminal, these parameters can be directly extracted by the proposed method.[6] According to previous studies,[7,8] it shows a reliable demonstration in their experimental results. In addition to

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the extrinsic parasitic resistances/inductances, the lossy substrate becomes more significant due to the power loss from thinner bulk material in deep sub-micron CMOS technologies. Thus, a new equivalent-circuit for lossy substrates has been proposed[8] to simulate the lossy parasitic effects through gate/drain terminals, which can accurately capture the unique frequency response associated with the lossy substrate. Although a good agreement has been realized between measured and modeled results in terms of S-parameters and NF_{min},[8] the proposed extraction procedure is very difficult and inconvenient because it requires a complicated curve-fitting approach and the accuracy depends on the fitted range of data. Besides, only S-parameter fitting results were shown and nonlinearity prediction was not included. In order to eliminate the curve-fitting process, a simple extraction method for the lossy substrate has been reported in this article. This new extraction method does not need the complex calculations and curve-fitting processes that can extract the parameters for lossy substrate networks. In this work, an improved BSIM4 large-signal model for a 0.13 μm CMOS device is presented by using a new extraction method, and verified by S-parameters for operation frequencies up to 40 GHz plus the DC I-V, low-frequency noise and power characteristics.

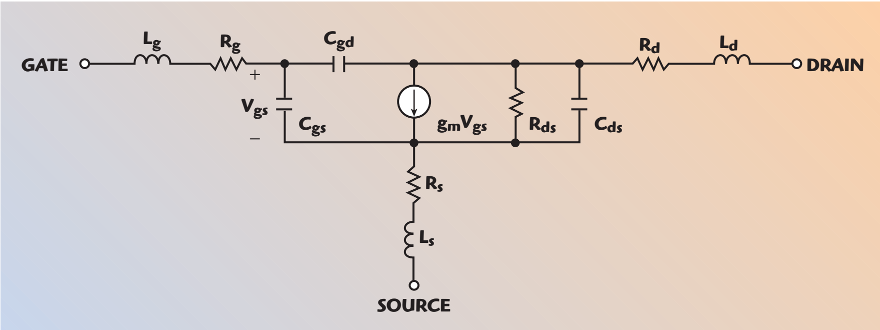

Fig. 1 Small-signal equivalent-circuit model for a MOSFET.

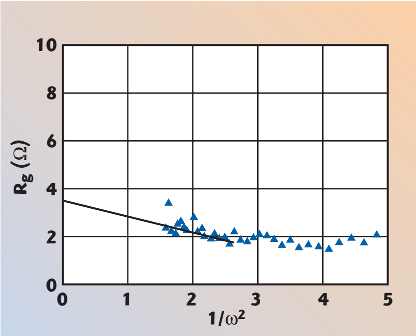

Fig. 2 Measured data of R_e (Z_{22}-Z_{12}) vs. $1/\omega^2$ for R_g extraction using linear regression.

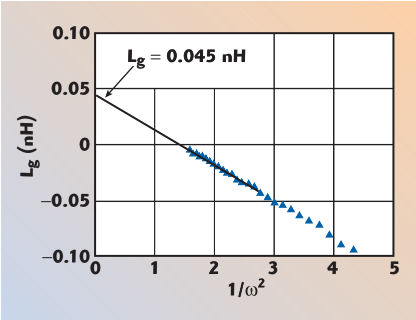

Fig. 3 Measured data of $(1/\omega)\, I_m$ (Z_{11}-Z_{12}) vs. $1/\omega^2$ for L_g extraction using linear regression.

EXTRACTION METHOD

A 0.13 μm NMOS transistor with a total gate-width of 200 μm was measured and extracted in this article. The device layout is employed by a multi-finger structure with a finger width of 5 μm and a finger number of 40. Microwave S-parameters were measured on-wafer using a E8364A network analyzer from 0.1 to 40.1 GHz, and the de-embedding "open" pad was used to remove the pad parasitic effects. In order to improve the RF large-signal model, the parasitic effects of layout and lossy substrate must be taken into account for accurate S-parameter prediction. ***Figure 1*** shows a simple small-signal equivalent-circuit model for a MOSFET. This equivalent-circuit mainly consists of two parts, intrinsic and extrinsic. The intrinsic part represents the characteristics for the transistor core, which can be well predicted by the BSIM model. The extrinsic part, representing the parasitic resistance/inductance from physical layout, plays an important role for fitting S-parameters at high frequencies. However, the gate resistance R_g represents the distributed gate resistance, and R_d and R_s represent the contact and sheet resistances for drain and source terminals that is related to the diffusion area. Three parameters of L_g, L_d and L_s are the series parasitic inductances in each terminal from metal connections. In this study, a proposed extraction method was used for obtaining these extrinsic parameters.[6] The above equivalent-circuit shown in the figure can be expressed by the following Z-parameters:

$$Z_{11} = R_g + R_s + j\omega\left(L_g + L_s\right) + \frac{g_{ds} + j\omega\left(C_{gd} + C_{ds}\right)}{Y_{11}^{in}Y_{22}^{in} - Y_{12}^{in}Y_{21}^{in}} \qquad (1)$$

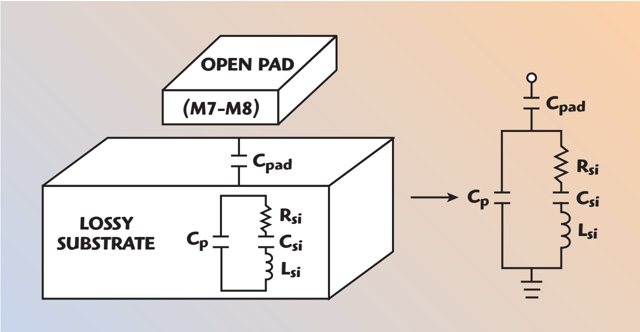

Fig. 4 Proposed equivalent-circuit model for an open pad with a lossy substrate.

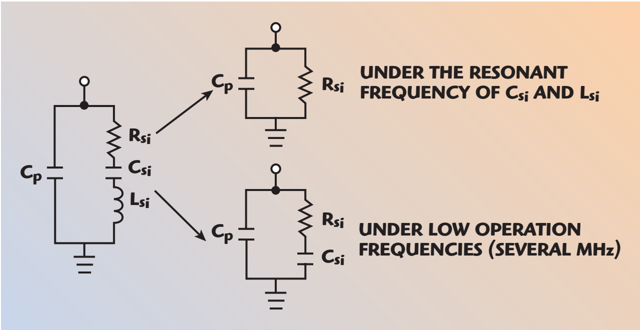

Fig. 5 RLC substrate network simplification for extraction procedures.

$$Z_{12} = R_s + j\omega L_s + \frac{j\omega C_{gd}}{Y_{11}^{in}Y_{22}^{in} - Y_{12}^{in}Y_{21}^{in}} \quad (2)$$

$$Z_{21} = R_s + j\omega L_s - \frac{\left(g_m - j\omega C_{gd}\right)}{Y_{11}^{in}Y_{22}^{in} - Y_{12}^{in}Y_{21}^{in}} \quad (3)$$

$$Z_{22} = R_d + R_s + j\omega\left(L_d + L_s\right) + \frac{j\omega\left(C_{gs} + C_{gd}\right)}{Y_{11}^{in}Y_{22}^{in} - Y_{12}^{in}Y_{21}^{in}} \quad (4)$$

where $Y_{11}^{in}Y_{22}^{in} - Y_{12}^{in}Y_{21}^{in} = -\omega^2 (C_{gs}C_{ds} + C_{gs}C_{gd} + C_{gd}C_{ds}) + j\omega[g_m C_{gd} + g_{ds}(C_{gs} + C_{gd})]$ is the calculated Y-parameter results of the intrinsic part. In the case where the real and imaginary parts in Equations 1 to 4 are considered individually, the extrinsic resistances and inductances can be derived by the following equations:

$$\mathrm{Re}\left(Z_{11} - Z_{12}\right) = R_g + \frac{A_g}{\omega^2 + B} \quad (5)$$

$$\mathrm{Re}\left(Z_{22} - Z_{12}\right) = R_d + \frac{A_d}{\omega^2 + B} \quad (6)$$

$$\mathrm{Re}\left(Z_{12}\right) = R_s + \frac{A_s}{\omega^2 + B} \quad (7)$$

$$\frac{1}{\omega}\mathrm{Im}\left(Z_{11} - Z_{12}\right) = L_g - \frac{E_g}{\omega^2 + B} - \frac{F_g}{\omega^2\left(\omega^2 + B\right)} \quad (8)$$

$$\frac{1}{\omega}\mathrm{Im}\left(Z_{22} - Z_{12}\right) = L_d - \frac{E_d}{\omega^2 + B} \quad (9)$$

$$\frac{1}{\omega}\mathrm{Im}\left(Z_{12}\right) = L_s - \frac{E_s}{\omega^2 + B} \quad (10)$$

where B, Ag, Ad, As, Eg, Ed, Es and Fg are expressed as functions of intrinsic parameters and constant values under a fixed bias condition.

At much higher frequencies, ω^2 is much greater than B in Equations 5 to 10. B can be significantly reduced by minimizing g_m and g_{ds} at the zero V_{gs} bias condition, so the frequency dependent terms related to the intrinsic part are much smaller than the extrinsic terms in previous equations. Thus, the extrinsic resistances and inductances can be extracted as ultimate values at an infinite frequency. ***Figure 2*** plots the measured data of $\mathrm{Re}(Z_{22}–Z_{12})$ against $1/\omega^2$, which means the gate resistance R_g can be obtained with a value of 3.5 Ω by using a linear regression method to find the y-intercept of $\mathrm{Re}(Z_{22}–Z_{12})$ against $1/\omega^2$ at an infinite frequency. ***Figure 3*** also demonstrates the extracted gate inductance L_g of 0.045 nH from the y-intercept of $(1/\omega)\mathrm{Im}(Z_{11}–Z_{12})$ against $1/\omega^2$. As for the other parameters, the same extraction method was used where the extracted L_d = 0.04 nH, R_d of 2 Ω, L_s = 0.02 nH and R_s = 1.5 Ω.

With regard to the substrate network, the standard BSIM4 model offers a built-in substrate network. However, this substrate network does not have the ability to describe the nonlinear frequency dependent characteristics due to its construction by resistance only,[1] so that the published paper[8] proposed a series RLC in parallel with a capacitance to accurately predict the behavior of the silicon lossy substrate. Therefore, to obtain the parameters of this network, an "open" pad is used for extraction of these values in this article.

The proposed equivalent-circuit model for an "open" pad is shown in ***Figure 4***. It consists of a RLC network incorporating the pad capacitance C_{pad} and substrate parameters R_{si}, C_{si}, L_{si} and C_p. The pad capacitance C_{pad} is used to model the dielectric capacitance under the signal pad, which is mainly dominated by the pad size and thickness between the metal and the substrate layer. The main substrate parameters R_{si}, C_{si}, L_{si} and C_p connected from gate/drain to ground are used to simulate the silicon lossy substrate. Capacitances C_p and C_{si} account for the capacitive coupling while substrate resistance R_{si} and L_{si} were proposed to model the semi-conducting nature of the silicon substrate at high frequency operation. The parameters of C_{si}, R_{si} and L_{si} are three key parameters to capture the lossy substrate feature up to 40 GHz. The C_{si} is the primary component for the phase deviation and nonlinear response in lower frequencies, and L_{si} reveals increasing these effects at higher frequencies.

In the work, the C_{pad} value of 160 fF is a calculated parameter by physical process and layout rather than from extraction. After de-embedding the pad capacitance C_{pad}, the measured Z-parameters of the lossy substrate can be obtained from the S-parameter transformation. The first step of the proposed extraction method is to assume the series C_{si} and L_{si} can be considered as a short circuit at their resonant frequency, and the effect of this series LC can be removed from this network. As shown in ***Figure 5***, the RLC substrate network is simplified to one capacitance C_p in parallel with R_{si}. Therefore, both parameters C_p and R_{si} can be directly extracted from the substrate network. ***Figure 6*** plots the measured Z-parameters for an open pad after de-embedding the pad capacitance. In this figure, a minimum value found at 27.1 GHz, which was representing the R_{si} value of 237.5 Ω, since the series C_{si} and L_{si} were eliminated at their resonant frequency. The C_p value of 18.59 fF was extracted from the $\mathrm{Im}(Z_{11})$ at the same resonant frequency of 27.1 GHz. This information can also be obtained in Figure 6.

After extracting the C_p and R_{si}, two unknown parameters C_{si} and L_{si} still exist. Therefore, the second step of our extraction method is to assume the L_{si} can be omitted at very low frequencies such as several megahertz. The equivalent-circuit for the lossy substrate can be simplified to Figure 5, and the C_{si} at such low frequencies can be expressed by

$$C_{si} = \frac{1 - j\omega C_p Z}{j\omega\left(Z - R_{si}\right) - \omega^2 C_p R_{si} Z} \quad (11)$$

According to Equation 11, C_{si} can be determined by the extracted C_p, R_{si} and measured Z-parameters at 10 MHz, which was determined to be 216 fF. Finally, the last unknown parameter L_{si} can easily be calculated from the resonant frequency $f_0 = 1/2\pi\sqrt{L_{si}C_{si}}$, and the L_{si} value is 0.16 nH.

IMPROVED BSIM4 MODEL

The BSIM model is a standard model widely used in sub-micron

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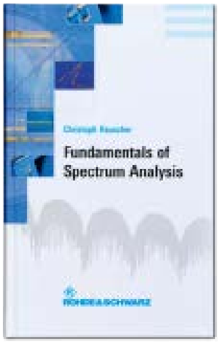
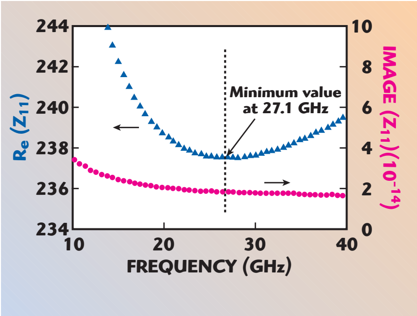
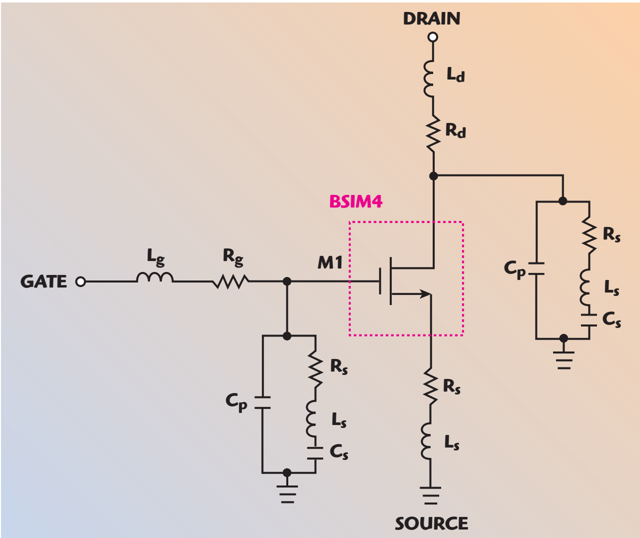




▲ *Fig. 6 Measured Z-parameters for an open pad after de-embedding the pad capacitance for R_{si} and C_p extraction.*

MOSFETs for general circuit designs below 1 GHz. Recent works have demonstrated that it is capable up to several gigahertz by adding RLC networks to represent the parasitic effects at higher frequencies.[3-5] Providing the device channel length is scaled down to deep sub-micron technologies, the combined effects of ever-shortened channel devices and millimeter-wave operation frequencies become a major challenge for device modeling. However, the BSIM4 model provides good predictions for short-channel effects under high supply voltages which are related to the output power at microwave frequencies and have better descriptions for some RF behaviors by high-frequency correlation parameters.[1] In response to this situation, it is proposed to adopt the BSIM4 model as the intrinsic core for DC I-V characteristics prediction and add RLC networks incorporating the parasitic effects of layout and lossy substrate to accurately accomplish a large-signal RF CMOS model.

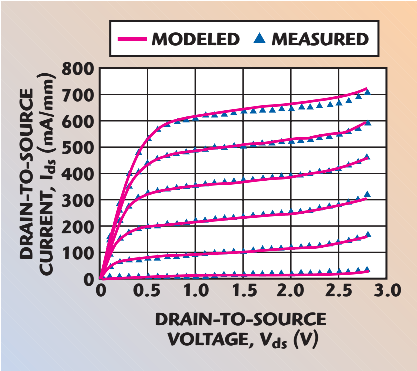
The proposed equivalent-circuit model of a 0.13 µm NMOS transistor is shown in ***Figure 7***. The fully equivalent-circuit contains an intrinsic core M_1 as represented in the original BSIM4 model. The BSIM4 model was transferred and modified through the BSIM3 model provided by the foundry. The RLC networks at each terminal are the extrinsic resistances/inductances and lossy substrate, which represent the high-frequency parasitic effects associated with practical layout and process. All parameters were extracted by the extraction methods discussed in this article. The optimization was done by using the Agilent ADS simulator to achieve the best fitting results on S- and Y-parameters.



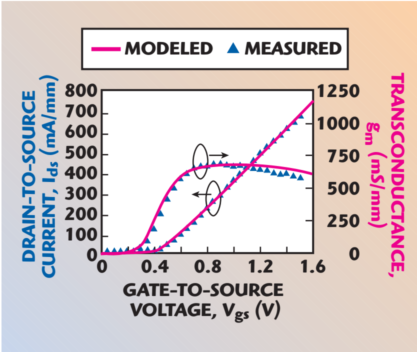
▲ *Fig. 7 Proposed equivalent-circuit model for a 0.13 µm NMOS transistor.*

RESULTS AND DISCUSSION

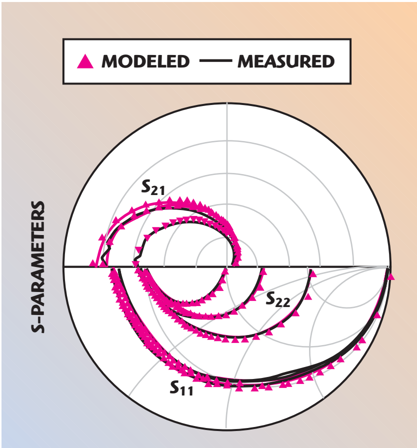
The 0.13 µm NMOS transistor with 200 µm gate-width fabricated by Taiwan Semiconductor Manufacturing Co. (TSMC) CMOS 1P8M standard process was measured and modeled for DC I-V, S-parameters, low-frequency noise and load-pull power characteristics. ***Figure 8*** shows the measured and modeled DC I-V characteristics, while V_{gs} was 0.4 to 1.4 V with steps of 0.2 V, and V_{ds} was 0 to 2.8 V. The predicted DC I-V characteristics were done by the BSIM4 model and matched well to the experimental data. This result is very important for mixer and power amplifier designs due to the nonlinearly knee-voltage and breakdown-voltage regions that are the key factors to the nonlinear circuits. ***Figure 9*** plots the transconductance (g_m) of this device; a normalized peak gm of 650 mS/mm was obtained under a V_{gs} of 0.8 V. The extracted f_T and f_{MAX} under peak g_m condition are 96 and 55 GHz, respectively. ***Figure 10*** shows the measured and modeled results of S-parameters up to 40 GHz under biased voltages V_{ds} of 1 V, and V_{gs} 0.6 to 1.4 V with steps of 0.4 V. This figure indicates that the S-parameters with bias-dependent conditions can be predicted well by the proposed model. In case the lossy substrate networks are not included in this model, the accuracy



▲ *Fig. 8 Measured and modeled DC I-V characteristics of a 0.13 µm NMOS transistor.*



▲ *Fig. 9 Measured and modeled transconductance of a 0.13 µm NMOS transistor.*



▲ *Fig. 10 Measured and modeled S-parameters of a 0.13 µm NMOS transistor.*

of the S-parameter is limited to only several gigahertz. ***Figure 11*** shows the low-frequency noise characteristics at V_{ds} of 1 V with a biased current of 10 mA. This result is extracted by the SPICE-Flicker equation,[9] that is given by

$$\overline{i_d^2}\Big|_{FLICKER} = KF\frac{\left(I_{DS}\right)^{AF}}{C_{ox.e}L_{eff}^2 f^{EF}} \quad (12)$$

where KF is flicker noise coefficient, and AF and EF are flicker noise exponent and frequency exponent. This 1/f noise expression in BSIM4 is identical with that in BSIM3, except for the definition of oxide thickness. The BSIM4 adopts the electrical oxide thickness for the most of its capacitance calculations ($C_{ox,e}$). In addition to the device's DC I-V, S-parameters and low-frequency noise verification, the evaluation of large-signal performance at 5.8 GHz at V_{ds} of 1 V with a biased current of 50 mA was also conducted. ***Figure 12*** plots

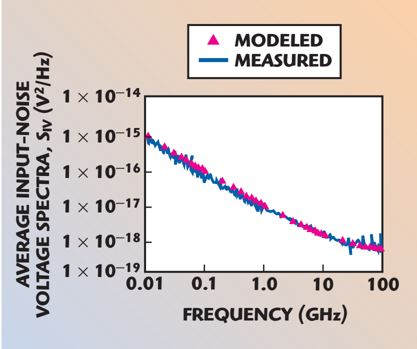


Fig. 11 Measured and modeled low frequency noise characteristics of a NMOS transistor.

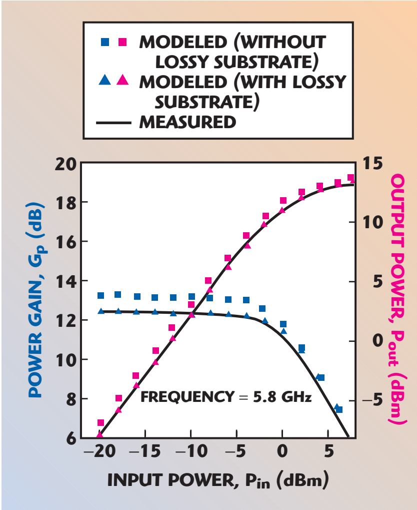


Fig. 12 Measured and modeled power gain and output power as a function of input power for a 0.13 μm NMOS transistor.

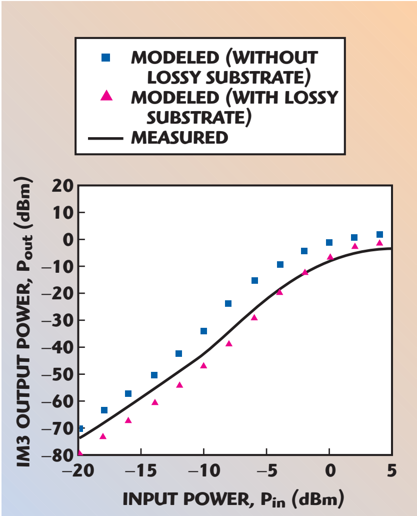


Fig. 13 Measured and modeled third-order inter-modulation (IM3) output power vs. input power.

power gain (G_p) and output power (P_{out}) as a function of input power (P_{in}) for measured and modeled results. In this figure, the model with the lossy substrate shows a well matched trend with the measured data, with a linear power gain of 12.4 dB and a 1 dB compression point of 0 dBm. The traditional model without the lossy substrate achieves higher G_p and P_{out} compared to the measured results, due to the model that cannot precisely simulate the power loss without substrate leakage current and parasitic effects considerations. Furthermore, the two-tone test was performed at frequencies of 5.800 and 5.801 GHz, as shown in ***Figure 13***, that plots the verification results of third-order inter-modulation (IM3) and output power versus P_{in}. This figure demonstrates not only that the fundamental output power can be well predicted, but also the IM3 output power, which is helpful for harmonic predictions in large-signal circuits. These results demonstrate good agreement between the predictions of the improved BSIM4 model and the measurement of the experimental characterization.

CONCLUSION

According to the obvious short-channel effects in advanced CMOS technology, the BSIM4 model achieves better predictions compared to the BSIM3. The additional RLC networks representing the extrinsic resistances/inductances and lossy substrate must be taken into account for employing the deep sub-micron CMOS devices into microwave circuit designs. To accurately obtain the lossy substrate parameters, a simple extraction method without any complicated calculations and curve-fitting processes is proposed in this article. A 0.13 μm NMOS transistor was measured and extracted in terms not only for S-parameters, but also DC I-V, low-frequency noise and power characteristics. Excellent agreement has been obtained between measured and modeled results. This accurate model is useful for operation frequencies up to 40 GHz to improve the simulation accuracy in microwave applications. ■

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The International Microwave Symposium is the headline conference of the IEEE Microwave Theory and Techniques Society (MTT-S). This will be the largest technical Conference to be held in Atlanta in the next two years and will feature a large trade show as well as a wide variety of technical papers and workshops. The IEEE MTT-S International Microwave Symposium 2008 (IMS2008) will be held in Atlanta, GA, Sunday, June 15 through Friday, June 20, 2008, as the premiere event of Microwave Week 2008.

Microwave Week 2008: The IMS 2008 technical sessions will run from Tuesday through Thursday of Microwave Week. Workshops will be held on Sunday, Monday and Friday. In addition to IMS2008, a microwave exhibition, a historical exhibit and the RFIC Symposium (www.rfic2008.org) will also be held in Atlanta during Microwave Week 2008.

LIQUID CRYSTAL POLYMER: ENABLING NEXT-GENERATION CONFORMAL AND MULTILAYER ELECTRONICS

For microwave systems that operate below 5 GHz, conventional circuit board materials are readily available with low cost and good performance. However, as systems migrate to higher frequencies, and as the demand for improved integration schemes increases, microwave and millimeter-wave designers look for the next generation of materials with improved versatility. Since its introduction to the microwave world about a decade ago, liquid crystal polymer (LCP) has become very attractive as a substrate and packaging material due to its unique electrical and mechanical characteristics. One of LCP's most attractive properties is its flexibility, which enables the emergence of conformal microwave circuits. The number of innovations that become possible using conformal electronics are endless. Sensors and wireless communication devices can be fabricated on LCP and integrated into fabric for use in military uniforms or personal health monitoring systems. Large antenna arrays can be assembled on LCP, rolled into a cylindrical shape, packed into a rocket payload, launched into space, and unrolled for a less costly deployment method since size and weight are minimized. A similar rolling and unrolling technique could be used by the military to quickly and covertly deploy an antenna array on the battlefield. The versatility of using LCP along with some of the advantages, limitations and challenges are discussed in this article. Several examples of state-of-the-art components and systems that are using LCP as a substrate or packaging material are presented.

It is widely accepted that as a technology matures, it typically shrinks in size, reduces in cost and offers improved performance. Often, these new technologies become a building block for product spin-offs. For example, a device that operates at S-band may be scaled to work at X-band. An emphasis is continually

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being placed on making devices that are versatile, scalable, reconfigurable, reliable and low cost. What makes this a challenge is the ability to choose microwave materials that are suitable for a broad spectrum of applications. The limiting factor at the module or system level is often the packaging. Improving the insertion loss of a device from 0.5 to 0.1 dB does not matter as much if the packaging losses are well over a dB.

In modern systems, an increased emphasis is being placed on 3D integration. The footprint size of a device can be greatly reduced by moving some of the components to a different vertical layer. These layers are connected with either metalized vias or capacitive coupling. Conventional materials, like low temperature co-fired ceramic (LTCC), can be used to make multilayer systems, but the high temperature firing (up to 900°C) makes it impossible to embed devices sensitive to high temperature.

An increased emphasis is also being placed on conformal and flexible electronics. The ability to wrap electronics around curved or angled surfaces can add new capabilities to modern systems. Laminating a receiver circuit flush against the nose cone of an aircraft, for example, may improve performance. Weaving a flexible circuit into a soldier's uniform may create a comfortable and convenient way to carry communication devices.

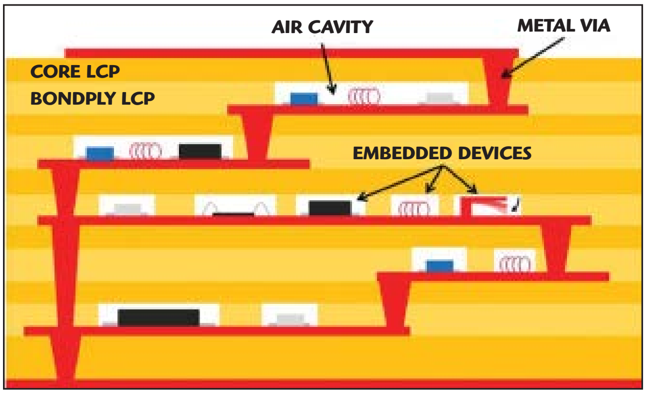
For microwave systems that operate below 5 GHz, conventional circuit board materials are readily available with low loss and low cost. Materials like Duroid and FR4 have been in use for decades for everything from high school breadboard experiments to deep space satellites. As the frequency increases, however, the number of options drops quickly. Ceramic materials, like alumina and LTCC, start to become more attractive, but these materials have drawbacks of their own, including higher cost and dimensional instability during firing (a step necessary for multilayer systems).

Liquid crystal polymer (LCP) is a potential solution to all of the mentioned issues and shortcomings of conventional microwave materials. LCP is an organic material that offers low loss and dielectric stability from DC to 110 GHz,[1] making it applicable to almost every consumer and military frequency band. With a permittivity of approximately 3, LCP is particularly appealing for antenna systems since the material naturally prohibits the excitation of surface waves. LCP can be made with a low melting temperature, which gives it a key advantage over other packaging materials. As system-on-package (SOP) approaches gain in popularity, LCP can provide a useful medium for multilayer and embedded designs.

Many current and next-generation microwave systems could benefit from using this unique material. In this article, the advantages and disadvantages of using LCP in modern electronics are discussed. Several emerging technologies that are taking advantage of LCP will be presented.

WHAT IS LCP?

LCP is a thermoplastic polymer made of aligned molecule chains with crystal-like spatial regularity. If heated to the liquid crystal state, rigid segments of the molecules align next to one another in the direction of shear flow. This structure persists even after cooling below the melting point. The uniform makeup of the material gives it unique electrical properties as well as strong mechanical and chemical properties.



▲ *Fig. 1 Multilayer LCP package with embedded devices.*

LCP has been used for decades as a material for making sails, high strength rope and nets. In the 1980s, researchers started to make LCP in thin-film form. The first thin films made were brittle, non-uniform and would tear easily. By the 1990s, enough improvements had been made so that the material was suitable for high frequency applications.

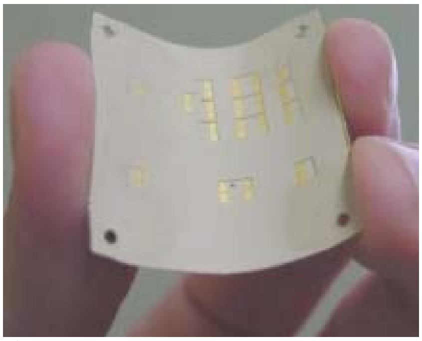
One unique feature of LCP is that it can be made to melt at 290° or 315°C. The lower melting temperature material is called "bondply" and the other is called "core." In all other electrical and mechanical aspects, the two materials are identical. To make a multilayer device with LCP, a layer of bondply is sandwiched between two core layers. The stack is compressed and heated to a temperature between 290° and 315°C. The bondply melts and chemically bonds to the core layers. Once bonded, the layers cannot be separated. Using this method, it is possible to bond together dozens of layers of LCP. An example of a multilayer stack-up (not to scale) is shown in ***Figure 1***. Cavities are formed by cutting holes in the bondply before bonding and metal vias are used to connect the two layers.

It is important to consider that LCP is a polymer. It will never be as hermetic as ceramic and it will never be as thermally rugged as silicon. LCP is not intended to completely replace any conventional material, like FR4, Duroid, LTCC or alumina but, for many applications, LCP offers a distinct advantage. When the operating frequency exceeds X-band, many conventional materials become too lossy to use. LCP does not have this limitation. If the application can benefit by flexible or conformal electronics, LCP is an ideal option. When the footprint size must be minimized and a multilayer approach will be implemented, LCP becomes very attractive as a combination substrate and packaging material.

LCP BENEFITS

LCP combines the best qualities from almost every popular microwave material used today. Its electrical performance is comparable to that of polytetrafluoroethylene (PTFE), but it is as easy to fabricate as Duroid. Its multilayer capability rivals that of LTCC, but it can remain as flexible as paper. It can be as thin as 1 mil or extruded into any size and shape. It can be used as a substrate, a superstrate and a packaging material, but its cost is not much more than that of FR4. Several key benefits for using LCP are listed below:

- Wide frequency range: It has been shown that LCP offers low-loss (loss tangent less than 0.004) and dielectric stability from DC to 110 GHz.[1] This wide frequency range makes LCP suitable for practically every application.
- Conformal: In thin-film form, LCP is as flexible as paper, as shown in ***Figure 2***, where passive microwave devices and MEMS switches are embedded in the package. Only the coplanar waveguide probe pads are visible. It can be conformed into any shape and it can be laminated onto almost any surface. Extrusion and molding are also possible with this material.
- Low permittivity: LCP has a permittivity of approximately 3, which is electrically advantageous for packaging. The presence of a low-permittivity superstrate requires little or no additional design consideration. Packaging with a high permittivity material, like silicon, changes the impedance significantly and this must be taken into account.[2]
- Light weight: With a density of 1.4 g/cm^3, LCP is 40 percent lighter than silicon, 65 percent lighter than alumina and almost 30 percent lighter than FR4. Air and space-borne applications greatly prefer light-weight materials.
- Biocompatible: LCP has been proven for safe use inside the human body (that is, it is non-toxic).
- Radiation resistant: LCP resists the harmful effects of radiation. This is advantageous for space-borne applications.
- Thickness variety: LCP can be made as thin as 1 mil or as thick as desired. This is ideal for antenna applications where the substrate thickness is determined by the tradeoff between wide bandwidth and low profile.[3]
- Low melting temperature: LCP bondply melts at approximately 290°C. Multilayer technologies are possible with embedded structures as long as the device can withstand short exposures at the melting point.[3]
- High dielectric strength: LCP has a dielectric strength of approximately 550 V/mil, making it suitable for high voltage and high power devices.
- Easy to process: LCP can be processed like any other material in a clean room. It is easy to laser cut or plasma process. It can also be drilled and machined.
- Low cost: As the technology matures, the cost of manufacturing LCP will continue to decrease. Currently, the price of LCP is comparable to that of other organic boards, like Duroid.
- Customized CTE: The coefficient of thermal expansion (CTE) of LCP can be tuned by changing the chemical formula. Values ranging from 3 to 30 ppm/°C are possible, but the standard CTE is 17 ppm/°C to match that of copper.
- Low moisture absorbing: LCP absorbs and retains only 0.02 to 0.04 percent of moisture by weight. The permittivity of water can be as high as 90 (depending on temperature and frequency) which, when absorbed, can have a profound effect on the substrate permittivity. By not absorbing moisture, LCP maintains a constant permittivity even in humid environments.[3]
- Chemical resistance: LCP is able to withstand prolonged exposures to harsh chemicals, even under high temperatures. This includes solvents, metal etchants, oxide etchants, strong acids and bases. Durations of constant exposure for over a month have been tested with a negligible change to the mechanical and electrical properties.



▲ *Fig. 2 The flexibility of LCP is demonstrated.*

One area of microwave engineering that can greatly benefit from the advantages of LCP is antennas. The permittivity is high enough to keep the antenna size small, but low enough to minimize surface wave excitation (surface waves cause radiation pattern distortion, reduced efficiency and other negative effects). Thin LCP can be used for low-profile antennas and thick LCP can be used for antennas requiring higher bandwidth. The Sierpinski antenna shown in ***Figure 3*** was made on 100 μm thick LCP.[4] Micro-electro-mechanical (MEMS) switches were integrated to make the antenna frequency reconfigurable.

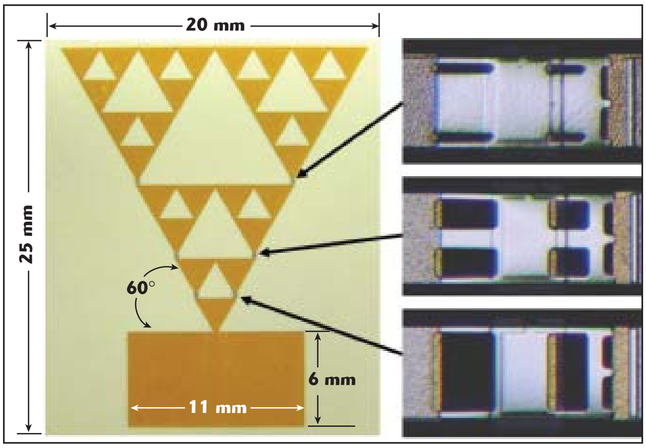
Since the material is flexible, conformal antennas on LCP are possible. For example, a large antenna array could be laminated onto the side of an aircraft fuselage or the nose cone of a rocket. Since the material does not absorb moisture and can withstand chemical exposure, it is well-suited for outdoor deployment. Antennas are scalable by frequency and a material that operates across a wide frequency spectrum is usually desired. A unique antenna design could be scaled to work for L-band communications or W-band collision avoidance using the same material for both applications. This can provide considerable cost savings.

The benefits for using LCP are not restricted to only multilayer and conformal systems. It can also be used as a low-loss substrate for rigid circuits. The cost of LCP is currently not low enough to make it competitive against FR4 for rigid circuits operating at less than 10 GHz. However, for X-band and higher, LCP would excel as a rigid substrate material. There are several fabrication companies that currently offer LCP as a circuit board material, including Modular Component National (www.modularcomp.com) and Dynaco Corp. (www.dynacocorp.com).

LCP LIMITATIONS

Even though LCP has many ideal properties, it does have some limitations. For example, it is an insulator so it cannot be used as the bulk material of a transistor (although it can be used as a carrier for bare die and packaged transistors). It is a polymer, so it cannot be used to make a hermetic package. Some of LCP's current limitations and misconceptions are listed below:

- "Near-hermetic": Since LCP is a polymer, it cannot be truly hermetic. Although the extent of LCP's hermeticity is still under debate, the general consensus is that LCP performs well in gross-leak testing, but poorly in fine-leak testing. Micro-cracks in the LCP packages are effective at repelling liquid, but not moisture (such as vapor). The material itself absorbs very little moisture, as previously discussed. For this reason, LCP is commonly classified as "near-hermetic."[5]
- New material: LCP is often considered a new material and is therefore too experimental to be used in a developing system. Actually, LCP has been used in its current form for almost a decade with consistent performance.
- Strong bases: LCP is chemically resistant and has demonstrated no deterioration with prolonged exposures to strong acids. However, strong bases, especially when heated, will dissolve LCP over time. For example, photo resist remover with a pH of 12 will dissolve a piece of LCP in less than 24 hours if heated to 60°C. This sensitivity to strong bases is true of all organic materials.
- Poor thermal conductor: Since LCP is a polymer, it does not conduct heat well. Any heat that is generated inside of an LCP package will not dissipate quickly. However, LCP does provide a thermal barrier to any heat sources outside of the LCP package. Depending on the application, poor thermal conductivity can be beneficial or problematic.[6]



▲ *Fig. 3 Example of a Sierpinski antenna with MEMS switches on LCP.*

• Surface roughness: LCP has a natural surface roughness of a couple of microns. By comparison, a polished silicon wafer may have a surface roughness of a couple of nanometers. For applications that require a polished surface, the LCP must be mechanically polished before using. This is not a difficult process and can be performed at production scale.[7]

CURRENT LCP INNOVATIONS

LCP certainly has the potential to provide never before seen consumer and military innovations. Conformal electronics are rarely heard of because flexible materials are not readily available. A few decades ago, a low-cost, flexible, low-loss material that could operate to 110 GHz was unheard of and inconceivable. Today, LCP can do all of these things and more. Microwave engineers have been using LCP for nearly a decade and several exciting new technologies have emerged from this effort. The Georgia Electronic Design Center (GEDC) at Georgia Tech is one of the key research facilities for LCP technologies. Since LCP is very advantageous for antenna systems, most of the research that has been performed to date is focused on novel antenna designs and systems. Several examples of recent LCP innovations are presented below.

RFID

A radio frequency identification (RFID) tag or transponder is a device capable of storing and wirelessly transmitting a packet of information. These devices can be integrated into products, animals and even people for providing fast and secure identification. Many department stores are currently using RFIDs to monitor their products. A toll pass transponder that commuters can use to pay their fee without stopping is another example of an RFID.

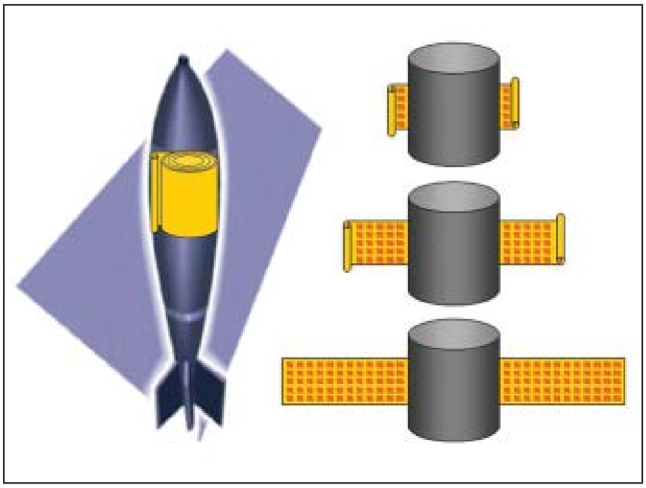
LCP is particularly attractive for RFID antennas because it lends itself well to conductive printing techniques. In this process, LCP can be fed into an inkjet printer similarly to a piece of paper and the antenna pattern can be printed on using a conductive ink. This fabrication method has the potential of being fast and super low-cost, which are key elements to a successful RFID. The ultimate goal is to place an RFID tag on every consumer product for easy tracking.

The "Printed Electronics Laboratory" at the South Dakota School of Mines and Technology is one of the leading research facilities for conductive printing on LCP. The ultra-wideband (UWB) antenna shown in ***Figure 4*** was designed by Dimitris Anagnostou and fabricated by Ahmad A. Gheethan using an M3D (Maskless Mesoscale Materials Deposition) machine.[8] On a piece of unpolished LCP, a printing accuracy of ±20 µm is possible with this technique.

Inflatable Arrays

Organizations like NASA have been interested in using LCP as a satellite antenna material since it was first introduced. Deploying a large satellite in space is challenging be-

▲ *Fig. 4 UWB antenna fabricated on LCP using a conductive printing technique.*



▲ *Fig. 5 Process for deploying an LCP antenna into space.*

cause it must be able to fit inside a rocket or Shuttle payload. Ideally, a large antenna array could be rolled up like a round bale of hay, loaded into a rocket, blasted into space, deployed into orbit, and unrolled, as demonstrated in ***Figure 5***.[7] This method minimizes the size of the rocket needed to launch the payload, which drastically reduces the cost of satellite deployment.

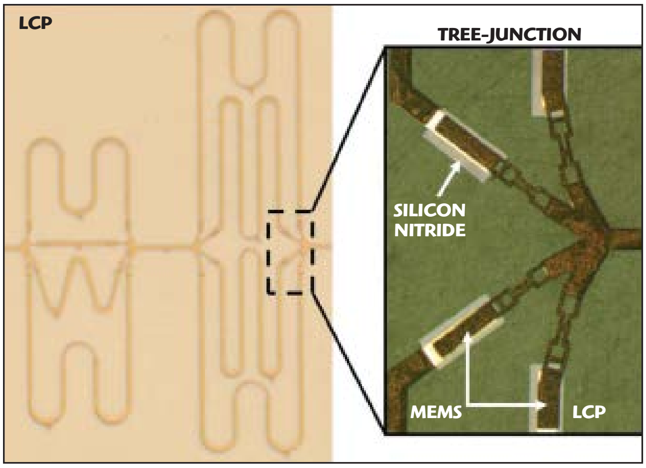
The military has also been interested in inflatable arrays for some time. A large array can be packed tightly for easy mobility and quickly deployed on the battlefield as needed. When not in use, the inflated array can be deflated and packed away. Both of these processes are much more covert, because they allow for easy mobility and a negligible radar cross section when not in use.

MEMS Switch Substrate and Packaging

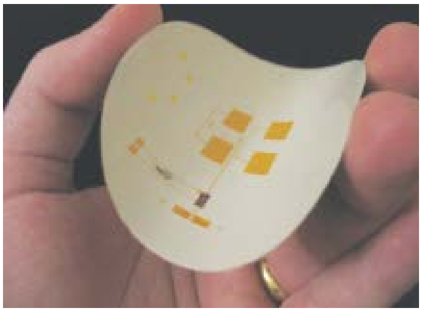
The ability to make MEMS switches directly onto a polymer material offers an opportunity to greatly decrease the cost of a MEMS device. The high cost of MEMS is due partly to the expensive metal and ceramic packaging. MEMS are incredibly sensitive to heat and moisture, so careful packaging is essential. Aside from cost issues, ceramic packaging can be lossy and bulky as well.

MEMS can be fabricated on LCP after polishing the surface to a mirror finish. At that point, the surface roughness is no longer an issue for reliable operation. MEMS switches on LCP have demonstrated hundreds of millions of cycles and testing is still in progress.[7]

MEMS can be packaged in LCP, but unfortunately most MEMS devices cannot survive the 290°C bonding temperature. Therefore, other bonding methods have been explored. Some examples of localized bonding techniques that have been investigated include metal rings,[6] infrared lasers and ultrasound. The four-bit switched-line phase shifter shown in ***Figure 6*** was packaged in LCP using epoxy. A cavity was formed in the bondply to protect the MEMS tree-junctions.[7] This MEMS phase shifter is one of the passive devices packaged in the flexible circuit shown previously.



▲ *Fig. 6 A four-bit switched-line phase shifter with integrated MEMS.*



▲ *Fig. 7 A completely flexible communication module fabricated on LCP.*

Communication Module

For a long time, the Holy Grail of 3D integration was to combine active, passive and electromechanical devices onto one multilayer package. Such a technology would demonstrate that system-on-package (SOP) design strategies were possible.

In the spring of 2007, researchers at the Georgia Institute of Technology created a fully functional, multilayer receiver module on LCP. A 2 × 2 patch antenna array was integrated with MEMS reconfigurable phase shifters to create a beam steering array. A low-noise amplifier (LNA) was used to amplify the received signal. The LNA could have been replaced with a power amplifier to create a transmit module as well. The operating frequency of the device was 14 GHz for satellite communication applications.[9]

The researchers implemented the module using a single layer and a multilayer approach. By moving the LNA to a different vertical layer, they were able to reduce the size of the module by 25 percent. The single layer implementation is shown in ***Figure 7*** and the flexibility is demonstrated.[7]

CONCLUSION

LCP was introduced to the microwave industry almost a decade ago and since then many companies, universities and national laboratories have used the material in their designs. For applications requiring flexible or conformal electronics, LCP is the forerunner in microwave materials. Even as a rigid board material, LCP offers low-loss performance through W-band, dielectric stability and low cost.

LCP is also an excellent packaging material. With a low melting temperature bondply available, making a multilayer device is a straight-forward process. Since the permittivity is low, very few design considerations need to be given to the packaging effects.

To date, most of the innovations being developed with LCP are antennas. LCP is well suited for antenna applications due to its dielectric stability, wide frequency range, low permittivity and resilience to harsh environments.

Researchers are already planning future microwave systems that are more compact, lighter-weight and better performing. To do this, versatile materials are desired that can satisfy a variety of electrical and mechanical needs. LCP is ready to fulfill the requirements of current and next generation systems. ■

ACKNOWLEDGMENTS

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SOFTWARE-DEFINED RADIO TRANSMITTERS FOR ADVANCED WIRELESS AND SATELLITE COMMUNICATIONS SYSTEMS

This article reviews and discusses the critical issues in designing software-defined radio (SDR)-based transmitters for wireless and satellite applications. Digital predistortion-based linearization techniques as an enabling technology for SDR transmitters are briefly explained and discussed. Switching-mode amplifiers, including classes E, D and F are discussed as potential candidates for advanced digital transmitter radio systems such as Doherty, LINC, EE&R and delta-sigma transmitters. Simulation results as well as experimental results are provided to illustrate the respective performance of these advanced radio systems.

The wireless and satellite communications communities have always been looking for power efficient radios. However, the power efficiency is greatly dominated by the efficiency of the RF power amplifier (PA) in the transmitting path. Recently, most of the communication systems being deployed or to be deployed in the near future use time-varying envelope signals. With such signals, PAs are required to operate in their back-off region to meet the required linearity. This linearity is defined either by the adjacent channel power ratio (ACPR) or the error vector magnitude (EVM) in the context of wireless applications or noise power ratio (NPR) in satellite communications. The setting of the back-off level is generally a function of the input signal's peak-to-average power ratio (PAPR). Unfortunately, the power efficiency of the amplifier decreases when the back-off level increases. In most cases, this leads to the design of very low-efficiency amplifiers that require large DC power modules, with bulky thermal dissipators for fixed terminals or have short battery life in mobile terminals. From the base station prospective, these linear and low-efficiency amplifiers turn out to be very costly to manufacture and very expensive for the telecommunication operators who run the infrastructure. Linearization techniques are being used to improve the achievable power efficiency. However, the resulting power efficiency is still in the range of 15 to 30 percent.[1–3] Recent advances in semiconductor process technologies such as GaN- and SiC-based devices[4] are making the design of highly

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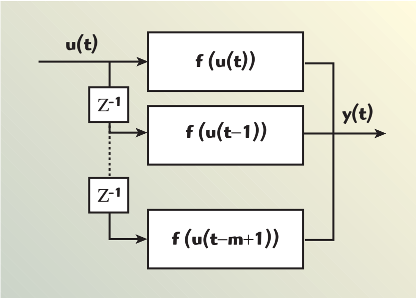
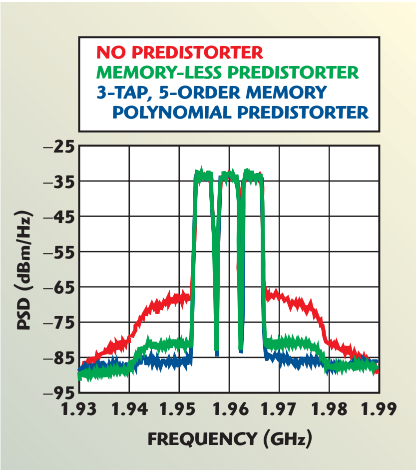
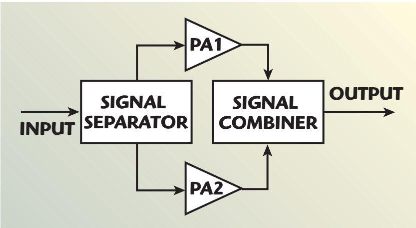
efficient switching mode RF power amplifiers a feasible solution for such applications. To be able to use such power amplifiers, their design has to be considered closely together with the system architecture in order to ensure optimal system-level performance. This implies that conventional transmitters' architectures have to be adapted or modified to be able to integrate this new type of amplifier. Several attempts have been made to adjust standard architectures or even to propose alternative architectures that are based on switching mode amplifiers. Among these, one can distinguish sigma-delta modulator-based transmitters,[5,6] digital power amplifier concept-based architecture[7] and linear amplification using nonlinear component (LINC) transmitter architecture.[8–11] Indeed, the use of class D, class E and class F switching mode RF power amplifiers as well as their derivative classes in such architectures are considered as enabling technologies for the realization of highly efficient transmitters for satellite communications, and 3G and beyond applications.



▲ *Fig. 1 Memory predistorter block diagram.*



▲ *Fig. 2 Comparison of the transmitter output spectra under a three-carrier WCDMA excitation.*



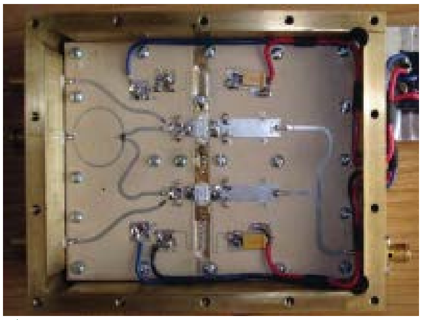
▲ *Fig. 3 Load-modulated amplifier.*

In this article, an overview of the actual state-of-the-art in power amplification and software-based transmitters is presented, along with emerging trends. First, the state of power amplifier technology and the performance of the different architectures are discussed. Second, advanced SDR-based transmitter architectures are introduced. Conclusions are then drawn and prospects for futures radio systems are discussed.

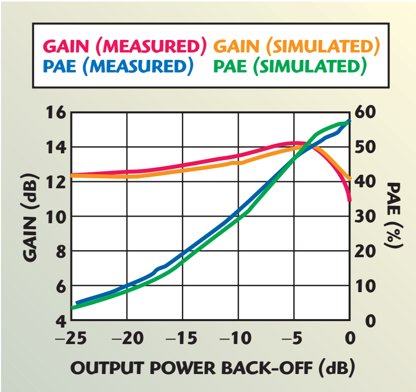
STATE-OF-THE-ART AMPLIFIER TECHNOLOGY

Continuously Driven Amplifiers

Several solutions have been proposed and are used to partially circumvent the power efficiency limitations in continuously driven amplifiers such as class A, class AB and balanced or push-pull amplifiers. The most commonly adopted solutions consist of using continuous mode power amplifiers, mainly class AB power amplifiers, combined with one of the well established linearization techniques such as feedback, feed forward, RF predistortion and baseband digital predistortion.[12] The selection of the adequate technique in most cases is dependant on the application/standard, which dictates the targeted level of linearity to be reached. Despite the fact that most of these technologies can lead to an acceptable level of nonlinearity correction for power amplifiers, the only compatible solution with SDR-based transmitters is the baseband digital predistortion, considered as an enabling technology for 3G and beyond radio systems. This technology, in most cases, allows the radio designer to meet the linearity requirements, but the power efficiency of these systems is currently limited to approximately 25 percent.[2]



▲ *Fig. 4 A 16 W 3G Doherty amplifier.*



▲ *Fig. 5 Doherty amplifier performance.*

Linearization Techniques

A memory polynomial predistorter, shown in ***Figure 1***, is utilized to pre-compensate the static nonlinearity as well as the electrical memory effects of the RF transmitter.[13] The predistortion function of each branch of the multi-branch polynomial predistorter is defined by

$$f(u(t-i)) = u(t-i)\,(a_{i0}+a_{i1}\,|u(t-I)| + \ldots + a_{i,p-1}\,|u(t-i)|^{p-1}$$

As a demonstration of the capability of the digital predistortion technique, a three-carrier WCDMA signal is synthesized and applied to the transmitter to assess the performance of the described memory predistorter. The comparison results of the output spectra shown in ***Figure 2*** demonstrate that the memory polynomial predistorter can effectively suppress the out-of-band emission as well as the in-band distortion caused by the electrical memory effects.

Load Modulated/Doherty Amplifiers

In load-modulated PAs, the load impedance seen by the transistor varies depending on the input power level. The load modulation mechanism is designed and controlled in such a way that the overall performance of the amplifiers is improved in comparison with the case of a PA having a constant load.

A generic block diagram of load-modulated amplifiers is presented in ***Figure 3***. The Doherty power amplifier is among the architectures that beneficially use the load modulation mechanism. Doherty amplifiers that are capable of handling envelope-varying signals are perceived as a dazzling way of improving the efficiency of the power amplification stage. This is accomplished through an active load-pulling effect seen by the carrier amplifier as an extension of its saturation point. Therefore, the efficiency of the Doherty amplifier is effectively increased in the back-off zone, without compromising its maximum output power.[3,14–16] ***Figures 4*** and ***5*** show a photograph of a 16 W Doherty amplifier for 3G applications and its performance, respectively. As shown, Doherty amplifiers have a mild nonlinearity that can be improved using DPD, but improved power efficiency.

Switching Mode Amplifiers

Several attempts have recently been made to build switching mode RF power amplifiers (class D, class E and class F) that greatly boost the power efficiency. Such amplifiers can theoretically permit close to 100 percent power efficiency. However, this power efficiency degrades as the operating frequency increases, due to the parasitic reactances, the nonzero switching resistance and the switching time. Traditionally, class D amplifiers, which consist of two active devices that are alternately switched on and off, are very popular at audio frequencies. At RF frequencies, however, the output shunt capacitance of the transistor causes significant losses. Newly proposed current-mode class D (CMCD) amplifiers adapt the class D concept to RF applications by partially eliminating these losses.[17] Alternatively, in class E amplifiers, the zero voltage switching operation mode is advantageous since it eliminates the shunt capacitance losses of class D amplifiers. Furthermore, optimal harmonic loading used in class F amplifiers leads in general to 10 to 20 percent enhancement in the power efficiency of continuously driven class AB and class B power amplifiers.[18,19] Recent realizations of switching mode amplifiers have reported power efficiencies ranging from 40 to 80 percent for frequencies from 1 to 2 GHz.[17,20] These amplifiers have been constructed primarily in LDMOS[18] and HBT[17,19] technologies. However, HBT technology has been used more widely, due to its high reliability and monolithic integration that make it suitable for satellite communication as well as wireless communication systems. Switching mode amplifiers are thus considered potential candidates to replace continuously driven amplifiers in advanced transmitter architectures, such as those based on the LINC concept, the envelope elimination and restoration (EE&R) technique, the delta-sigma modulator and the Doherty amplifier.

ADVANCED SDR-BASED TRANSMITTER ARCHITECTURES

LINC Transmitters

The LINC concept uses two nonlinear RF PAs to form a linear amplifi-

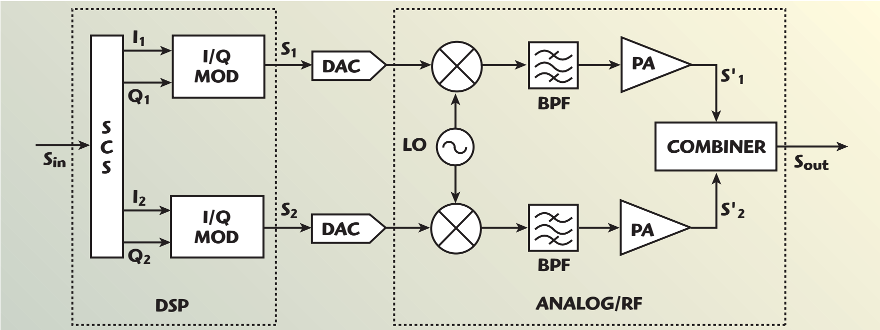


Fig. 6 LINC-based transmitter.

cation system. This is achieved by driving the two RF PAs with signals having constant envelope and time-varying phases. The phases are controlled in such a manner that the combination of the outputs of both PAs produces a system output with the desired amplitude and phase modulation.[8,9] This architecture is very sensitive to gain and phase imbalance between the two signal paths. In addition, it has limited dynamic range and the overall power efficiency is greatly affected by the type of RF combiner used and the statistics of the signal.[10] Indeed, the average efficiency enhancement of a LINC-based amplifier decreases as much as the signal's PAPR increases.[11] ***Figure 6*** is a block diagram of LINC-based transmitters. The two constant-envelope signals generated to drive the nonlinear power amplifiers are given by

$$s_1(t) = \frac{s_{in}(t)}{2}\left[1 + je(t)\right]$$

and

$$s_2(t) = \frac{s_{in}(t)}{2}\left[1 - je(t)\right]$$

with

$$e(t) = \left[\frac{r_{max}^2(t)}{r_{in}^2(t)}\right]^{1/2} \quad (1)$$

In such a case, and when the two paths are perfectly balanced, the output signal is a linear amplified replica of the input signal, and is given by

$$s_{out}(t) = Gs_{in}(t) \quad (2)$$

where

G = gain of the power amplifier

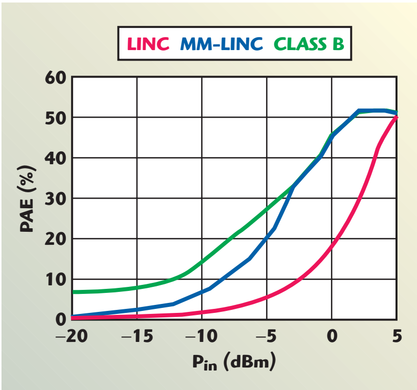


Fig. 7 Measured LINC, class B and mode-multiplexing LINC efficiency as a function of input power back-off.

Recent development and implementations of LINC-based architectures demonstrated the ability of this technique to provide very good linearity as well as significantly improved power efficiency for WiMAX applications, as shown in ***Figures 7*** and ***8***.[21]

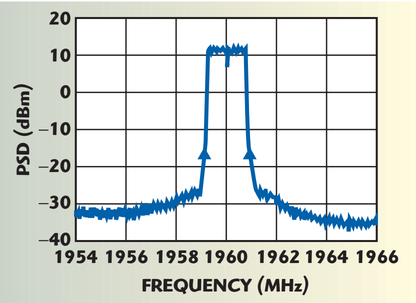


Fig. 8 Measured mode-multiplexing LINC output spectrum.

EE&R Transmitter

The EE&R technique uses a limiter to transform the original input signal into a constant envelope signal. The amplitude information is then recovered by varying the bias of the power amplifier.[22,23] This technique has a limited dynamic range, is sensitive to delay mismatch and is also limited by the DC/DC converter speed and power handling requirements.[23] However, polar modulation technology using the EE&R technique has been implemented commercially for handheld low power terminals, creating a single, universal, multimode handset radio transmitter, which can support GSM/GPRS and EDGE signals, as well as the WCDMA signal. Polar modulation is well poised to enable development of multimode handsets for these multiple air interface standards.

A generic block diagram of a polar modulation transmitter is shown in ***Figure 9***. ***Figure 10*** shows the output spectrum of EE&R handheld-based transmitters driven with 3G signals.[24]

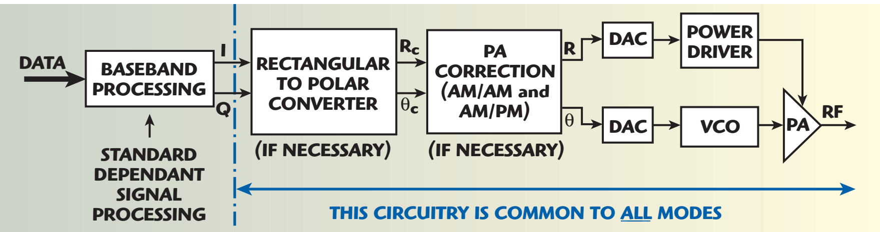


Fig. 9 Multimode polar transmitter.

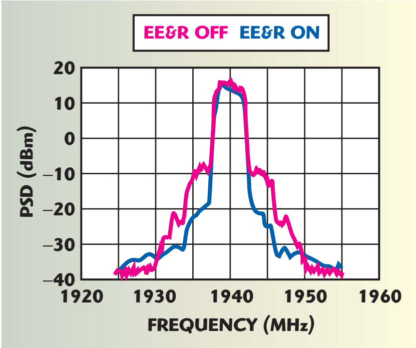


Fig. 10 Output spectrum of an EE&R transmitter.

Delta-sigma Modulator-based Transmitter

The delta-sigma modulator also offers a valuable potential solution to convert analog complex modulation information of envelope varying signals into digitally coded pulses to drive the switching mode amplifiers.[5,6] However, the conventional architecture requires tremendous sampling rate, which exceeds the capability of current technology for 3G and beyond applications. A block diagram of a typical bandpass ΔΣ transmitter is shown in ***Figure 11*** along side with the signal waveforms at the different points in the system. It consists of a ΔΣ analog-to-digital converter (ADC), a switching-mode power amplifier and a bandpass filter. The filter is required to restore the analog signal before transmitting the information to the antenna. The RF input signal is digitized by the ΔΣ-ADC to a two-level signal. The bandpass ΔΣ modulator maps the baseband signal to a range around an intermediate frequency that is equal to a quarter of the sampling frequency. The quantization noise is spectrally shaped and normally falls outside of the bandpass.[5,6] However, practical implementation generally results in a relatively high noise floor that affects the quality of the signal and its linearity. ***Figure 12*** shows the output spectrum of a ΔΣ transmitter that uses a second-order ΔΣ modulator designed for 800 MHz applications, when driven with a two-tone signal. Since the output of the ΔΣ modulator has fixed amplitudes, a highly efficient switching-mode power amplifier, typically an RF class S power amplifier, can be used for amplification without introducing harmonic distortions. Prior to transmission toward the antenna, the original signal is restored by filtering the amplified RF digital signal with a high quality factor bandpass filter. The bandpass filter is required to attenuate the out-of-band quantization noise and to suppress all higher harmonics. Hence, this transmitter topology has the potential to amplify digitally modulated signals with large peak-to-average-power ratios (PAPR) while maintaining high power efficiency and high linearity.

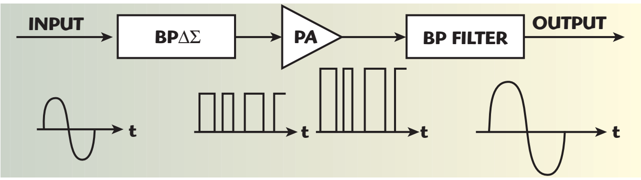


Fig. 11 Block diagram of a generic delta-sigma transmitter.

CONCLUSION

Emerging technologies and planned applications worldwide are increasingly using bandwidth-efficient, non-constant envelope modula-

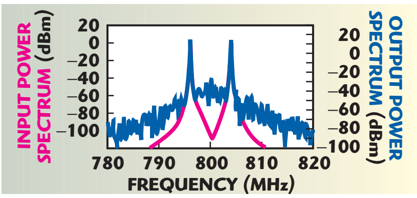


Fig. 12 Two-tone signal spectra at the input and output of an 800 MHz ΔΣ transmitter.

tion schemes such as MC-CDMA and OFDM. These modulation schemes call for the development of spectrum and power efficient SRD transmitters that can support multiple air-interface standards. In this article, advanced power amplification architectures that have the potential to meet both the linearity and power efficiency requirements for emergent broadband wireless and satellite communications were presented. Typical performance of digitally predistorted continuously driven power amplifiers and Doherty amplifiers have been discussed and their performance assessed. The state-of-the-art in switching mode amplifier design was briefly presented. Finally, the principle and limitations of power amplification stages and transmitter architectures appropriate for use in switching mode power amplifiers were discussed. This included LINC and EE&R transmitters, and delta-sigma modulator-based transmitters. ■

ACKNOWLEDGMENT

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ANALYSIS AND DESIGN OF A COMPACT MULTI-BAND ANTENNA FOR WIRELESS COMMUNICATIONS APPLICATIONS

A compact multi-band and single-feed microstrip antenna is proposed for wireless communications applications at 0.9, 1.8, 1.9 and 2.4 GHz. The antenna in this article consists of a microstrip feedline, a two-step power coupler, a rectangular loop and a meander line. The meander line is shorted at specific positions within the loop. All these components together provide multi-paths for the current resulting in multiple resonances. The meander line is used to lengthen the electrical paths while maintaining a compact size. The parametric study and the computed and measured results of a prototype of this antenna are presented.

Personal wireless communications have recently gained wide popularity. Presently, the trend is to provide a wireless link to every kind of electronic device. In particular, there is a specific need for greater capacities and transmission speeds, which, together with a growing demand from users for more complicated services, require the design of higher performance systems. In this context, multi- and wideband antennas are required. Many researchers have investigated the design of multi-band antennas to cover different frequency ranges.[1–5] Other researchers investigated techniques to improve the antenna bandwidth.[6–11]

On the other hand, a small antenna size is required to meet the miniaturization requirements of the mobile communication system. Several methods have been used to miniaturize microstrip antennas such as loading the microstrip patch with a high dielectric substrate, short circuiting the microstrip patch to the ground plane, modifying the basic microstrip patch structure, or using a meander line.[12-14]

In this article, a compact antenna is presented, which operates in several frequency bands in the range between 0.5 and 3 GHz including GSM 900, GSM 1800, GSM 1900, UMTS-2110, and the industrial, scientific and medical (ISM) band around 2.4 GHz, as well as WLAN and Bluetooth applications operating at 2.4 GHz. The proposed antenna con-

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sists of a microstrip feedline, a two-step power coupler, a rectangular loop and a meander line, which is connected to the loop at certain positions. The meander line is used to decrease the antenna size, and all these components together provide multi-paths for the current, resulting in multiple resonances. The proposed antenna belongs to a category similar to the one described by Thakur, et al.[14] However, the antenna here has only one port, and provides more operating frequencies. The simulation and analysis for the present antennas were performed using the commercial computer software package, Ansoft HFSS, which is based on the finite element method. A prototype

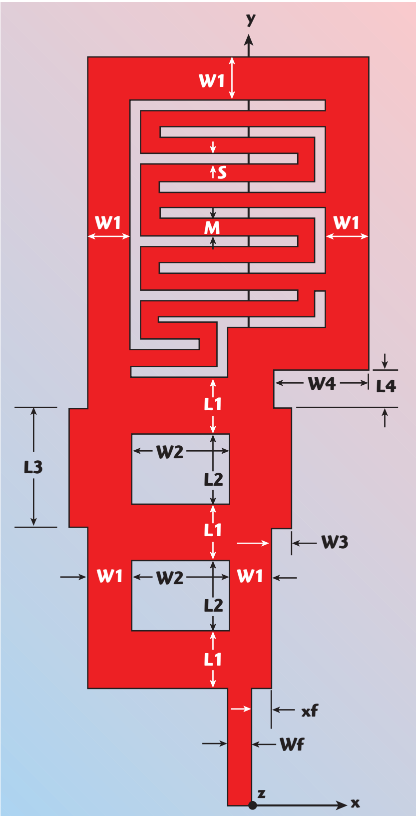


Fig. 1 Antenna geometry.

TABLE I

ANTENNA INITIAL DIMENSIONS (MM)

xf	1.5	Wf	3
W1	6	W2	13.5
W3	2.75	W4	13.5
L1	7	L2	10
L3	17	L4	5.5
M	2.3	S	1.5

was manufactured and measured and a good comparison between measurements and simulations is obtained.

ANTENNA GEOMETRY AND ANALYSIS

The geometry of the proposed antenna is shown in ***Figure 1***. The antenna is built on an FR4 epoxy substrate of height h = 1.6 mm and dielectric constant ε = 4.4. The right, left and top edges of the substrate are 3 mm away from the edges of the antenna. The antenna is fed by a 50 Ω microstrip line of width Wf and is placed at distance xf from the lower right corner of the antenna. The length of the microstrip line is 16 mm.

The antenna consists of two consecutive power couplers to excite different modes and provide different

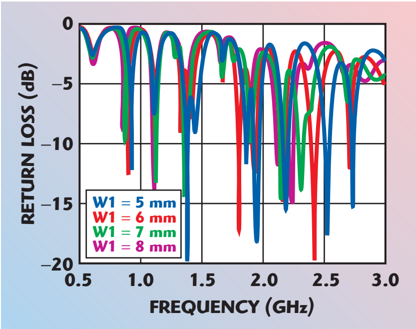


Fig. 2 Effect of W1 variation.

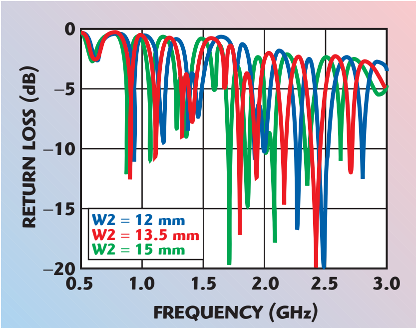


Fig. 3 Effect of W2 variation.

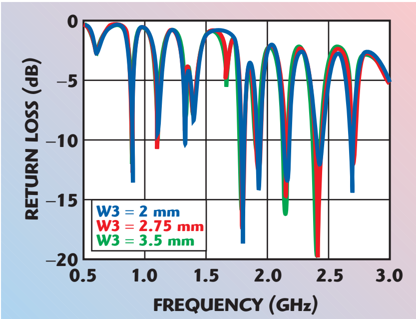


Fig. 4 Effect of W3 variation.

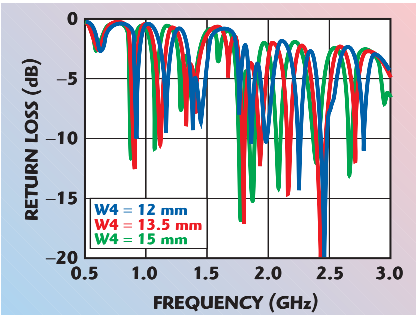


Fig. 5 Effect of W4 variation.

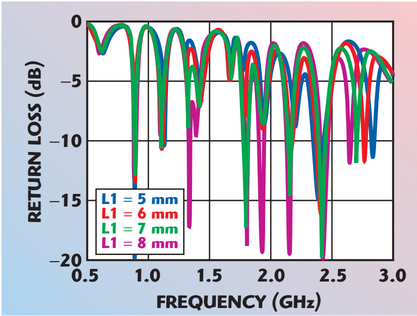


Fig. 6 Effect of L1 variation.

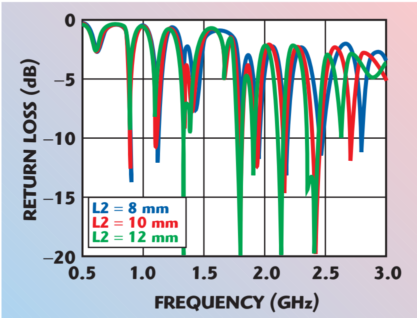


Fig. 7 Effect of L2 variation.

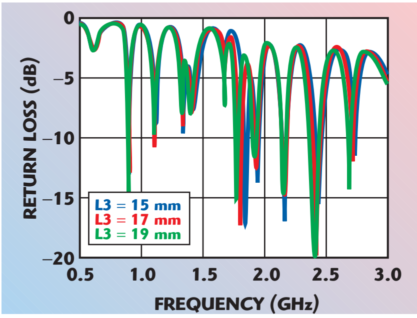


Fig. 8 Effect of L3 variation.

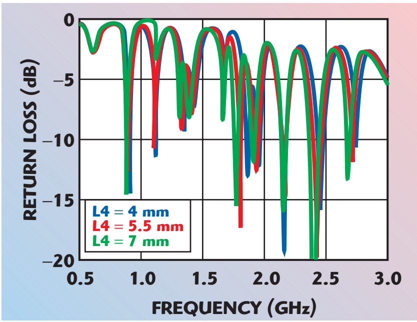


Fig. 9 Effect of L4 variation.

current paths. They are defined by the parameters W1 and W2 in the x-direction, and L1 and L2 in the y-direction. A stub is added to the second coupler for matching, and is defined by the parameters W3 and L3. The power couplers are then connected to a microstrip loop of width W1. The right lower corner of the loop is defined by the parameters W4 and L4. A meander line is placed within the loop to efficiently fill the entire space. The meander line width is M and the distance between the lines is S. Short circuits between the loop and the meander line are added to provide extra current paths. Based on an extensive preliminary study of this antenna, the initial design is chosen to have the dimensions shown in ***Table 1***.

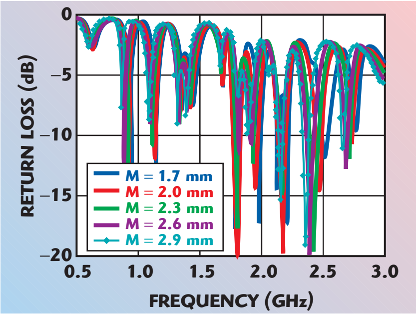


Fig. 10 Effect of M variation.

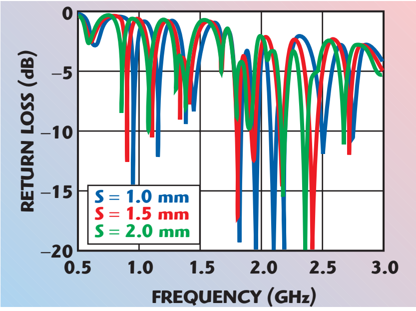


Fig. 11 Effect of S variation.

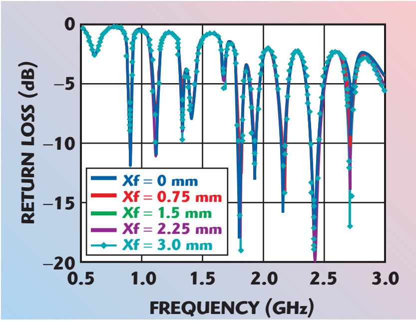


Fig. 12 Effect of xf variation.

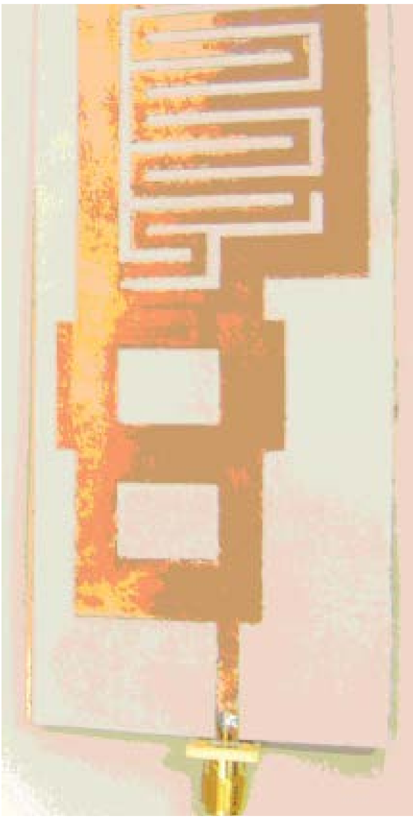


Fig. 13 Antenna prototype.

The parameters of the antenna are studied by changing one parameter at a time, while keeping the other parameters constant. The results are shown in ***Figures 2*** to ***12*** for the W, L, M, S and xf parameters, respectively. Generally, increasing all parameters decreases all the resonance frequencies of the antenna because this increases the antenna size. The parameter W3 controls the level of the return loss because it affects the S-parameters of the second coupler, which lies between the loop and the meander in one side, and the feedline and the first coupler in the other side, and consequently affects the matching between them.

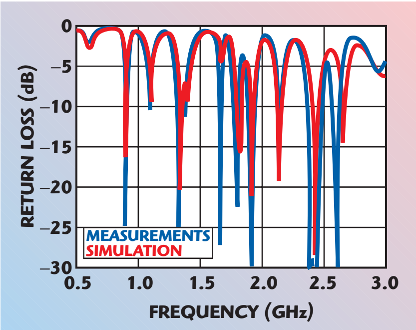


Fig. 14 Measured and computed return loss.

FINAL ANTENNA RESULTS

The final design of this antenna has L_1 = 8 mm and xf = 0; the other parameters are the same as in Table 1. This antenna was manufactured using a milling machine and measured using an Agilent E5071B network analyzer (ENA series) in the Oak Ridge National Laboratory. A prototype of the an-

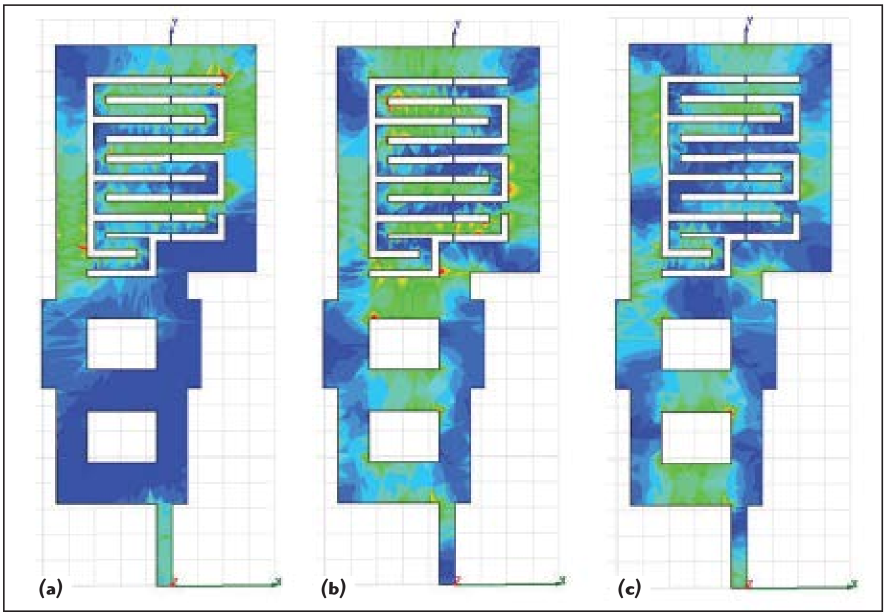
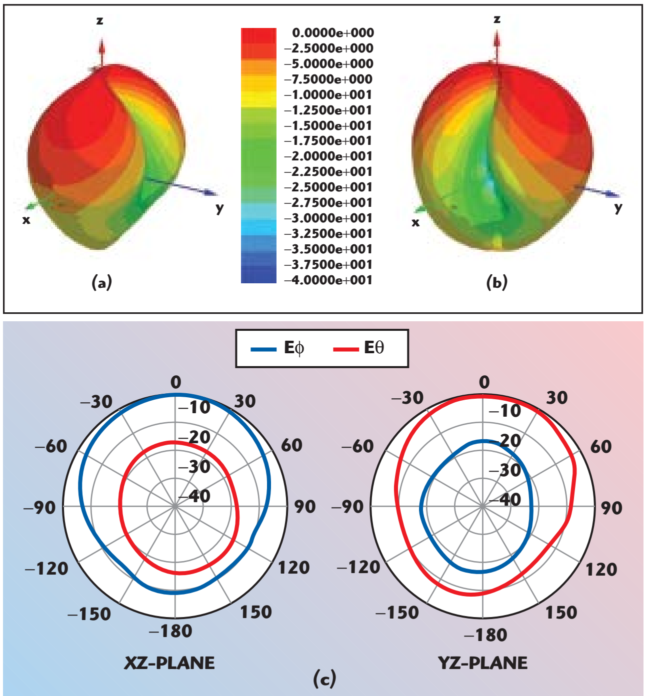
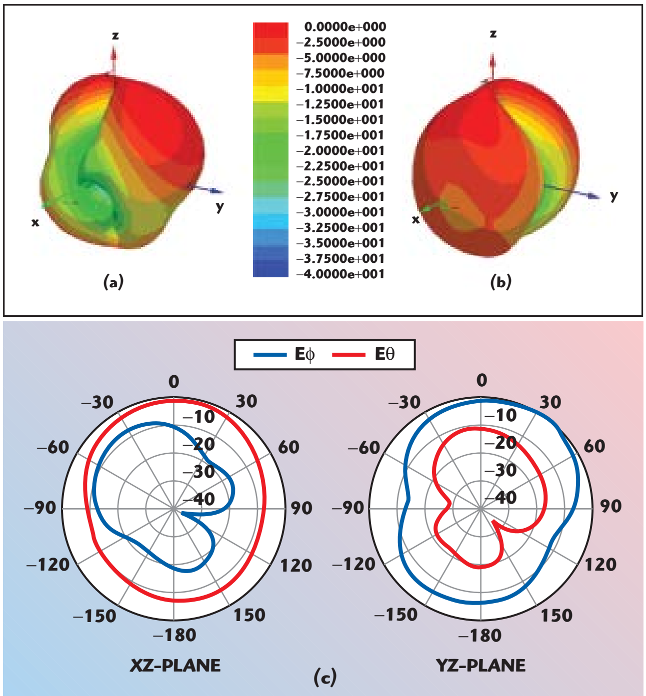


Fig. 15 Computed surface current at (a) 0.9, (b) 1.9 and (c) 2.4 GHz.

tenna is shown in ***Figure 13***. The measured and computed return loss of this antenna are shown in ***Figure 14*** from 0.5 to 3 GHz. A good agreement is obtained between measurements and simulations which verify the results obtained by HFSS for the proposed antenna design, and shows the low sensitivity to the manufacturing tolerances.



▲ *Fig. 16 Radiation patterns at 0.9 GHz: (a) 3D Eϕ, (b) 3D Eθ and (c) 2D patterns.*



▲ *Fig. 17 Radiation patterns at 1.9 GHz: (a) 3D Eϕ, (b) 3D Eθ and (c) 2D patterns.*

In simulation, the antenna has nulls at 0.9, 1.11, 1.34, 1.39, 1.67, 1.82, 1.92, 2.14, 2.43 and 2.65 GHz, while the measurements show that the antenna operates at 0.89, 1.09, 1.32, 1.38, 1.66, 1.8, 1.91, 2.15, 2.4 and 2.61 GHz. The small differences between the two results are caused by the SMA connector, the inaccuracy of the milling machine and the uneven substrate surface which results from peeling off the copper. The antenna size (47.75 mm) compared to the wavelength at the lowest operating frequency is only $0.14\lambda_0$. These results prove that this antenna is a good candidate for many wireless applications such as GSM 900, GSM 1800, GSM 1900, UMTS-2110, and the industrial, scientific and medical (ISM) band around 2.4 GHz, as well as WLAN and Bluetooth applications operating at 2.4 GHz.

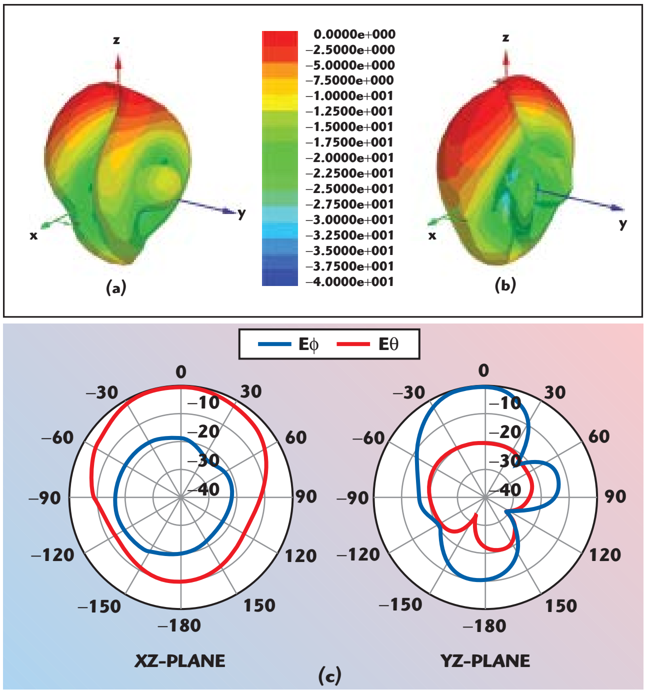


Fig. 18 *Radiation patterns at 2.4 GHz: (a) 3D Eϕ, (b) 3D Eθ and (c) 2D patterns.*

The computed magnitude and vector surface current distributions at 0.9, 1.9 and 2.4 GHz are shown in ***Figure 15***. A combination of two or more elements of the antenna provides each of these three resonances. The 2D and 3D radiation patterns are calculated using Ansoft HFSS at 0.9, 1.9 and 2.4 GHz and are presented in ***Figures 16*** to ***18***. The radiation patterns at the three frequencies are almost similar to each other. The only clear difference is in the polarization, where the antenna is quasi y-polarized at 0.9 GHz, and quasi x-polarized at 1.9 and 2.4 GHz, which is due to the difference in the excited mode.

CONCLUSION

A compact microstrip antenna fed by a single microstrip line has been proposed and analyzed for multi-band wireless communications applications. The prototype of the antenna has been designed using Ansoft HFSS and realized through measurements. The presented antenna has a compact size of $0.14\lambda_0$ at 0.9 GHz. Similar radiation patterns are obtained at 0.9, 1.9 and 2.4 GHz. This antenna can be easily integrated into and accomplish the requirements of modern mobile communication systems. ■

ACKNOWLEDGMENT

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HARMONIC LOAD PULL WITH HIGH GAMMA TUNERS

Automated load pull has become a standard tool for characterizing microwave power devices. Power devices operate in a nonlinear mode in order to achieve reasonable efficiency, so testing must be done with actual drive power and impedance matching. This includes the harmonic impedances, which can have a significant effect on both efficiency and linearity performance. This article reviews the common types of tuners used for load pull, and methods that have been used for harmonic tuning. Finally, it will show how the High Gamma Tuner, used with the Cascaded Tuner method of harmonic tuning, can produce exceptionally high gamma at both the fundamental and harmonic frequencies. This provides an excellent measurement solution for low impedance power devices when both efficiency and linearity are important parameters.

Microwave power devices, widely used in modern wireless and communications systems, must operate in a nonlinear mode in order to operate efficiently. Nonlinear operation means that the only valid way to test them is under actual operating conditions of DC bias, RF power and impedance. Small-signal S-parameters are not sufficient.

Because of the need to control impedances seen by power devices, load pull has become a primary method for characterizing active RF and microwave devices. Load pull systems generally include tuners for impedance control, in addition to whatever equipment is needed for the stimulus and measurement of the Device Under Test (DUT). Typically, whatever can be measured in a matched environment, such as 50 Ω, can then be measured as a function of impedance.

Some general applications of load pull include: process development, where load pull measurements are used to determine the effects of varying process parameters; direct amplifier or oscillator design, where load pull measurements are used to determine the optimum source and load impedances that can then be synthesized with matching networks using a linear simulator; large-signal device modeling, where load pull data is used to adjust device models to make them more accurate; production, where the tuners typically set specific load and source impedances for a single measurement on-wafer; and ruggedness testing of modules, where the device is measured with a specified output VSWR at all phases.

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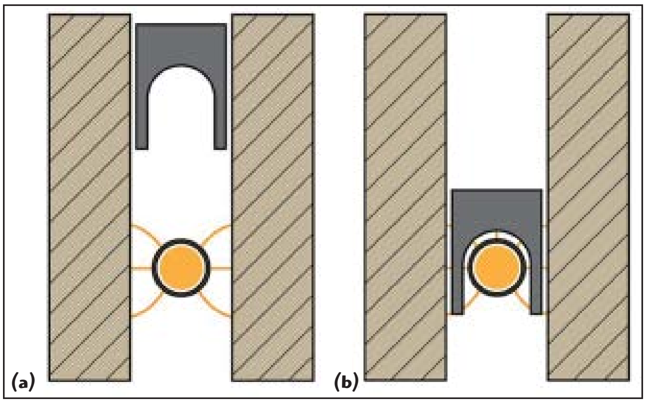
TYPES OF TUNERS

Most load pull systems use passive tuners to control impedance. These tuners may be mechanical or solid state. Mechanical tuners use motors to move mechanical parts to change the impedances, while solid state tuners typically use switch elements, such as PIN diodes, to select from a fixed set of impedances.

The most common tuner type in use today is the mechanical slide screw tuner. For coaxial tuners, it typically uses a 50 Ω slab line, consisting of two parallel ground planes with a center conductor. When the mismatch element, called a probe, is far from the center conductor, the slab line acts like a very good, low-loss, 50 Ω TEM transmission line. As the probe is moved toward the center conductor, the mismatch smoothly increases until it reaches a maximum when the probe is close to the center conductor. Phase of the mismatch is varied by moving the probe parallel to the center conductor.

A cross-section of a typical mismatch probe is shown in ***Figure 1***. ***Figure 1a*** shows the probe far from the center conductor, where it has no effect on the fields, resulting in a good 50 Ω transmission line. ***Figure 1b*** shows the probe at the opposite end of its travel, close to the center conductor. In this position, it interferes with the electrical fields, producing a large mismatch. As the probe is moved between these two extremes, the mismatch magnitude is varied smoothly.

Ideally the probes should be non-contacting, touching neither the ground planes nor the center conductor. This enables the motors to move the probes very quickly with no perceptible wear or change over time. This provides long tuner life, excellent repeatability, and saves time because a single calibration is often good for a long time, even years. Some mechanical tuners use probes that make sliding contact to connect the probe with the ground planes. Contacting probes are easier to design, but at the cost of shorter tuner life, slower operation and poor repeatability.



▲ *Fig. 1 Cross-section of a slide screw tuner with probe retracted (a); cross-section of a slide screw tuner with probe inserted close to the center conductor (b) .*

THE HIGH GAMMA TUNER

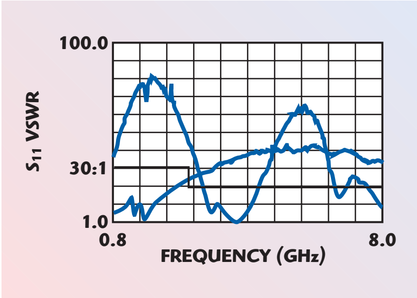
The traditional slide screw tuner probe has a frequency response similar to a low impedance line section that is one quarter-wave long at the center frequency. The maximum available mismatch peaks at the center frequency, and drops off on either side. So if the specified bandwidth is narrow, fairly high matching is available. If a wider bandwidth is specified, then at the band edges, the available matching range will be reduced. The measured response of one model tuner of this type is shown in ***Figure 2***. In this case, there is a low frequency probe and a high frequency probe. Only one probe is used at a time, depending on the frequency of operation. The maximum VSWR vs. frequency of the two probes are overlaid on the plot to show the overall matching range vs. frequency for the two-probe tuner. This matching range is adequate for many applications where the fixture losses are low.

The frequency response of the High Gamma Tuner (HGT) is dramatically different. An HGT is shown in ***Figure 3***, and a typical HGT response is shown in ***Figure 4***. This tuner produces an extremely high mismatch over its entire frequency band, also with low and high frequency probes. Of course, as the probe is retracted away from the center conductor, the mismatch reduces very smoothly until the tuner again looks like a very good 50 Ω line. The probes are non-contacting for long life and good repeatability.

The high matching range of the HGT is very helpful in overcoming losses in a fixture or wafer probe. This has opened the door to on-wafer measurement of 35 dBm power devices,[1] since the high matching range allows matching of the low device impedance. This saves a tremendous amount of turn-around time and expense during device design and production stages. The high matching range of the HGT over its full band is also very effective in harmonic tuning.

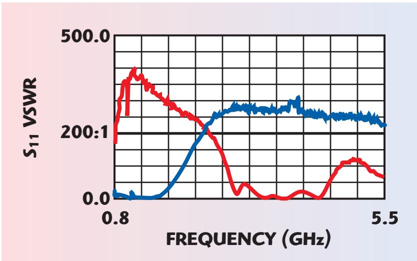
INTRODUCTION TO HARMONIC TUNING

Harmonic load pull consists of controlling the source or load impedance at a harmonic of the fundamental frequency. For example, if the



▲ *Fig. 2 Frequency response of a traditional slide screw tuner.*


▲ *Fig. 3 High Gamma Tuner.*



▲ *Fig. 4 Frequency response of a High Gamma Tuner.*

DUT operating frequency is 2 GHz, then harmonic load pull might vary the impedance at the second harmonic, which is 4 GHz. The measured data would still be at the fundamental frequency, but the harmonic load pull would show the effect of the harmonic impedance on the fundamental frequency operation.

Harmonic load pull primarily affects efficiency and linearity parameters. Efficiency is usually computed as power-added efficiency, which is the ratio of RF power added by the DUT divided by the DC power into the DUT. Linearity is measured with a variety of parameters, including two-tone intermodulation, ACPR, ACLR, EVM, PM/PM, or AM/PM. All of these parameters show how the performance changes as a function of power level.

An example of harmonic load pull data is shown in ***Figure 5***. This is a plot of efficiency at the fundamental frequency vs. the second harmonic impedance. All other variables, including the DC bias, RF input power and fundamental impedances were held constant. There are 14 contours plotted, with each contour representing a one percent efficiency change, so the harmonic impedance changed the efficiency by over 14 percent. The worst efficiency is in the upper right part of the Smith chart, and the best efficiency is in the lower part of the chart. Note that efficiency is not very sensitive to impedance in the area of the chart that gave the best values.

In amplifier design, efficiency and linearity parameters often produce a conflicting trade-off. Higher efficiency may come with worse linearity, and vice versa. Harmonic load pull will often find impedance combinations that will allow both to improve together.

Harmonic load pull is really only useful when the fundamental impedance is already tuned up fairly well. If the fundamental impedance is off, then the DUT will not be operating very well, and the harmonic impedance will not matter. Also, DUT operation is typically very sensitive to the fundamental impedance, so it is important for the harmonic tuning to be independent of the fundamental impedance. Without this tuning isolation between the harmonic and fundamental impedances, the resulting data may not be meaningful.

Harmonic load pull is also only useful when the DUT is operating in a nonlinear mode and generating harmonic energy from the fundamental frequency input. The data in Figure 5 was taken with the DUT somewhat saturated. In back-off operation, the harmonic load pull may have less effect. Nevertheless, this shows that harmonic tuning is an important tool for optimizing DUT performance.

Most of the time, the best harmonic impedance will be at the edge of the Smith chart. There are exceptions, but power delivered at the harmonic is generally undesirable, so it should be all reflected back to the DUT at an appropriate reflection phase to allow the signals to recombine advantageously. In that case, a harmonic tuner that tunes only at the edge of the Smith chart may be sufficient to show the best reflection phase to optimize the DUT operation. However, as shown in Figure 5, tuning over the entire chart may give insight about tuning sensitivities. Also, even if losses limit the harmonic reflection magnitude, the measurement is still quite useful because the best phase can still be clearly seen.

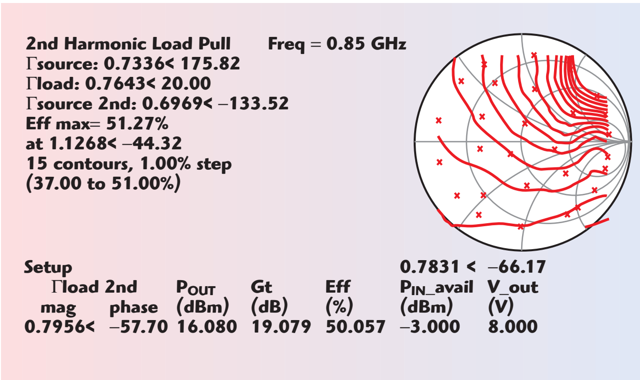
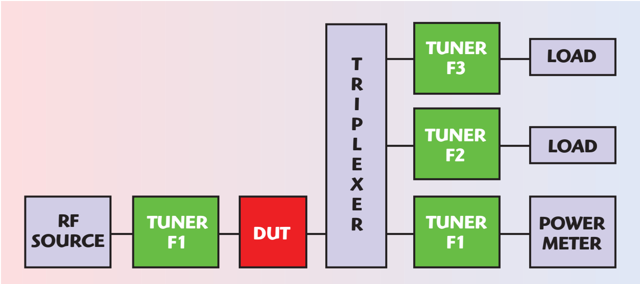


Fig. 5 Efficiency contours from a second harmonic load pull.

HARMONIC TUNING METHODS

There are several methods of harmonic tuning. Some of the most common methods of passive tuning include the Fixed Impedance method, the Multiplexer



▲ *Fig. 6 Block diagram of the Multiplexer method of harmonic tuning.*

method, the Cascaded Tuner method and the Stub Resonator method. No single method is perfect, as there are benefits and weaknesses to each method. The best method depends on the specific needs.

The Fixed Impedance method consists of putting a fixed harmonic circuit into a fixture. Often this might be just a shunt stub that reflects all the harmonic energy at the desired phase. This method is not exactly harmonic load pull, since it is not tunable, but it does control the harmonic impedance and it is simple and widely used in fixtured measurements.

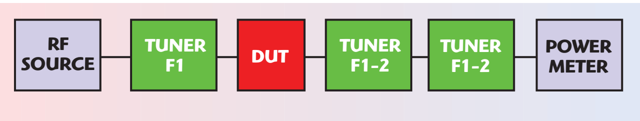
The Multiplexer method, as shown in ***Figure 6***, uses filters to separate the fundamental and harmonics. A triplexer has three filters. One path passes the fundamental and blocks all harmonics. The second path passes the second harmonic and blocks the fundamental and third harmonic. The third path passes the third harmonic and blocks the fundamental and second harmonic. Three separate tuners are used, each tuning only one harmonic (or fundamental) because that is the only energy that it sees.

The biggest benefit of the Multiplexer method is excellent accuracy due to very high tuning isolation between harmonics. This comes because the frequency separation between harmonics is fairly wide, so good isolation is easy for the filter designers. This method also provides uniform tuning over the entire Smith chart at each harmonic. This method is widely used, since these benefits have made it the method of choice for many applications. The disadvantages of the multiplexer approach include the need for a multiplexer for each band, since it is necessarily band limited. It also requires a more complex bench layout and has multiple outputs, which complicates some measurements. The multiplexer also has some loss, which reduces the tuning range by a small amount.

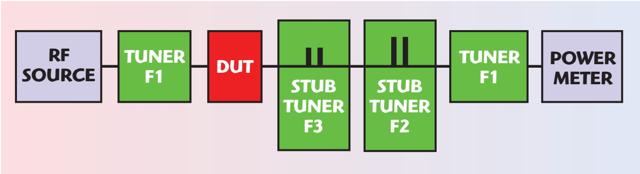
The Cascaded Tuner method, as shown in ***Figure 7***, combines positions of multiple cascaded tuners. For example, if the two cascaded load tuners in Figure 7 are both characterized at 1000 positions, then there are 1,000,000 possible combinations of characterized positions available. If all the combinations producing the same fundamental impedance are selected, a wide variety of harmonic impedances will be produced by those combinations. Measuring the DUT with the selected combinations would then be a harmonic load pull with the fundamental impedance held constant.

Two cascaded tuners produce two degrees of freedom, so the fundamental and the second harmonic may both be tuned independently, or the fundamental and the third harmonic may both be tuned independently. Three cascaded tuners produce three degrees of freedom so that the fundamental, second harmonic and third harmonic may all be tuned independently.

The benefits of the Cascaded Tuner method include the fact that no band limiting component is needed. The only limitation is the response of the tuners themselves. Also, the matching range is helped by not having a component between the DUT and tuners. In addition, it uses a fairly simple bench layout, with only one output. A disadvantage of the Cascaded Tuner method is limited tuning isolation. When multiple combinations are selected to give the same fundamental impedance, it is



▲ *Fig. 7 Block diagram of the Cascaded Tuner method of harmonic tuning.*



▲ *Fig. 8 Block diagram of the Stub Resonator method of harmonic tuning.*

really the same impedance within some tolerance. So a harmonic load pull also moves the fundamental impedance a little bit. Since the DUT performance is usually very sensitive to the fundamental impedance, it may be hard to separate the effects of moving the harmonic a lot vs. moving the fundamental a little. However, this problem may be overcome by constraining the harmonic impedance during a final fundamental load pull, since the harmonic is usually less sensitive.

The Stub Resonator method is shown in ***Figure 8***. The first tuner reflects all the third harmonic energy with a controllable phase. The second tuner reflects all the second harmonic energy with a controllable phase. The third and final tuner then is a normal tuner to tune the fundamental frequency.

The two harmonic tuners each consist of two shunt open stubs that are one quarter-wave long at the particular harmonic. This reflects all that harmonic energy back to the DUT, and the reflection phase is controlled by sliding the stubs along the center conductor. The stubs connect to the center conductor with a metal spring.

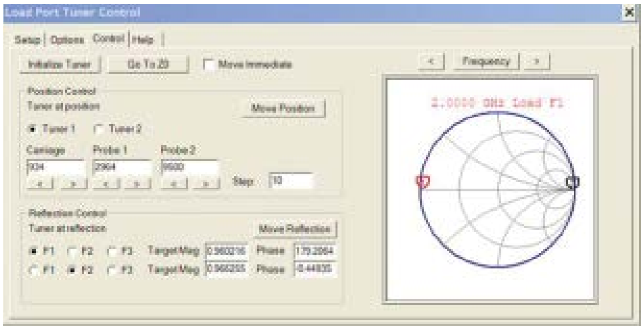
The benefit of the Stub Resonator method is a fairly simple bench layout. There are some major disadvantages to the Stub Resonator method. It has very poor tuning isolation. Tuning the harmonic has a fairly significant effect on the fundamental impedance. This problem can be reduced by re-tuning the fundamental after the harmonics are set, but the poor isolation may require multiple iterations. It is very narrow band—separate resonators are required for every frequency, and the tuners must be recalibrated when the resonators are changed. The sliding contacts may work fairly well when new, but tend to become unreliable after some use the loss of the harmonic tuners limits the tuning range of the fundamental tuner.

HARMONIC TUNING WITH THE HIGH GAMMA TUNER

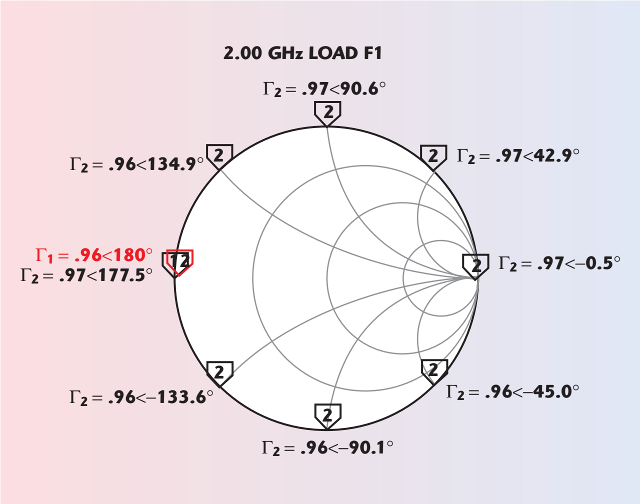
The low loss and high matching range of the HGT make it an ideal tuner for use with the Cascaded Tuner method of harmonic tuning. ***Figure 9*** shows a software Tuning Control Panel with the Cascaded Tuner method of Figure 7 selected for harmonic tuning. The Position Control block shows the physical tuner positions. The Reflection Control block shows or sets the target gamma for each harmonic. Markers on the Smith chart show the actual gamma produced by the current combination of tuner positions. Marker 1 shows the fundamental gamma, and marker 2 shows the second harmonic gamma.

For this setup, the load pull operator would enter a target magnitude and phase for both the fundamental and second harmonic gammas in the Reflection Control block. Clicking on "Move Reflection" would then move the tuners and update the entries to show the actual gammas achieved. Alternately for this setup with two tuners, the fundamental and third harmonic could be controlled.

Figure 10 shows an overlay of several Smith charts from the Tuning Control Panel. It shows the markers as the second harmonic gamma is swept around the edge of the Smith chart in 45° increments. During this



▲ *Fig. 9 Software Tuning Control Panel from Maury.*



▲ *Fig. 10 High gamma harmonic tuning at all reflection phases.*

second harmonic tuning sweep, the fundamental gamma remained constant at 0.96 magnitude with 180° phase. The magnitude of the second harmonic gamma was either 0.96 or 0.97 at every phase angle around the Smith chart. This high gamma at every phase combination for both the fundamental and harmonic impedances is only possible with the High Gamma Tuners. This provides an excellent solution for testing low impedance power devices.

SUMMARY

Load pull is necessary to test non-linear power devices. Harmonic tuning consists of controlling the harmonic impedance independent of the fundamental impedance as seen by the DUT. High Gamma Tuners provide a much higher matching range as compared to traditional mechanical tuners, and the high matching range applies to the entire operating bandwidth. This is very useful for matching high power devices that have very low impedances, especially with the losses of a fixture or wafer probe.

Harmonic tuning is useful to improve efficiency and linearity of non-linear power devices. In most cases, it is desirable to set the harmonic impedance to a high reflection, and just select the right phase to get the best DUT performance at the fundamental frequency. There are several methods of harmonic tuning that have been used in the industry, but the Cascaded Tuner method when used with High Gamma Tuners provides some of the best performance available. Very high gammas are available for both the fundamental and harmonic impedances at any phase combination. ■

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A HARMONIC AND SIZE REDUCED RING HYBRID USING HAIRPIN-TYPE LUCS

New hairpin-type low pass unit cells (LUC) are applied to the design of a microstrip hybrid ring for size reduction and harmonic suppression. This LUC is superior to the previously reported LUC in the simplicity of its structure and its ability to suppress harmonics. By substituting the LUCs for each one of the six λ/4 portions of the conventional hybrid ring, significant size reduction and excellent harmonic suppression have been achieved without degrading the hybrid characteristics themselves. The area size of the fabricated hybrid ring is reduced to one fourth of the conventional one. The simulated and measured responses show that not only the third but also the fifth harmonics are suppressed by approximately 20 dB.

The hybrid ring has been widely used in microwave systems, due to its simplicity and performance. Because of the long electrical length of the ring itself, size reduction is becoming a major design consideration for many practical applications. Furthermore, when designing a microwave system, how to effectively handle the harmonic signals from nonlinear devices is one of the decisive factors for system performance. For these reasons, many attempts to reduce the size and/or harmonics of the hybrid ring have been reported.[1–6,8]

To simultaneously achieve a significant size reduction and harmonic suppression, a low pass unit cell (LUC) was proposed to design the hybrid ring.[4,5] The hybrid was one fourth of the conventional one in size, and the third harmonics are suppressed by approximately 20 dB. However, due to the complicated LUC structure, close attention had to be paid to the LUC's arrangement, which includes the bending of six open stubs and considering the parasitic effects from the complexity in designing the ring hybrid. In this article, to solve the problem and reduce additional harmonics, a new miniaturized ring hybrid is proposed, in which an LUC is used, simply composed of a parallel-coupled line of the hairpin-type and two short transmission lines.

DESIGN

The prototype of the hairpin-type coupled line was used to design a compact low pass fil-

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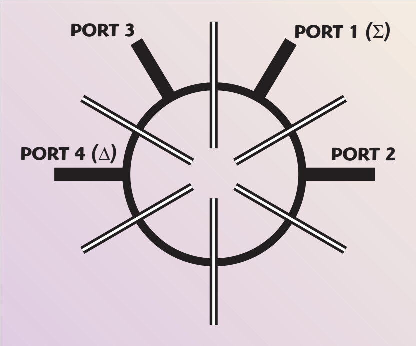
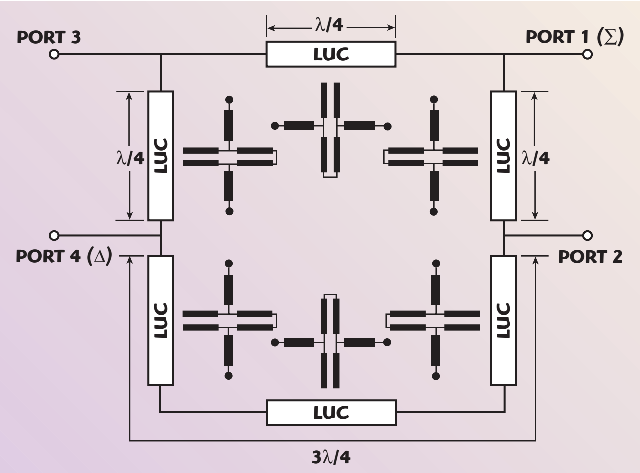
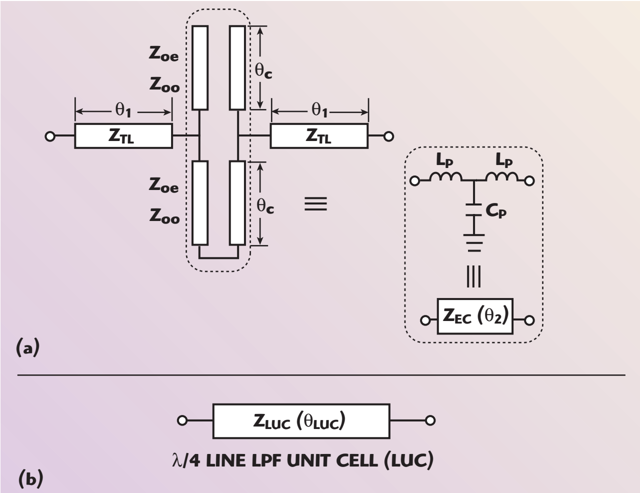


▲ *Fig. 1 Layout of the proposed ring hybrid.*



▲ *Fig. 2 Ring hybrid configuration using six LUCs.*



▲ *Fig. 3 The proposed LUC structure (a) and its equivalent λ/4 LUC line (b).*

ter with a wide stopband.[7] It is possible to create its equivalent circuit to be a λ/4 transmission line, maintaining the low pass filter (LPF) characteristic, by adjusting the dimensions. This LUC is superior to the previously reported LUC in the simplicity of its structure and its ability to suppress the harmonics.

Figure 1 shows the proposed ring hybrid layout; its schematic configuration is shown in ***Figure 2***. Here, the transmission line sections of the conventional ring hybrid are replaced by six LUCs. The LUC and its equivalent transmission line model are shown in ***Figure 3***. A coupled line, shown in the dotted line box, for which the electrical length is λ_g ($4\theta_c$) at $3f_0$, is connected with two short transmission lines (θ_1), as shown. The coupled line is considered as a transmission line (θ_2).

Using Equations 1 to 3 and a process similar to the one reported previously,[4] one can obtain the proper LUC, which has the properties of an equivalent λ/4 transmission line ($2\theta_1 + \theta_2$) with an impedance of 70.7 Ω. The ABCD-parameter of the LUC, $[\cdot]_{LUC}$, can be defined by the matrix $[\cdot]_{TL}$ and $[\cdot]_{LB}$ for $Z_{TL}(\theta_1)$ and $Z_{EC}(\theta_2)$, respectively, as follows:

$$\begin{bmatrix} A_T & B_T \\ C_T & D_T \end{bmatrix}_{LUC} = \begin{bmatrix} A & B \\ C & D \end{bmatrix}_{TL} \begin{bmatrix} A & B \\ C & D \end{bmatrix}_{LB} \begin{bmatrix} A & B \\ C & D \end{bmatrix}_{TL} \quad (1)$$

$$A_T = D_T = K^2M - \omega C_p Z_{TL} KL + jY_{TL} KLN - L^2M$$
$$B_T = K^2N + j2Z_{TL}KLM - j\omega C_p Z_{TL}^2 L^2$$
$$C_T = j2Y_{TL}KLM + j\omega C_p K^2 - Y_{TL}^2 L^2 N \quad (2)$$

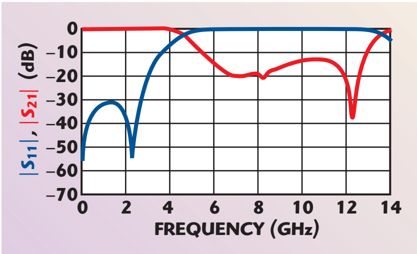
where

$$K = \cos\beta_1 l_1$$
$$L = \sin\beta_1 l_1$$
$$M = 1 - \omega^2 L_p C_p$$
$$N = j2\omega L_p - j\omega^3 L_p^2 C_p \quad (3)$$

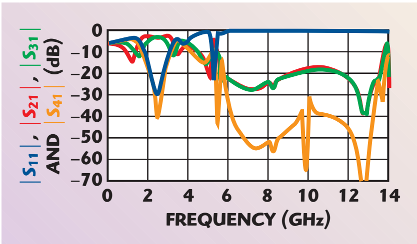
The properties of the LUC are shown in ***Table 1*** and ***Figure 4***. The stopband of the LUC is extended up to the fifth harmonic for this hybrid design. Also, the physical length of the LUC is only 8.95 mm, compared to the conventional λ/4 line, which is 19.12 mm at 2.45 GHz, a 53 percent reduction. The miniaturized and harmonic-suppressed hybrid ring can then be designed by using the LUCs instead of the six λ/4 lines of the conventional hybrid.

SIMULATION AND MEASUREMENT

The simulated results of the hybrid ring using LUCs, obtained with the circuit simulator ADS™, are shown in ***Figure 5*** and with the EM program HFSS™ in ***Figure 6***. The



▲ *Fig. 4 Simulated S-parameters of the LUC.*



▲ *Fig. 5 Circuit simulation results for the proposed hybrid ring coupler.*

TABLE I

PHYSICAL PARAMETERS OF THE LUC

$Z_{IL}(\theta_1)$ Line (mm)	Coupled Line θ_C (mm)	Microstrip Substrate
Width: 0.97	Width: 0.40	ε_r: 3.38
Length: 4.00	Space: 0.15	Loss tan: 0.0042
Z_{IL}: 70.7 Ω	Length: 5.60	Thickness: 0.762 (mm)

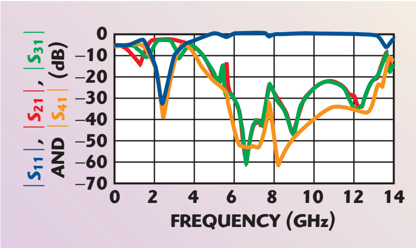
substrate used is WINUS IS640-338 with a thickness of 0.762 mm, ε_r = 3.38 and a tan δ = 0.0042. The power division, impedance matching and isolation properties, in the passband at approximately 2.45 GHz, are as good as a conventional one. In the EM simulation, the harmonics are suppressed by more than –23 dB up to 13 GHz.

Figure 7 shows a photograph of the proposed and conventional hybrid ring couplers, both having the same center frequency of 2.45 GHz. The area size of the proposed hybrid ring is reduced to one fourth of the conventional one. The measured results are shown in ***Figure 8***. They agree well with the EM simulated results, for power division, matching, isolation and harmonic suppression properties. The measured losses in the passband, including SMA connectors, are 0.20 and 0.31 dB at ports 2 and 3. The reflection coefficient at port 1 and the isolation between port 1 and port 4 are both better than 15 dB. Good in-phase (within ±1.5°) and out-of-phase (180° ±1.5°) characteristics are also obtained

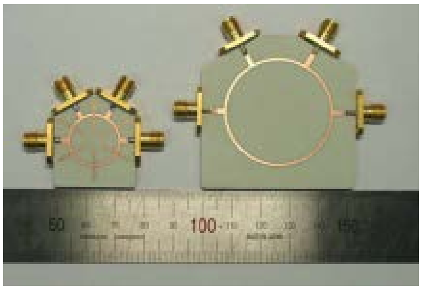
Furthermore, this hybrid ring suppresses not only the third but also the fifth harmonics by more than –20 dB. Considering the simplicity of the structure, this is an important figure of merit compared to the one reported previously.[4]

CONCLUSION

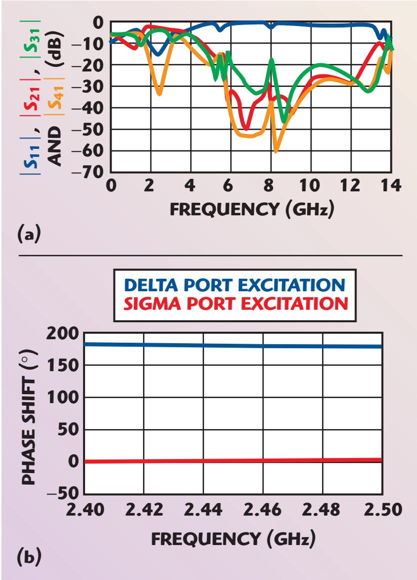
A new compact hybrid ring structure is proposed, with significantly re-



▲ *Fig. 6 EM simulation results for the proposed hybrid ring coupler.*



▲ *Fig. 7 The proposed and conventional hybrid ring coupler.*



▲ *Fig. 8 Measured results for the proposed hybrid ring coupler; (a) S-parameters and (b) in- and out-of-phase properties.*

duced size and good harmonic suppression properties, simultaneously. It is based on a simple hairpin-type LUC, showing a broad stopband characteristic. The proposed hybrid ring has not only the same advantages as the one reported previously, but also the additional ability to suppress harmonics, up to the fifth, and also simplicity of the structure and fabrication. The measured and simulated results show high harmonic suppression (> 20 dB) up to 13 GHz without degradation of the passband characteristics (f_0 = 2.45 GHz). The ring area size of the proposed ring hybrid is only one fourth of the conventional one. ■

ACKNOWLEDGMENT

The authors wish to thank AMOTEC Co. Ltd. for its discussion about industrial trends.

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CALCULATING MISMATCH UNCERTAINTY

Mismatch uncertainty is a very common and often underestimated source of error in microwave power measurements. It arises from an incomplete knowledge of the phase of the reflection coefficients of the source and load impedances, plus their interconnection, and is usually a large component of the overall measurement uncertainty budget in a microwave power transfer. It is easy to estimate and should not be ignored.

THEORY

From ***Figure 1***

$$b_1 = a_2 = b_s + a_1\Gamma_s$$

and

$$b_2 = a_1 = a_2\Gamma_l$$

so

$$a_2 = b_s + a_2\Gamma_s\Gamma_l$$

$$a_2\left(1-\Gamma_s\Gamma_l\right) = b_s$$

$$a_2 = \frac{b_s}{\left(1-\Gamma_s\Gamma_l\right)} \qquad (1)$$

and

$$b_2 = \frac{b_s\Gamma_l}{\left(1-\Gamma_s\Gamma_l\right)} \qquad (2)$$

The power absorbed in the load is

$$P_a = |a_2|^2 + |b_2|^2 = |b_s|^2 \frac{1-|\Gamma_l|^2}{\left|\left(1-\Gamma_2\Gamma_l\right)\right|^2} \qquad (3)$$

The numerator of the fraction, $1-|\Gamma_l|^2$, is known as the mismatch loss. If only the voltage reflection coefficient magnitudes of the source and load are given, and not their phases, the denominator term cannot be evaluated precisely. However, the maximum and minimum values can be determined.

$$P_a \le |b_s|^2 \frac{1-|\Gamma_l|^2}{\left(1-|\Gamma_s||\Gamma_l|\right)^2}$$

$$P_a \ge |b_s|^2 \frac{1-|\Gamma_l|^2}{\left(1+|\Gamma_s||\Gamma_l|\right)^2} \qquad (4)$$

To derive an easily remembered approximation for these formulae, using the binomial series

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$$\frac{1}{(1+z)^m} = (1+z)^{-m} = 1 - mz + \frac{m(m+1)}{2!}z^2 - \frac{m(m+1)(m+2)}{3!}z^3 + \ldots \qquad (5)$$

If this series is truncated to the first two terms, and z is replaced by product $|\Gamma_s||\Gamma_l|$ and m by 2, then

$$P_a = |b_s|^2 \frac{1-|\Gamma_l|^2}{|(1-\Gamma_s\Gamma_l)|^2} \cong |b_s|^2\left(1-|\Gamma_l|^2\right)\left(1 \pm 2|\Gamma_s||\Gamma_l|\right) \qquad (6)$$

The approximation is valid for $|\Gamma_s||\Gamma_l| << 1$, and the mismatch uncertainty is given approximately by $M_u = \pm 200\,|\Gamma_s||\Gamma_l|\%$. Some examples will clarify the sizes of the errors involved.

Example 1

A power sensor with a VSWR of 1.2:1 is connected to a signal generator with a VSWR of 1.5. What is the mismatch uncertainty?

Solution:

First the VSWR figures are converted to reflection coefficient magnitudes:

$$\rho_l = \frac{VSWR-1}{VSWR+1} = \frac{(1.2-1)}{(1.2+1)} = 0.091 \qquad (7)$$

$$\rho_g = \frac{VSWR-1}{VSWR+1} = \frac{(1.5-1)}{(1.5+1)} = 0.2 \qquad (8)$$

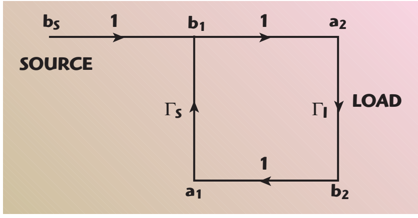
Then the mismatch uncertainty is: M_u = ±200 (0.091) (0.2%) = ±3.64% or ±10 × log10(103.64/100) = ±0.155 dB.

Example 2

A power sensor with a return loss of –23 dB is connected to a calibration source with a return loss of –20 dB. What is the mismatch uncertainty?

Solution:

First the return loss figures are converted to reflection coefficient magnitudes:



▲ *Fig. 1 Signal flow diagram for source and load.*

$$\rho_l = 10^{(RL/20)} = 10^{-23/20} = 0.071 \qquad (9)$$

and

$$\rho_g = 10^{(RL/20)} = 10^{-20/20} = 0.1 \qquad (10)$$

Then the mismatch uncertainty is: M_u = ±200 (0.071) (0.1%) = ±1.41% or ±10 × log10(101.41/100) = ±0.061 dB.

CONCLUSION

Mismatch uncertainty can explain some of the variation that is seen when repeating microwave power measurements when the test set-up is slightly different from the original. Perhaps an adaptor with a different electrical length was selected, or a connector might have been tightened with and without a torque wrench. A deeper analysis[1] suggests that the more extreme values are actually quite likely. Calculating the mismatch limits is straightforward and serves to set expectations of repeatability. ■

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EXTENDING ELECTROMAGNETIC SIMULATION AND ANALYSIS FROM VERIFICATION TO DESIGN

Electromagnetic (EM) simulation provides accuracy at the expense of speed. In situations where accuracy is crucial and the problem size large, such as compacting an RFIC or complex RF board onto a small area to meet cost and size requirements, simulation times can be unbearably long. When each simulation takes more than a day to complete, the designer's patience and desire to use EM analysis soon runs out. This is why EM is often used as a last resort or as a one-time, sign-off verification tool rather than the accurate, interactive design tool that it can be.

Transforming EM from a verification to a design tool is the focus of the latest release of Momentum, the 3D planar EM simulator from Agilent EEsof EDA. Innovations that include algorithmic improvements in meshing and solving, together with computing usage of multi-core threading and multi-computer parallelism, give at least a 10x improvement in simulation speed with greatly reduced memory usage. This enables large problems to be solved accurately in hours instead of days. The improved Momentum simulator is part of the Advanced Design System (ADS) 2008 and RF Design Environment (RFDE) Update 1 release.

MOMENTUM TECHNOLOGY IMPROVEMENTS

The 10x speed improvement is generated through a combination of new features, including:

- A layout pre-processor to remove layout inconsistencies.
- A new, multi-level compression matrix solver for faster loading and convergence.
- Multi-threaded simulations on single multi-core machines for fast parallel Momentum simulations.
- Distributed simulations on computer clusters for additional speed and performance improvements.

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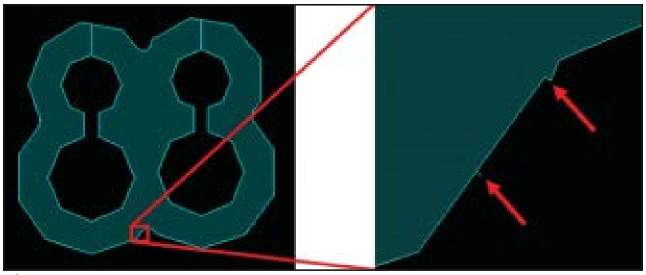
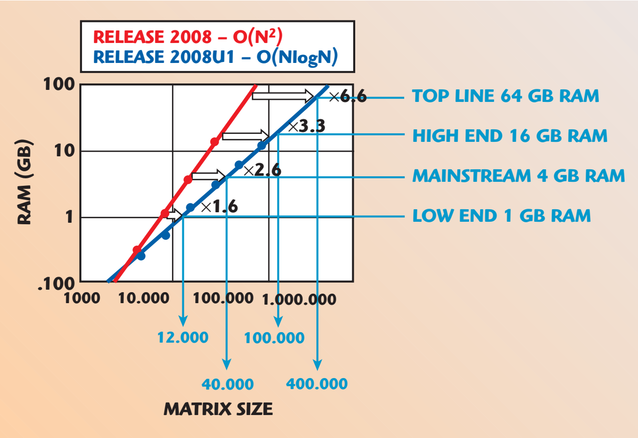


▲ *Fig. 1 Layout inconsistencies are removed before Momentum creates the mesh that is needed for EM simulation.*



▲ *Fig. 2 O(Nlog N)$^{1.5}$ matrix breaks down the capacity limit, significantly increasing the complexity of the designs that can be solved.*

LAYOUT PRE-PROCESSOR

Momentum works at the physical design level and therefore needs a layout from which to start its computations. The principles that guide mask generation from layout information are not the best for simulation. Masks contain overlaps and long and narrow wedges that can lead to ill-defined mesh elements and ultimately to a lack of simulation convergence. Momentum now contains a layout pre-processor that removes visible and invisible layout resolution problems prior to meshing (see ***Figure 1***).

MULTI-LEVEL COMPRESSED MATRIX SOLVER

More complex problems solve much faster with Momentum's new matrix solver, as shown in ***Figure 2***. The order reduction of the momentum solver enables a faster direct solver method that uses less memory. The new direct solver algorithm brings problems that once took a day to solve to below an hour of simulation time through improved convergence and load times.

Figure 3 shows how the different solvers have increased simulation speeds. The classic direct LU factorization solver simulation time grows at the rate of O(N^3) while an iterative solver reduces it to O(N^2), where N is the number of unknowns representing the problem size. The latest multi-level compressed matrix direct solver reduces simulation times further to grow at only O(NLogN)$^{1.5}$.

MULTI-THREADED SIMULATIONS ON SINGLE MULTI-CORE COMPUTERS

Modern-day computers have dual cores as a standard feature. Optimal use of the available cores on today's computers help to parallelize Momentum simulations.

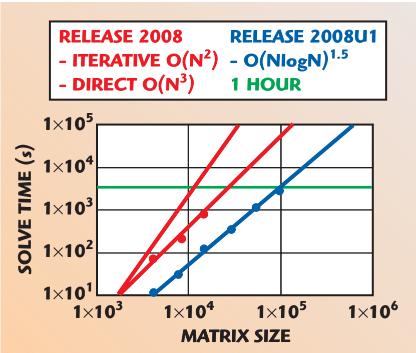
Figure 4 compares the S_{11} simulation results of a 16-element array of a multilayer-aperture-coupled antenna. The simulations show a 3x simulation speed-up and a 40 percent memory reduction.

DISTRIBUTED SIMULATION

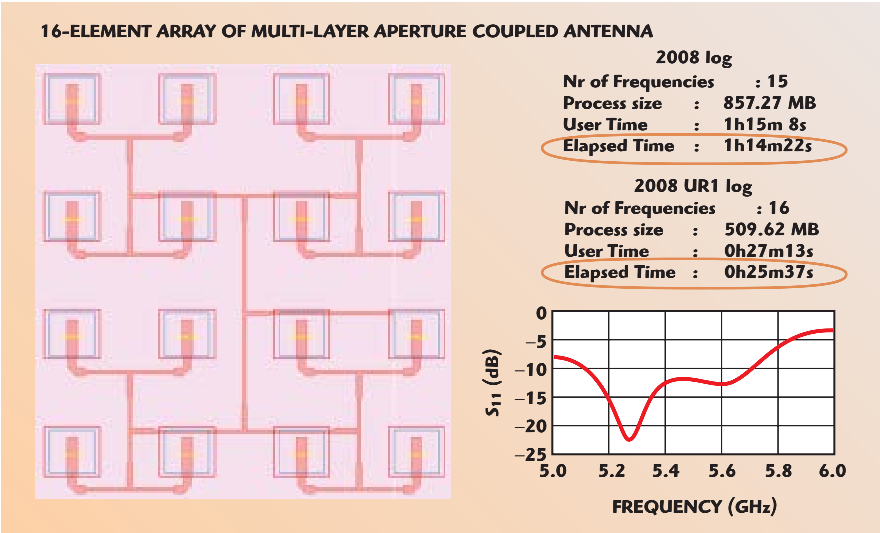
With Momentum's distributed simulation feature, designers can spin off a simulation to a different machine in a computer cluster for every frequency point in the simulation. Multi-grid structures can make use of their full capacity to speed up simulation; multi-threaded simulation processes running on separate computers will yield additional speed.

EXAMPLE: POWER AMPLIFIER DESIGN AND OPTIMIZATION FOR A WLAN 802.11B TRANSCEIVER

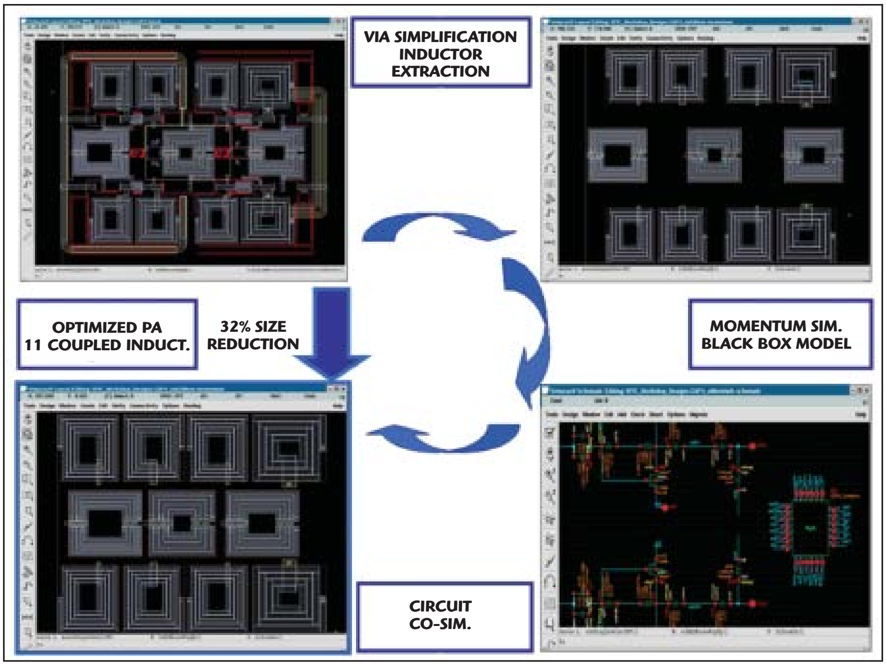
Silicon power amplifier design has thus far been the realm of synthesis tools that allow generation of spiral inductor models and RF interconnects, but perform poorly in providing true, whole-chip EM optimization and verification. The new Momentum engine provides full planar 3D simulation of the inductors of the power amplifier in less than a minute, making optimization practical. The die size was re-



▲ *Fig. 3 Matrix load time scales O(NlogN)$^{1.5}$ so the direct compressed matrix solver is fast with no convergence problems.*



▲ *Fig. 4 Parallel processing examples for performing Momentum simulations on multi-core computers (Platform: LINUX RHEL4, 64 bit, 4 GB RAM).*



▲ *Fig. 5 Power amplifier design for a WLAN 802.11b transceiver.*

duced by over 32 percent through planar EM simulation of an existing power amplifier, directly impacting chip performance and costs.

The power amplifier shown in ***Figure 5*** has 11 coupled inductors, the effects of which need to be taken into account along with the electrical behavior of the circuit. The design and simulation flow consists of the following steps:

1. A via simplification algorithm to remove irrelevant vias.
2. An inductor extraction process.
3. The Momentum simulation of the 11 coupled inductors leading to the black-box generation using S-parameters.
4. The black-box circuit co-simulation.

A power gain compression and power-added efficiency simulation of the power amplifier was then performed, while optimizing the structure to occupy a minimal footprint. ***Table 1*** shows an analysis of the ef-

TABLE I

ANALYSIS OF THE EFFECT OF SPIRAL INDUCTOR PLACING ON PA CHARACTERISTICS

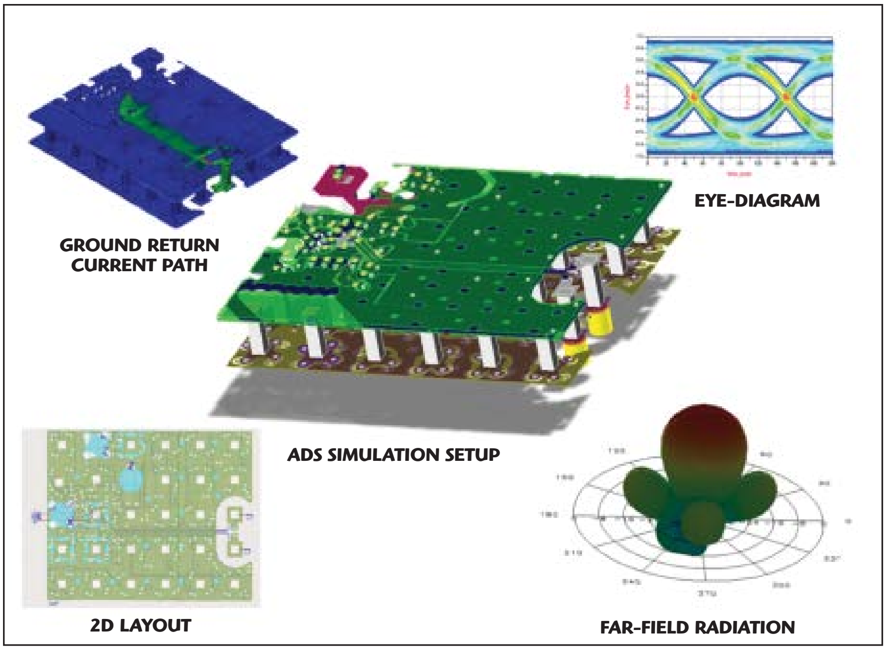
	Before Optimization	*After Optimization*
11 spirals – area (μm)	975 × 800	810 × 650 (32% reduction)
Small-signal gain (dB)	29 with 35 dBm IP3 point	25.7 with 31.3 dBm IP3 point
1 dB gain compression output power (from a two-tone simulation) (dBm)	19	17 power-added efficiency is also much lower

TABLE II

A MOMENTUM SPEED AND MEMORY COMPARISON FOR SIMULATION OF THE PA FOR THE WLAN 802.11b TRANSCEIVER*

	RFDE/ADS 2008	*Update 1*	*Distributed Simulation*
# unknowns	11372 (5513)		
Memory	1.15 GB	651 MB	8 computers
Simulation time; 0 to 50 GHz, 11 freq. points	37m47s	12m06s	Simulation time/5 2 to 3 m

*See Figure 5



▲ *Fig. 6 Signal integrity verification.*

fects of placing the spiral inductor on the power amplifier. The table shows that the power amplifier footprint was reduced by 32 percent. Follow-on optimization runs can take the amplifier specifications into account.

With Momentum for RFDE/ADS 2006A, a machine with 2 GB of RAM was unable to simulate all 11 spirals together, because the simulation ran out of memory. Instead, the four bias spirals were simulated together and the three spirals in the signal path were simulated individually. With the new Momentum release, all 11 of the spirals can be simulated together using about 1.2 GB of RAM and taking 38 minutes on the same machine. Today's Momentum cuts the problem size in half and triples the simulation speed using the multi-level compressed matrix solver, as shown in ***Table 2***.

SIGNAL INTEGRITY VERIFICATION

Another excellent application for the new Momentum simulator is for signal integrity verification of high-speed digital designs. ***Figure 6*** shows an example of a multi-gigabit PCB board for a high speed serializer/deserializer (SERDES) chip where the serial link between the chip and board interconnect must preserve signal integrity for optimal BER and eye diagram opening. For signal integrity verification, structures of several wavelengths quickly become challenging: For accurate simulation, at least eight frequency points per turn on the Smith chart need to be considered.

This previously unsolvable structure with 30,000 unknowns in earlier Momentum versions can now be solved for 77 frequency points in under two hours, with 1.7 GB of memory on a quad-core machine. Parallelizing the simulation on n number of machines can yield another (n–2)x of speed-up.

CONCLUSION

RFIC designers can now use full EM simulation in their design work, and not just as a verification tool. Simulations that took days to finish and were used only to verify the final design can now be run in minutes, bringing design and optimization well within reach. In addition, structures that can be verified for signal integrity problems with Momentum are limited only by the number of parallel computers in the distributed network.

To learn more about Agilent's Momentum planer EM simulator, visit www.agilent.com/find/eesof-momentum. For more information about all of Agilent's EEsof EDA solutions, visit www.agilent.com/find/eesof.

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TO 20 GHZ AND BEYOND: AN INVESTIGATION INTO PASSIVE TEMPERATURE COMPENSATION

The current drive for increased bandwidth will ultimately pressure the wireless community to exploit higher operational frequencies beyond 20 GHz. A major obstacle associated with high frequency operation is signal distortion which can be the result of nonlinear effects, typically introduced by active devices. Signal distortion resides on the forefront of each engineer's mind and must be accounted for. The distortion can be compensated by using complex linearizing circuits or simply accounted for in the link budget as a power penalty. This penalty will adversely affect the overall communication system efficiency, resulting in higher operational costs over the lifetime of the system. Many designers will go to great lengths to maximize the reliability of a design and minimize complexity, which eventually prompted the birth of a passive temperature compensation solution for amplifiers.

Market available GaAs- and GaN-based amplifiers specified past 20 GHz tend to be very temperamental with respect to changes in operational temperature. Generally speaking, transistor gain (β) decreases with increasing temperature. This effect is self-compounding considering transistors are not 100 percent efficient and dissipate power as heat resulting in further heating and reduced gain.

Designs do exist where temperature variation is not that important; however, this is not the norm. Temperature induced gain variations must be considered for a majority of designs and are usually corrected by employing either passive or active compensation techniques. Active compensation is flexible and can be advantageous in some applications; however, this flexibility comes with a hefty price tag in performance related drawbacks, such as distortion introduction, system complexity and overall MTBF. The shortcomings of active compensation can be addressed with

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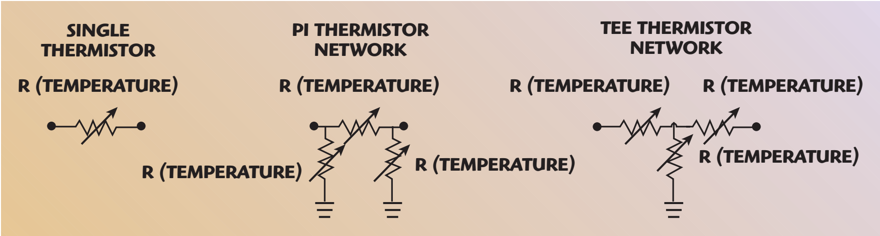


Fig. 1 Thermistor configurations.

an enhanced passive solution, which allows more temp-comp flexibility than previously available passive products while operating up to 40 GHz. The challenge is to provide enough passive temperature compensation to ensure stable, temperature invariant outputs from—55° to 125°C.

PASSIVE TEMP COMP HISTORY

Traditional passive temperature compensation techniques employ chip thermistors that respond quickly to changes in operating temperature. Thermistors are simply resistive elements with a predetermined temperature coefficient of resistance, usually specified in ppm, for linear temperature characteristics or β for exponential temperature characteristics. Either a single chip thermistor or a plurality of chip thermistors configured in a distributed PI or TEE structure can be used for temperature compensation requirements (see ***Figure 1***). This plurality of thermistors is comprised of thermistors with temperature coefficients that can be either positive or negative (PTC or NTC) and integrated into a single chip to provide optimum RF characteristics.

In a world where parasitics do not exist, the transfer function of a temperature variable attenuator (TVA) would follow the behavior exhibited in ***Figure 2***, which is a flat set of attenuation curves for three temperature points from DC to 40 GHz. With α_{-55C}, α_{25C}, α_{125C} being attenuation at –55°, 25° and 125°C, respectively.

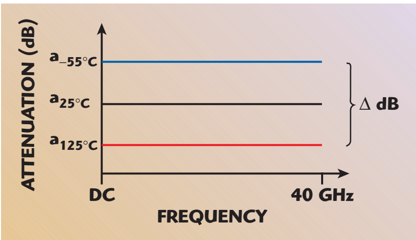


Fig. 2 Ideal temperature variable attenuator performance.

Ideally, the TVA will approach 0 dB at 125°C to minimize system loss. Due to this requirement, a figure of merit is used to quantify the normalized amount of temperature compensation, which is referred to as temperature coefficient of attenuation (TCA). TCA is used as a measure of compensation amount for a given nominal attenuation. TCA is determined by linear regression to calculate the best fit slope of attenuation vs. temperature and normalizing to nominal 25°C attenuation. The governing expression for TCA is:

$$\frac{n\sum_{i=m}^{n} i\alpha_i - \left(\sum_{i=m}^{n} i\right)\left(\sum_{i=m}^{n} \alpha_i\right)}{n\sum_{i=m}^{n} i^2 - \left(\sum_{i=m}^{n} i\right)^2} \bullet \frac{1}{\alpha_{25}}$$

where

α_i = attenuation in dB at "i" degrees C

$\alpha_i = \alpha_{-55}, \alpha_{-35}, \alpha_{-15}, \alpha_5, \alpha_{25}, \alpha_{45}, \alpha_{65}, \alpha_{85}, \alpha_{105}, \alpha_{125}$

During the manufacture of a TVA to be used in the GHz frequency range, ideal material properties, processing constraints and parasitic reactance come into play affecting the overall performance of the device. The end result of such non-ideal behavior can result in compression of temperature compensation as the operating frequency increases. The TCA becomes a function of frequency. This phenomenon is acceptable for many applications since the TCA frequency compression is a known, predictable quantity. An example of TCA compression can be seen in ***Figure 3*** and the corresponding TCA is plotted in ***Figure 4*** as a function of frequency.

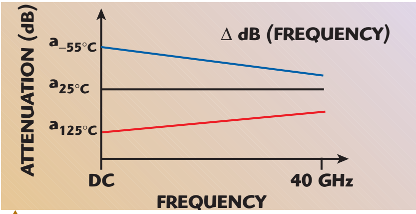
For applications requiring significant temperature compensation well into the GHz range, several TVAs are required to fully compensate a system. Referring to Figure 3, a 40 GHz application would require three times the number of TVAs as a 1 GHz application. This scenario also would introduce three times the nominal loss at 40 GHz. This exemplifies the need for a passive temperature compensation technique to improve TCA performance beyond 20 GHz.

PERFORMANCE MODELING, CORRELATION AND COMPENSATION

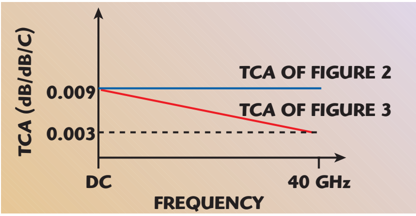
The high price of gain beyond 20 GHz is placing demands for more temperature compensation with less loss penalty, which is effectively a greater TCA. Creating accurate electromagnetic (EM) models in the design phase is critical when attempting to shorten the design cycle. Planar EM simulators can aid in the prediction of RF parasitics and discontinuities; however, some parameters can not be accounted for in the model and must be synthesized empirically. To empirically develop an enhanced EM model, it is imperative to compare simulated performance versus actual measured data. This comparison provides a significant amount of information for analysis and can be seen in ***Figure 5***. The corresponding TCAs as a function of frequency are plotted in ***Figure 6*** to help demonstrate the difference between expected performance across temperature and frequency and actual measured data. From the plot it is easy to see the measured data undergoes a TCA compression of approximately 80 percent from 4 to 36 GHz.

Having both predicted and measured data available, the original model can be modified to account for measurement discrepancies. This new model, referred to as the "enhanced model," can be utilized to more accurately predict the TVA performance. For example, analysis of the measured response in Figure 5 shows the transfer function of the attenuator begins to have mild, high-pass characteristics at the low temperature extreme. These characteristics appear due to stray, parallel capacitance across the series element of the attenuator network, as seen in ***Figure 7***, not to mention other random variables that contribute to this temperature dependant capacitance. This is the reason for an empirical solution versus and analytical approach.

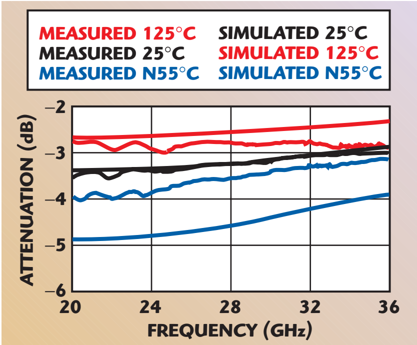
Adjusting the model to account for this temperature induced, capacitive event requires the addition of lumped-element, reactive components to the original model. With the information obtained in the comparative analysis, the correlation factors (reactance values) are fed back to the original TVA model. This feedback results in a correlated, "enhanced model" which now can be used for design optimization for specific TVA requirements. Adjusting the amount of reactance in the model at each temperature is adequate to provide a correlated model to be used for TVA synthesis. For example, the model used in the simulation to create the data in Figure 5 was adjusted with the



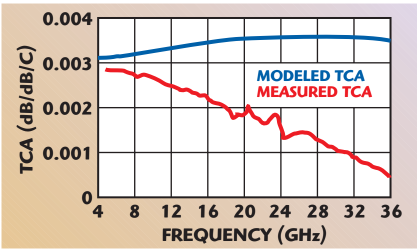
▲ *Fig. 3 Actual temperature variable attenuator performance.*



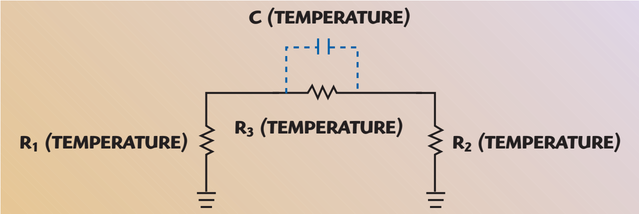
▲ *Fig. 4 TCA vs. frequency (ideal–blue; actual–red).*



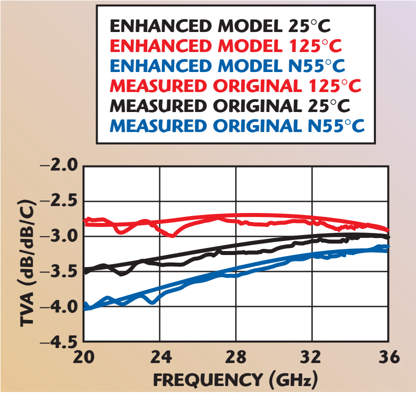
▲ *Fig. 5 Measured vs. modeled TVA performance.*



▲ *Fig. 6 Measured vs. modeled TCA performance.*



▲ *Fig. 7 Enhanced thermistor.*

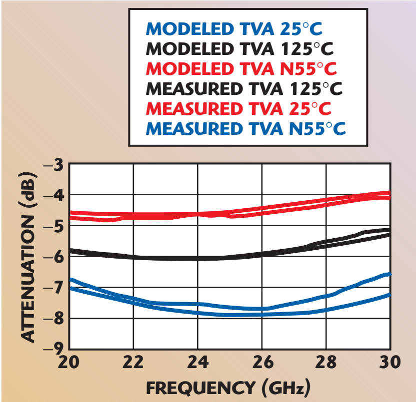


▲ *Fig. 8 Measured vs. enhanced TVA model.*

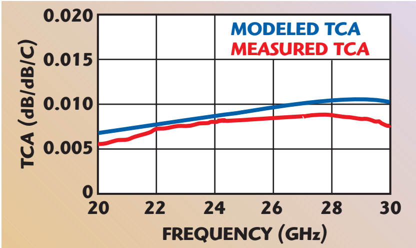
correlation factors empirically derived by the comparative analysis between the simulated and measured performance. This "enhanced model" was then re-simulated. The enhanced simulation data is superimposed on the original measurements and can be seen in ***Figure 8***.

Most Ka-band temperature compensation requirements are for the greatest TCA with the lowest nominal attenuation. Communication channels operating at Ka-band are generally upconverted signals having a small percent bandwidth. Because the bandwidth requirements are narrow, compensating the previously defined enhanced model can be accomplished by the introduction of a reactive tuning structure. As with any RF tuning, this technique will introduce frequency selection into the TVA design and ultimately limit the bandwidth of the TVA. This technique will mitigate the high-pass filtering effect.

Compensating the enhanced model to meet specific temperature compensation requirements can be accommodated by fabricating distributed reactance's on the same chip as the TVA.



▲ *Fig. 9 Compensated TVA model and measured attenuation.*



▲ *Fig. 10 Compensated TVA model and measured TCA.*

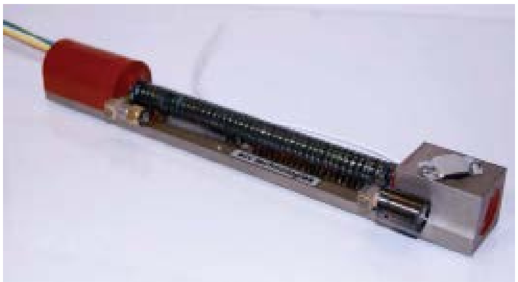
This allows a compact, single chip temperature compensation with a TCA as high as –0.010 dB/dB/C. The technique is currently proven out to 40 GHz, with approximately 2 GHz of bandwidth. A compensated TVA model along with the corresponding measured data can be seen in ***Figure 9*** with the TCA of each depicted in ***Figure 10***. This showcases EMC Technology's ability to accurately predict TVA performance, thus reducing the overall development cycle for RF temperature compensation.

CONCLUSION

Enhancements in modeling and measuring temperature variable attenuators has reduced the product design cycle. This has enabled EMC Technology to address current temperature compensation requirements that were once considered beyond the technology. The flexibility and reliability of this proven technology has paved a way for passive temp comp to be the choice for designers developing products operating as high as Ka-band.

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

RS No. 303



NEW GENERATION TRAVELLING WAVE TUBES

Building on its strong background in the development and production of Helix travelling wave tubes (TWT) for military airborne applications, e2v has developed a 'new generation' of TWTs that expands upon established airborne decoy applications and anticipates future system requirements. Over the past 20 years the company has manufactured broadband mini-TWTs (6 kV operating voltage) for use in airborne towed decoy systems. In the late 1990s, it developed a mini-TWT (4.5 kV operating voltage) for use in airborne towed decoy systems, which addressed major European and US military programs.

The standard mini-TWT range was based upon e2v's original broadband (4.5 to 18 GHz), 100 W, 4.5 kV device, designed primarily for high altitude (70,000 ft) and high temperature operation (> 140°C measured at TWT base plate). The new range of tubes also introduces custom narrow-band mini-TWTs, the goal being to supply a range of devices to meet future applications, including Electronic Counter Measures (ECM), Electronic Warfare (EW), Microwave Power Modules (MPM), Synthetic Aperture Radar (SAR) and microwave data links. Building upon present-day rugged and proven technology, these new tubes offer enhanced output power, frequency range and efficiency.

NEW GENERATION MINI-TWTs

Design modeling of key areas of the TWT, coupled with rapid prototyping has seen a new family of mini-TWT tubes evolve, using the standard mini-TWT as the host design vehicle. The result is three new mini-TWT ranges:

- The N20173 6 to 18 GHz TWT range, achieving a minimum 100 W
- The N20160 4.5 to 18 GHz TWT range, 140 W typical
- The N20154 13.75 to 14.5 GHz (Ku-band) TWT range, achieving a minimum 120 W

Key performance data, attributes and operating parameters for these three new devices are covered in this article.

E2V TECHNOLOGIES (UK) LTD.
Chelmsford, UK

THE N20173

Current standard mini-TWTs typically operate over this 6 to 18 GHz bandwidth, but fall short of output power in the upper frequency range. The design driver for the N20173 (shown in ***Figure 1***) was to increase the efficiency of the new device at higher frequencies without degrading performance at the lower end of the operating band. This was achieved by the use of a Slow Wave Structure (SWS) with a novel phase velocity taper.

Consequently, the new N20173 tube achieves >100 W over the full operating frequency band and the new RF structure reduces the second-harmonic output to < –9 dBc at 6 GHz. ***Figure 2*** shows the power to frequency performance of the N20173 compared to e2v's standard mini-TWT.

Also, an optimized coaxial TNC output achieves better than 2.2:1 VSWR and variants within the range include two- and three-stage collectors and a focus electrode switched option for pulsed or CW operation. The N20173 maintains the compact design of the standard e2v mini-TWT, being 220 mm long, 27 mm wide and 29 mm high, with a mass of less than 320 g. It can operate at base plate temperatures up to 140°C and altitudes up to 70,000 ft, under severe shock and vibration levels.

THE N20160

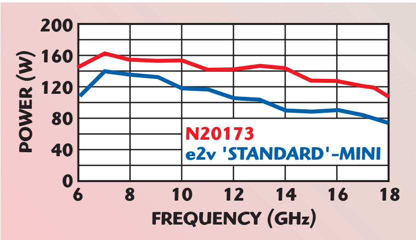
There has recently been increasing demand for higher-powered mini-TWTs capable of operation over the extended 4.5 to 18 GHz bandwidth. Thus, the N20160 device (shown in ***Figure 3***) has been designed as a drop-in replacement for the standard mini-TWT, capable of operation at the same voltages and maintaining the same space envelope.

The increased performance has been achieved through a combination of efficiency enhancement, the utilization of velocity tapers in the slow wave structure and increased beam current. The N20160 device also offers a minimum of 140 W between 6 and 13 GHz, more than 100 W at 18 GHz and more than 50 W at 4.5 GHz. The maximum RF drive required for saturation is +22 dBm, and the small-signal gain achieved mid-band is 59 dB.

With optimization of the slow wave structure it has been possible to enhance the second-harmonic performance, which is a dominant characteristic of multi-octave devices. The device typically achieves second-harmonic levels of +1 dBc at 4.5 GHz and –10 dBc at 6 GHz. ***Figure 4*** shows the power versus frequency performance of the N20160 compared to e2v's standard mini-TWT.

Pre-production N20160 models have been tested using both dual- and three-stage collectors, achieving prime powers of less than 460 W. This increased performance has been achieved while maintaining compact size and weight—220 mm long, 27 mm wide and 29 mm high, with a mass of 320 g.

▲ *Fig. 1 The N20173 mini-TWT.*



▲ *Fig. 2 The power vs. frequency performance of the N20173 and standard mini-TWT.*

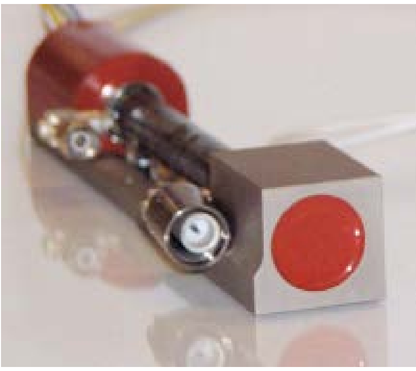
THE N20154

The N20154 mini-TWT (shown in ***Figure 5***) has been developed to satisfy the ever-increasing demand for low-cost, lightweight, high-efficiency, compact TWTs for communication and data link applications. The mini-TWT's design moves away from broadband convention and is optimized specifically for operation over the narrow communications band. This gives the advantage over broadband devices of improved linearity and gain flatness.

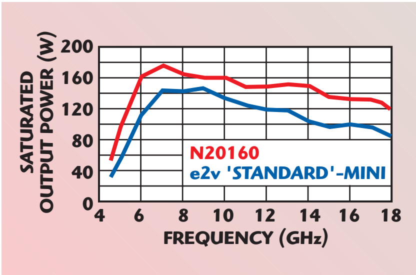
The RF circuit has been optimized around a negative velocity taper in order to achieve high circuit efficiency, combined with a multi-stage collector to realize an overall tube efficiency of greater than 33 percent. Output power across the band is 120 W minimum, with a small-signal gain of typically 52 dB. The linearity parameters are vital to communication tubes; the third-order IP performance at 4 dB Output Back-Off (OBO) is typically –22 dBc and –28 dBc at 7 dB OBO.

Other enhancements include optimization of the input and output VSWR to achieve better than 1.5:1 across the operating band. In order to meet the long operational life requirements of communications devices, the N20154 cathode has been designed to operate at less than 1.5 A/cm^2 current density. The packaged N20154 device weighs less than 280 g, is 171 mm long, 30 mm wide and 25 mm high, making it ideal for microwave power module applications.

Mechanical design of the N20154 shares many component parts and manufacturing processes with the standard e2v broadband mini-TWTs. This has resulted in a low-cost, high-reliability product that offers system manufacturers a serious alternative to



▲ *Fig. 3 The N20160 mini-TWT.*



▲ *Fig. 4 The power vs. frequency performance of the N20160 and standard mini-TWT.*

▲ *Fig. 5 The N20154 mini-TWT.*

TABLE I

PERFORMANCE CHARACTERISTICS OF THE NEW MINI-TWT SERIES

TWT Type	Operating Frequency (GHz)	Min. Output Power (W) Low Band	Mid Band	High Band	Cathode Voltage (V)	Prime Power (W)	Mass (g)	Size L × W × H (mm)
N20173	6.0 to 18	120	120	100	4550	430	320	220 × 27 × 29
N20160	4.5 to 18	50	140	100	4550	460	320	220 × 27 × 29
N20154	13.75 to 14.5	120	120	120	4500	380	280	171 × 30 × 25

solid-state amplifiers. ***Table 1*** shows the performance characteristics of the new mini-TWT series.

CONCLUSION

New generation mini-TWTs from e2v address the requirements of proven rugged design and enhanced RF performance characteristics. The latest three mini-TWT devices can be customized with dual- or three-stage collectors, SMA or TNC RF terminations, focus electrode switching and reduced gain power-booster versions. e2v will also consider bespoke packaging to meet specific customer requirements.

Looking forward, further design development and enhancement of the TWT product range continues, with planned efficiency enhancement through continued collector optimization. Further design targets include increased output power to 200 W, and the inclusion of a grid switched device. In addition, a narrow-band mini-TWT is under development, which will offer the (linearity, flatness) benefits seen in the Ku-band product but at X-band. This will complement the range and offer a compact lightweight device suitable for MPMs, radar and SAR applications.

e2v technologies (UK) Ltd.,
Chelmsford, UK
+44 1245 453 453,
e-mail: enquiries@e2v.com;
www.e2v.com.

RS No. 302

See us at MTT-S Booth 617

AN RF FRONT-END MODULE FOR LTE/EUTRAN

The third generation partnership project (3GPP) responsible for the universal mobile telecommunication systems (UMTS) 3G system has defined the high-level requirements for the next generation of cellular telecommunications services. These requirements include reduced cost per bit, increased service provisioning, flexible use of existing and new frequency bands, simplified architecture and open interfaces as well as reasonable terminal power consumption. Dubbed LTE for Long Term Evolution, this service will enable much higher speeds along with much lower packet latency, which is necessary for the growing use of services such as VoIP.

The first technical specifications for LTE radio access were approved in late 2007. Final approval of the remaining specifications is occurring now (early 2008) with the initial conformance test specifications scheduled for this September. Operators and equipment vendors have started to announce their timelines for LTE rollout and are planning the first equipment shipments for 2009 with the initial commercial deployments to begin in 2010. As system specifications for LTE and evolved UMTS terrestrial radio access network (EUTRAN) applications become available, RF integrated device manufacturers are busy developing power amplifiers (PA) and front-end modules (FEM) for user equipment (handsets). First to market is Skyworks Solutions' SKY77445 Band VII (2.6 GHz) high integration FEM, first introduced at the Mobile World Congress in Barcelona this past February.

LTE REQUIREMENTS

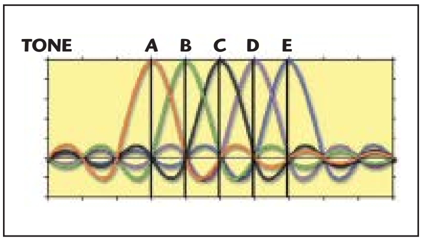
As a "3.9G" or 4G technology, LTE will try to gain market share in a field that includes: HSPA+ (an evolved version of 3GPP HSPA); 3GPP EDGE Evolution; 3GPP2 Ultra-Mobile Broadband (UMB) (an evolution of CDMA2000 and 1xEV-DO); and Mobile WiMAX. LTE will include support of at least 200 active users in every 5 MHz cell along with HSPA (High Speed Packet Access), a combination of HSDPA and HSUPA with download rates of 100 MPs and upload rates of 50 MPs for every 20 MHz of spectrum.

SKYWORKS SOLUTIONS INC.
Woburn, MA

LTE uses an OFDM (Orthogonal Frequency Division Multiplex) signal depicted in ***Figure 1***, comprised of 2048 different sub-carriers with 15 kHz spacing. The modulation format used within the OFDM signal is based on QPSK, 16QAM or 64QAM depending upon the prevailing operating conditions.

LTE allocates a sub-carrier(s) to the mobile device for its link to the base station. An OFDMA access scheme for both the uplink and downlink is used; however, the uplink uses an implementation of OFDMA called Single Carrier Frequency Division Multiple Access (SC-FDMA). This form of modulation overcomes the high peak-to-average power ratio (PAPR) associated with the 3G systems using CDMA. The high PAPR of CDMA systems led to a considerable reduction in the transmitter power amplifier efficiency, which in turn reduced the battery life. SC-FDMA overcomes this problem and results in greater PA efficiency and longer battery life.

LTE also utilizes Multiple Input Multiple Output (MIMO) for enhanced data throughput and spectral efficiency. MIMO employs multiple antennas on the receiver and transmitter, taking advantage of multi-path affects and resulting in more reliable signal quality and greater bandwidth for greater range and capacity.



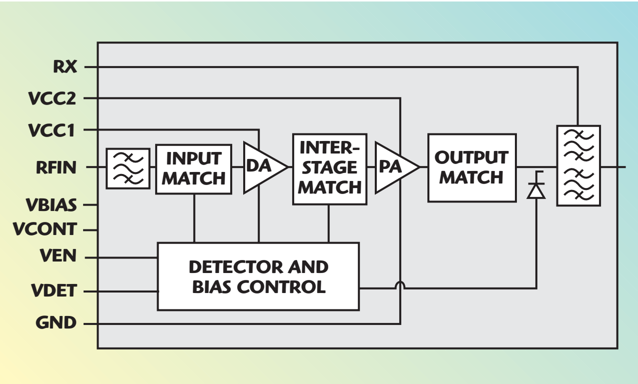
▲ *Fig. 1 Example of OFDM spectrum.*

The variable channel bandwidths specified for LTE increases the system's flexibility and capability, but also add to its complexity. The use of multiple antenna configurations and OFDMA (and SC-FDMA) adds further complication to the development of next generation devices and results in some challenges unique to LTE. With performance targets for LTE set exceptionally high, engineers have to make careful design trade-offs to cover each critical part of both transmit and receive chains.

INTEGRATED TECHNOLOGIES

Addressing these challenges is the SKY77445, a highly integrated, fully matched, 16-pin surface-mount module. The LTE FEM integrates the power amplifier, inter-stage filter, input and output matching, power detection and duplexer in a single 4 × 7 × 1.1 mm package. The FEM provides excellent Tx attenuation in the Rx-band, and operates at a low voltage of 3.3 V with high linearity and efficiency. The SKY77445 meets the stringent spectral LTE/EUTRAN requirements up to 23 dBm output power at 3.3 V battery voltage and up to 25.5 dBm for WCDMA. The FEM incorporates Skyworks' BAW Interstage Filter and Duplexer, InGaP BiFET PA, output power detector and MCM packaging. Control pads are available to enhance the FEM performance at different power levels, as shown in ***Figure 2***. The FEM's transmitter operates over the 2500 to 2570 MHz band while the receiver covers 2620 to 2690 MHz.

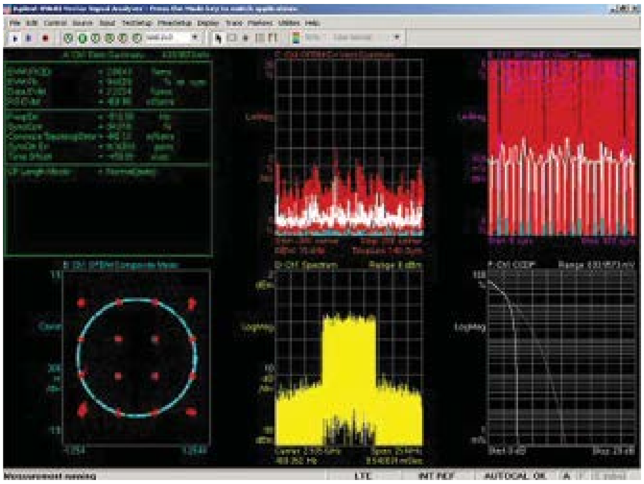
Integration of the RF front-end greatly simplifies the design of the 3.9G-compatible handset radio or data card as all critical matching between the inter-stage filter, PA, power detection and duplexer is optimized within the single module component. By optimizing the efficiency of the InGaP BiFET PA MMIC, reducing RF loss between the integrated components and within the duplexer itself, and improving the match between the PA and the duplexer, this FEM achieves low current at maximum output power that significantly reduces the power dissipated in the LTE-enabled handsets or data cards.



▲ *Fig. 2 SKY77445 FEM block diagram.*

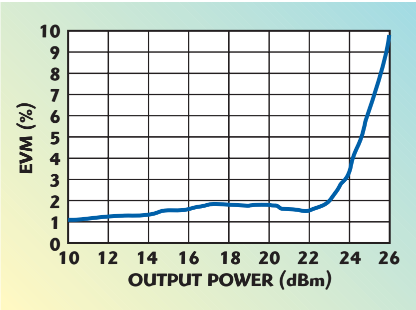
FEM PERFORMANCE

One new challenge facing LTE user equipment (UE) will be the need to handle variable channel bandwidths. All previous 3GPP systems have had one channel bandwidth, but LTE is being defined with eight different channel bandwidths varying from 1.4 to 20 MHz. Such flexibility allows for a rich set of new possibilities in deployment. However, this flexibility also presents significant new challenges with regard to how in-channel and out-of-channel requirements are specified as well as the operational aspects related to radio resource management (cell selection/re-selection, handover, etc.). To address these specific LTE needs, the SKY77445 supports up to 100 resource blocks and 1.25, 2.5, 5, 10 and 20 MHz bandwidths. ***Figure 3*** shows the FEM performance for the 16QAM-10 MHz LTE modulation at P_{out} = 23 dBm.



▲ *Fig. 3 SKY77445 constellation plots, waterfall curve, time and spectral plots for the 16QAM-10 MHz LTE modulation at P_{out} = 23 dBm.*

The SKY77445 addresses all LTE/EUTRAN transmitter requirements, including maximum output power (MOP) and maximum power reduction (MPR); frequency error; power control (minimum output power, transmit ON/OFF power, out-of-synchronization handling of output power); control and monitoring functions; occupied bandwidth; UE spectrum emissions mask and ACLR for LTE; spurious emission requirements for LTE; transmit inter-modulation; and transmit linearity requirements (EVM < 3%) (see ***Figure 4***).



▲ *Fig. 4 SKY77445 EVM vs. output power at 2535 MHz.*

PACKAGING

The device is packaged using Skyworks' miniaturized, low cost, multi-laminate substrate technology and is approximately half the size of individually packaged component solutions, as shown in ***Figure 5***. The SKY77445 front-end module can save handset and data card designers significant board space and design-cycle time, and significantly simplify supply chain and sourcing of RF components.

▲ *Fig. 5 Packaged SKY77445 FEM utilizing Skyworks' multi-laminate substrate technology.*

CONCLUSION

LTE is a strong contender for defining the next generation of wireless services. Addressing the stringent performance specifications called for by LTE will be especially challenging for engineers developing the microwave devices inside user equipment. The first FEM addressing LTE specifications, including variable channel bandwidths, spectral efficiency (via OFDM and MIMO), linearity and low power consumption has been introduced into the market. The availability of this part represents a shift from developing specifications to hardware realization, a critical step in LTE deployment.

Skyworks Solutions Inc.,
Woburn, MA (781) 376-3000,
www.skyworksinc.com.

RS No. 301

NEW WAVES: MTT-S Product Showcase

The following booth numbers are complete as of April 8, 2008.

Heavy Wall Waveguide

A-Alpha Waveguide offers heavy wall WR62, WR75, WR90, WR137, WR159, 6061 aluminum waveguide tube as well as WR62, WR75, WR90, WR112, WR137, WR187 heavy wall OFHC copper waveguide tube. These sizes along with all standard size wall waveguide tube in aluminum, copper, bronze, invar and silver are in stock for immediate delivery. A-Alpha Waveguide is the exclusive North American distributor of Micro Metalsmiths' aluminum and silicon bronze cast bends. Additional products offered include ridged and double ridged aluminum flange stock. A-Alpha Waveguide stocks all standard sizes.

A-Alpha Waveguide Co.,
El Segundo, CA (310) 322-3487,
www.a-alphawaveguide.com.
Booth 1805 **RS 216**

Workstation Products

Acceleware™ brings the power of a supercomputer to your desktop; you can interpret data faster, run more simulations and improve design quality. The ClusterInABox™ Workstation harnesses the parallel processing power of graphics processing units (GPU) to deliver unrivalled performance and data processing speeds. Acceleware products seamlessly integrate with existing simulation/modeling applications, increasing their speed by up to 35 times. These products accelerate electromagnetic simulations, such as antenna design, printed circuit boards and electromagnetic compatibility (EMC).

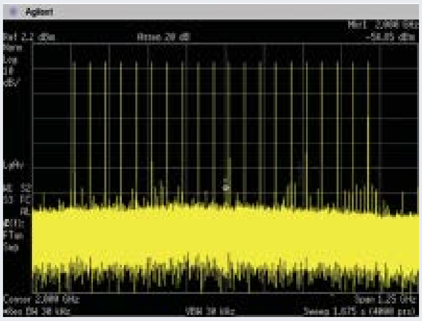
Acceleware Corp.,
Calgary, Alberta, Canada (403) 210-9650,
www.acceleware.com.
Booth 751 **RS 217**

10 W RF Amplifier

This high power amplifier generates approximately 10 W (typical) of power from 20 MHz to 6 GHz in a single module. The model SSPA 0.020-6.000-10 is a medium power, super broadband, GaN RF amplifier. This PA is ideal for broadband military platforms as well as commercial applications because it is robust and offers high power over an extremely large bandwidth with good power-added efficiency. This amplifier was designed for broadband jamming and communication system platforms. It operates with a maximum base plate temperature of 85°C and is packaged in a modular housing that is 2.50" × 6.40" × 1.06".

Aethercomm Inc.,
San Marcos, CA (760) 598-4340,
www.aethercomm.com.
Booth 1911 **RS 218**

PSG Vector Signal Generator



The new option H18 for the E8267D PSG vector signal generator, when coupled with the N8241A or N6030A wideband arbitrary waveform generators will enable 1 GHz wide waveforms at all carrier frequencies now including below 3.2 GHz. If you use your own baseband IQ waveform, the E8267D PSG vector signal generator can modulate signals with up to 2 GHz of RF modulation bandwidth. This option will be particularly useful for wideband communications and radar applications operating in the L-band and S-band.

Agilent Technologies –
Signal Sources Division,
Santa Rosa, CA (800) 829-4444,
www.agilent.com.
Booth 1123 **RS 219**

USB-based Average Power Sensors

The Agilent U2000B, U2000H, U2001B, U2001H and U2002H USB-based power sensors are the latest addition to Agilent's U2000 series, which was released in 2007. These new power sensors have built-in attenuators to enable power measurement up to +44 dBm, eliminating the use of an external attenuator. This reduces equipment set up time and wear and tear of the bulk head connector. Each power sensor comes with the upgraded Power Panel software N1918B that offers time-gated capability for RF burst signal measurement and improved Graphic User Interface. The USB power sensors will be available from July 2008.

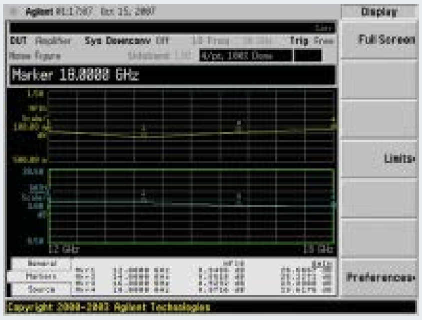
Agilent Technologies –
Basic Instrument Division,
Santa Clara, CA (800) 829-4444,
www.agilent.com.
Booth 1123 **RS 220**

Ultra High Speed SPST Switch

The model SWCH1-DC40-SK is an SPST switch that operates in a frequency range from DC to 40 GHz. This switch offers an insertion loss of 6.8 dB maximum, isolation of 55 dB minimum, and an ultra high speed switching time of 15 ns maximum. The switch has 1.85 mm "V" connectors for the input and output ports.

American Microwave Corp.,
Frederick, MD (301) 662-4700,
www.americanmicrowavecorp.com.
Booth 912 **RS 221**

12 to 18 GHz Amplifier



This amplifier operates in a frequency range from 12 to 18 GHz. The amplifier is a breakthrough in amplifier technology because the noise figure is 0.9 dB over the entire band. Not only is the noise figure consistent across the band, but so is the gain and output power. The APT2-12001800-1105-D2 is available in the company's smallest housing (D2).

AmpliTech Inc.,
Holbrook, NY (631) 521-7831,
www.amplitechinc.com.
Booth 1609 **RS 222**

High Performance Signal Generator

The new APSIN3000 is a compact, PC-controlled high performance signal generator with wide frequency coverage from 9 kHz to 3.4 GHz with sub-Hz resolution and broad power range up to 15 dBm. It provides excellent signal quality with better than –120 dBc/Hz phase noise (1 GHz, 20 kHz offset), < –40 dBc harmonics and < –65 dBc spurious. It has an internal OCXO reference and can be locked to an external reference. The APSIN3000 is available with an optional internal battery and weighs less than 3 kgs.

AnaPico AG,
Zürich, Switzerland +41-44-440 00 51,
www.anapico.com.
Booth 2118 **RS 223**

NEW WAVES

Cavity Dual Bandpass Combiner

The DB5248 is a cavity dual bandpass combiner used in INMARSAT communication with

PB1 at 1524 to 1560 MHz, PB2 at 1626.5 to 1660.5 MHz, insertion loss in both passbands = 2 dB maximum and isolation > 40 dB typical built-in a package size of 160 × 82 × 48 mm maximum. Anatech Electronics also offers other cavity dual bandpass combiners with low insertion loss, steep rejection and high power handling capacity.

Anatech Electronics Inc.,
Garfield, NJ (973) 772-4242,
www.anatechelectronics.com.
Booth 2222 **RS 224**

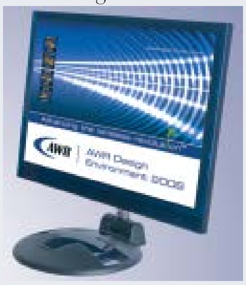
Waterproof QMA Connector

This waterproof QMA connector (CQMA) is a high performing quick lock SMA (QMA) connector. One hundred percent mateable with earlier QMA designs, the CQMA distinguishes itself by way of its waterproof seal (IP68) and the lowest VSWR available in frequencies up to 18 GHz. This is in addition to all the standard benefits snap-on coupling has over SMA's threaded interface i.e., 10× faster mating, denser packaging and the ability to rotate the connector 360° while in the mated position.

Anoison Electronics Ltd., Zhenjiang,
Jiangsu, China +86 511 8590 0277,
www.anoison.com.
Booth 2129 **RS 225**

Process Design Kits

Process design kits (PDK) in AWR's Microwave Office design suite now leverage the latest inno-



vations of ACE™, APLAC® and AXIEM™ technologies. Current foundries include TriQuint Semiconductor and WIN Semiconductors, and more will be available soon. The PDKs reduce the time required to go from design concept to working product by seamlessly integrating the full capabilities of Microwave Office software with those of the foundries.

Applied Wave Research Inc. (AWR),
El Segundo, CA (310) 726-3000,
www.awrcorp.com.
Booth 923 **RS 226**

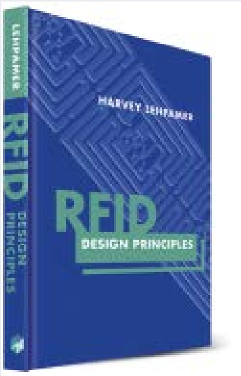
Solid-state Amplifier

This solid-state amplifier family operates in a frequency range from 8 to 20 GHz. Model 5S8G20A offers 5 W of power and model 20S8G20A provides 20 W. Both models are perfect for EMC and wireless testing. Like the other members of the "S" series amplifiers, both models are extremely tough, durable and are full Class A. These models have superior linearity and are 100 percent VSWR tolerant.

AR RF/Microwave Instrumentation,
Souderton, PA (215) 723-8181,
www.ar-worldwide.com.
Booth 1409 **RS 227**

RFID Book

A new book on one of today's fastest-growing technologies, RFID (Radio-Frequency Identi-



fication) makes its debut appearance at IMS 2008. *RFID Design Principles* by Harvey Lehpamer explores the growing role of RFID in applications ranging from supply chain management and intelligent building design, to transportation systems and defense. The book introduces readers to the essential technical details and organizational considerations that are critical to successful RFID system planning. This book and other recent and classic titles are offered at a 20 percent discount at the Artech House booth # 613.

Artech House,
Norwood, MA (800) 225-9977,
www.artechhouse.com.
Booth 613 **RS 228**

Small Amplifiers for Multiple RF Applications

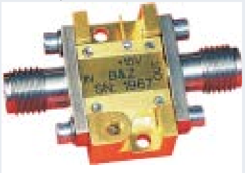
With miniature 0402 package dimensions and no wirebonds, the innovative VMMK-2x03 am-

plifiers experience almost no signal loss and minimal parasitics. Its ultra-small size and fully matched SMT design are optimized for 500 MHz to 12 GHz frequencies, making these high performance devices ideal to place in a variety of radio architectures.

Avago Technologies,
San Jose, CA (408) 435-7400,
www.avagotech.com.
Booth 509 **RS 229**

Low Noise Amplifiers

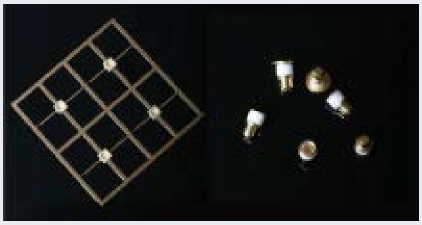
These low noise amplifiers are designed for the military band of 17.8 to 21.2 GHz. The BZ3-



17802120 series exhibits noise figures as low as 1.5 dB with output 1 dB compression point of +15 dBm. Gain can be specified up to 45 dB with flatness of ±0.5 dB. Phase linearity is ±2° maximum. Unit-to-unit phase tracking and gain tracking is available. The operating temperature is –55° to +85°C. This series is offered in the B&Z Ultra Chassis that measures 0.44" × 0.74" × 0.30". The Ultra Chassis ships with standard coaxial connectors that can be field removed to use the amplifiers as a drop-in.

B&Z Technologies,
Stony Brook, NY (631) 444-8827,
www.bnztech.com.
Booth 350 **RS 230**

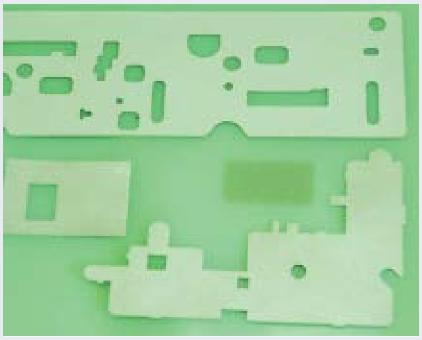
HTCC Products



Barry now offers high temperature co-fired ceramic (HTCC) products—microwave semiconductor packaging, i.e., chip carriers, diode packages via Semiconductor Enclosures Inc. This coupled with low temperature co-fired ceramic (LTCC) design and production makes Barry a total ceramics solutions provider. Barry product offerings include: LTCC products, HTCC products; semiconductor packages; high power terminations, resistors, attenuators and surface-mount products; pulsed power devices, WiMAX product selection; low capacitance resistors; low power precision chips; machining and plating services.

Barry Industries Inc.,
Attleboro, MA (508) 226-3350,
www.barryind.com.
Booth 805 **RS 231**

Laser Cut Epoxy Pre-forms



Bonding Source is the only company in the US that stocks conductive and non-conductive epoxy film manufactured by Emerson Cuming and Ablestik. Laser cut epoxy pre-forms can be shipped in five to 10 days. Primary uses of the epoxy pre-forms are mounting PCBs and hybrid circuits to carriers or housing. Pre-forms can be drop shipped to off-shore manufacturing sites with JIT shipments to match production schedules. Bonding Source also stocks epoxy pastes, bonding wire and bonding tools, and has no minimum order requirements.

Bonding Source,
Nashua, NH (603) 595-9600,
www.bondingsource.com.
Booth 2217 **RS 232**

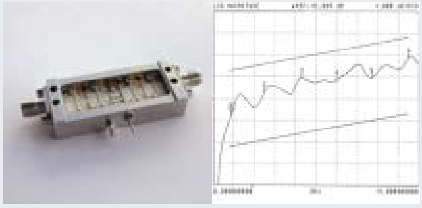
Wafer Probe Station

Cascade Microtech introduced the next step in 300 mm wafer probe stations designed to meet

the worldwide need for advanced on-wafer measurements for semiconductor devices. Based on the company's wafer probing products, the Elite 300 sets a new standard for extremely accurate and reliable 300 mm wafer probing for devices with process nodes at 45 nm and below. The Elite 300 solves the critical measurement challenges at each advancing technology node by incorporating state-of-the-art electrical and mechanical technology, advanced materials and leading-edge measurement techniques. Price: $80,000 to $400,000. Delivery: 12 weeks upon receipt of order.

Cascade Microtech,
Beaverton, OR (800) 550-3279,
www.cmicro.com.
Booth 1144 **RS 233**

Gain Sloped-equalized Amplifiers



These gain sloped-equalized amplifiers are designed for TWT drivers and subassemblies where gain equalization/sloping is required to help offset cable loss-variation. Positive or negative gain equalization/sloping is available over ultra-broadband ranges of 2 to 18 GHz, 6 to 18 GHz as well as typical tri-band frequencies common for SATCOM applications. Ciao offers from 2 to 20 dB of gain sloping/equalization range with customized gain, output power (up to +24 dBm) and noise figure values to meet specific requirements. Units feature good harmonic performance and are unconditionally stable. Delivery: two to four weeks ARO.

Ciao Wireless Inc.,
Camarillo, CA (805) 389-3224,
www.ciaowireless.com.
Booth 738 **RS 234**

WiMAX Band Diplexer

The model CCDP-222 is a diplexer that operates at the 2.4 GHz WiMAX band. This diplexer is designed to provide combining or splitting of narrow band signals. The diplexer may be specified with center frequencies ranging from 2.3 to 2.5 GHz with a minimum of 50 MHz channel-to-channel separation. Individual channel bandwidth is 20 MHz. The diplexer is provided with a Type 'N' Female connector on the common port and SMA female connectors on the in/out ports.

ClearComm Technologies LLC,
Fruitland, MD (410) 860-0500,
www.clearcommtech.com.
Booth 1533 **RS 235**

Rapid Prototyping System

This Rapid Prototyping System (RPS) is a laser-based system for quick turn thin film submounts and patterned copper microwave laminate materials such as Duroid and Arlon. With this process it can provide 2 mil traces and line spacing without the cost and lead time of producing a mask. Whether one piece or high volume is needed, the company can supply the parts in the shortest time possible.

Compex Corp.,
West Berlin, NJ (856) 335-2277,
www.compexcorp.com.
Booth 1833 **RS 236**

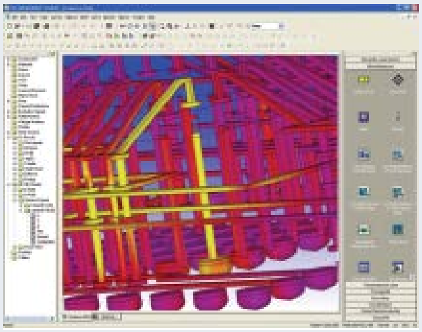
Voltage-controlled Oscillator

The CVCO55CC-1260-1400 voltage-controlled oscillator (VCO) operates from 1260 to 1400

MHz with a control voltage range of 0.5 to 12 V. This VCO features a typical phase noise of –115 dBc/Hz at 10 kHz offset and has excellent linearity. The model is packaged in the industry-standard 0.5" × 0.5" SMD package. Input voltage is 8 V, with a max current consumption of 35 mA. Pulling and pushing are minimized to 0.20 MHz and 0.20 MHz/V, respectively. Second harmonic suppression is –20 dBc typical. Price: starts at $18.46 each in volume.

Crystek Corp.,
Fort Myers, FL (239) 561-3311,
www.crystek.com.
Booth 2215 **RS 237**

CST MICROWAVE STUDIO



CST will be previewing the upcoming release version 2009 of its flagship product CST MICROWAVE STUDIO® (CST MWS). Fully integrated in CST STUDIO SUITE™, CST MWS helps designers solve electromagnetic problems, utilizing new solver technology, sophisticated filters, and automated optimization and parametric studies. Highlights of version 2009 include: transient EM/circuit co-simulation using the recently acquired Linmic circuit simulation technology, an MPI implementation for the fast solution of large problems on clusters, and the porting of the user interface to 64 bit in order to handle the increasing complexity of imported models. CST STUDIO SUITE will be enhanced by two new members: CST PCB STUDIO™ and CST CABLE STUDIO™. They will be integrated into CST DESIGN ENVIRONMENT and will further increase the SI and EMC capabilities inside CST STUDIO SUITE. Results can be used in CST MWS as field sources for further evaluation.

CST of America® Inc.,
Framingham, MA (508) 665-4400,
www.cst.com.
Booth 933 **RS 238**

Two-channel IF Conditioner Subsystem

This digitally-controlled two-channel IF conditioner subsystem was designed to address commonly encountered receiver issues including spurious emissions, harmonics and leakage, from both external and internal sources, which can cause degraded performance. To minimize such spurious interference in the 750 to 1250 MHz frequency range, CTT designed a VMEbus compatible subsystem with a proprietary intermediate frequency (IF) conditioning design that will find acceptance in many communications systems. The first in a family of VMEbus-compatible subsystem designs, the IF conditioner offers specifications including: RF input power of +5 dBm (max); gain flatness of 1 dB (max) at 775 to 1225 MHz, 3 dB (max) at 750 to 1250 MHz; noise figure of 10 dB (max) and attenuator control of 0 to 40 dB.

CTT Inc.,
Sunnyvale, CA (408) 541-0596,
www.cttinc.com.
Booth 1231 **RS 239**

NEW WAVES

Switches and Systems

Dow-Key manufactures and custom designs switches and systems for the commercial, military, wireless and Hi-Rel space industries. The company specializes in a broad range of RF coaxial relays operating from DC to 40 GHz, waveguide switches (operating to 70 GHz), T-switches, RF coaxial and solid-state matrices, PXI modules and L-band duplex switching systems.

Dow-Key Microwave Corp.,
Ventura, CA
(805) 650-0260,
www.dowkey.com.
Booth 1514 **RS 350**

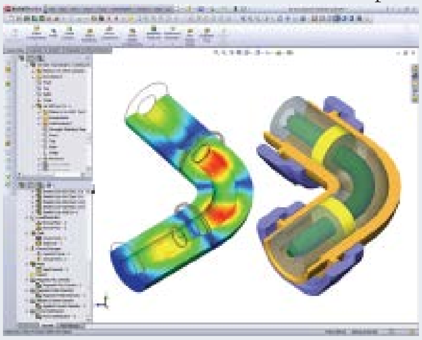
SPDT Switch

The 2S series features SMA connectors and a frequency range of DC to 18 GHz. The 2SE series also features options for SMA connectors and a frequency range of DC to 26.5 GHz. Both series are available with failsafe, latching self cut-off or pulse latching options. These connectors offer an RF impedance of 50 Ω nominal; operating temperature (failsafe) of –55° to +85°C ambient; operating temperature (latching) of –25° to +85°C ambient; operating life of 1,000,000 cycles minimum and a break before make switching sequence. Weight (max): 2.1 oz.

Ducommun Technologies Inc.,
Carson, CA (310) 513-7214,
www.dt-usa.com.
Booth 503 **RS 351**

High Frequency Simulation Suite

With the release of HFWorks 2008, high frequency field simulation has never been easier. This latest release completes ElectroMagneticWorks' suite of high and low frequency field simulator solutions, which are fully embedded inside the leading PC-based CAD software: SolidWorks®. The combined power of SolidWorks and ElectroMagneticWorks' proven FEM solver technology provide industry-leading field simulators to enhance productivity in the most user friendly environment.



ElectroMagneticWorks Inc.,
Montreal, Quebec, Canada
(514) 634-9797,
www.electromagneticworks.com.
Booth 1753 **RS 240**

Phase-Locked Crystal Oscillators

The PLXO series of phase-locked crystal oscillators are now available with significantly improved performance and smaller size. With the option of a surface-mount or connectorized package, PLXO offers several outputs: sine 7 dBm, 10 dBm, CMOS and PECL. The new smaller-sized surface-mount package (0.9" × 0.9" × 0.25") also features exceptionally low phase noise characteristics (< –140 dBc/Hz at 1 kHz typical) and enhanced spurious response (< –65 dBc). PLXO is available in fixed frequencies between 5 and 420 MHz with a lock range of ±5 ppm.

EM Research Inc.,
Reno, NV (775) 345-2411,
www.emresearch.com.
Booth 2138 **RS 241**

Ceramic Resonator-based Oscillator

The CLX series synthesizer is a ceramic resonator-based oscillator with exceptionally low phase noise, –110 dBc/Hz at 10 kHz offset. This series is an internally-programmed fixed-frequency unit in a small, 0.75" × 0.75" SMT package. Optimized loop performance for overall low RMS noise. Available in custom fixed frequencies from 200 MHz to 4 GHz. External frequency references from 5 to 250 MHz. Buffered outputs up to +13 dBm. Optional RoHS compliance.

EM Research Inc.,
Reno, NV (775) 345-2411,
www.emresearch.com.
Booth 2138 **RS 242**

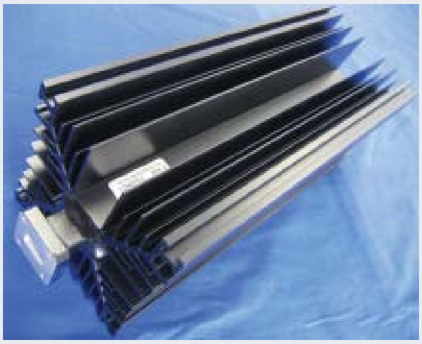
Horn Antenna

The model 3164-08 is an open boundary quad-ridged horn antenna designed to meet the demands of UWB, GSM, PCS, Wi-Fi and WiMAX testing. Big on performance, yet compact in design, the "open boundary" design makes this antenna unique in both appearance and capabilities. Notable features include excellent gain over the frequency range with low VSWR. For added convenience, the model 3164-08 antenna can be used on a tripod with an included flange mount, or placed in a chamber with an optional wall plate mount.

ETS-Lindgren,
Cedar Park, TX (512) 531-6400,
www.ets-lindgren.com.
Booth 304 **RS 244**

NEW WAVES

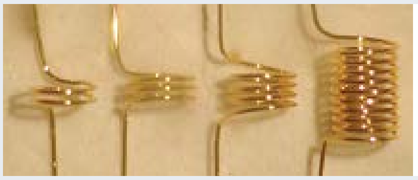
Waveguide High Power Loads



The new waveguide high power termination family covers C-band and Ku-band at powers up to 3 kW. It features aluminum-extruded heat sink with optimized distribution to maximize power handling. Heat sink patterns are available for vertical and horizontal installations. A typical example is a 1200 W Ku-band unit covering a frequency range of 14 to 14.5 GHz with a VSWR of 1.1 maximum with dimensions of 5.2" × 5.2" × 15". The waveguide flange can be ordered in any standard pattern.

Filtel Microwave Inc., Quebec, Canada (450) 455-6082, www.filtel.com.
Booth 2018 ***RS 245***

Gold and Silver Air Core Inductors



These build-to-print gold and silver air core inductors are designed for customer-specific applications. The inductors are un-insulated, space wound, with ID ranging from 0.020 to 0.080 inches, and wire diameter as fine as 47 AWG. Customers determine wire size, wire material, number of turns, coil ID, spacing between turns and lead exit/length. Gold inductors are ideal for high frequency micro-circuit applications requiring gold-to-gold interconnections (typically thermally bonded to the circuit); silver inductors (silver-plated copper) are used for similar applications, but are typically soldered to the circuit.

Gowanda Electronics, Gowanda, NY (716) 532-2234, www.gowanda.com.
Booth 2032 ***RS 246***

High Frequency OCXOs

The YH1518 series of OCXOs operate in a frequency range from 110 to 250 MHz. The YH1518 series design utilizes a precision SC-cut crystal to achieve low noise performance with an internal assembly thermally efficient housed in a small 1.06" × 1.42" × 0.5" hermetic package. Supply is +12 VDC and typical temperature stability of ±0.07 ppm over –40° to +70°C. A sinewave output of +3 dBm minimum (+6 dBm typical) is provided.

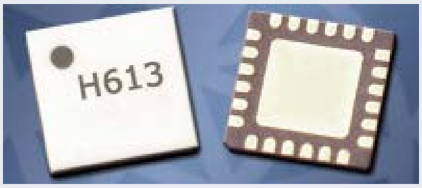
Greenray Industries, Mechanicsburg, PA (717) 766-0223, www.greenrayindustries.com.
Booth 2233 ***RS 247***

Process Integrated Quality Control

PiQC is a multi-dimensional control system that monitors the most applicable and significant measures to judge wire bond quality. For the first time in the wire bonding market, every physically relevant aspect of every wire bond connection is evaluated in real-time, providing individual quality indices to compare to ongoing real-time data. These measures are acquired during the bond process to avoid impact on machine throughput, enabling throughput-neutral, 100 percent quality control. This newly developed quality control system relies only on actual data, without any statistical assumptions.

Hesse & Knipps Inc., San Jose, CA (408) 436-9300, www.hesse-knipps.com.
Booth 1149 ***RS 248***

0.1 to 20 GHz SDLVA

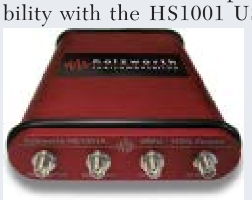


This SDLVA operates in a frequency range from 0.1 to 20 GHz, provides 65 dB of dynamic range and ±2 dB frequency flatness, and is ideally suited for EW/ELINT and radar systems. This device processes RF pulses with amplitudes from –55 to +5 dBm with 10 ns rise times and only 100 ns of recovery time. VSWR is specified at 3.0 and sensitivity is –55 dBm typical. The HMC613LC4B consumes 85 mA from a +3.3 V supply and is specified for –40° to +85°C operation.

Hittite Microwave Corp., Chelmsford, MA (978) 250-3343, www.hittite.com.
Booth 1345 ***RS 249***

Ultra-low Phase Noise Source

Holzworth demonstrates phase noise test capability with the HS1001 USB/Ethernet-controlled ultra low phase noise source. This 8 MHz to 1.024 GHz synthesizer (option to 4 GHz) has typical phase



New Waves

noise performance of –130 dBc/Hz at 1 GHz (10 kHz offset). Adjustable output power from –110 dBm to +15 dBm, harmonics below –30 dBc and spurious levels below –60 dBc. Compact form factor is 100 percent USB powered with DC-coupled AM/FM/PM and pulse modulation capabilities. When operated with an appropriate FFT analyzer, accurate phase noise measurements are possible.

Holzworth Instrumentation,
Boulder, CO (303) 704-8875, www.holzworth.com.
Booth 409 ***RS 250***

RF Power Switch

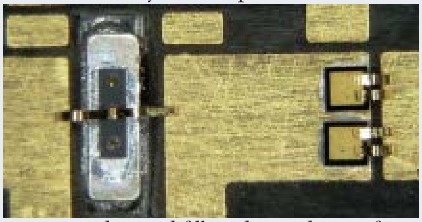
This RF power switch is small, reliable, powerful, easy to handle, requires little maintenance and is therefore cost-effective to use. The

switch promises best benefits for customers—everywhere where switching between channels is required. The 'plug and play' concept perfectly sums up this particular switch, which is quick, easy and convenient to install and operate. The new switch saves an enormous amount of space and guarantees indirect benefits for mobile phone users and network operators. The design of the RF power switch can be adapted to suit the specific requirements of customers.

HUBER+SUHNER AG,
Herisau, Switzerland +41 71 353 4111, www.hubersuhner.com.
Booth 701 ***RS 251***

Fully Automatic Assembly Capability

This fully automatic assembly capability is designed for high frequency module assembly. New capabilities include automatic epoxy die attach

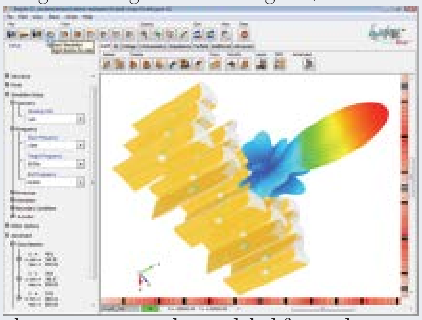


on the Newport MRSI work cell and automatic wedge/ribbon bonding on the Hesse & Knipps Bondjet wire bonder. Other automatic capabilities include ball bonding, aluminum wedge bonding, epoxy dam and fill, and a Mydata surface-mount line. IKE Micro is ISO 9001:2000 certified, ITAR compliant, and serves the defense and commercial RF electronics industries.

IKE Micro,
Nashua, NH (603) 880-6384, www.ikemicro.com.
Booth 2219 ***RS 252***

EMPIRE XCcel™ 5.15

The new 3D EM solver EMPIRE XCcel 5.15 covers nearly all today's design challenges for RF designers, like antennas, passive circuits, pack-



ages, waveguides or EMC/EMI problems. Due to the unique structure and processor adapted code generation a simulation performance up to 1600 Million FDTD Cells per second can be achieved on a conventional PC with full access to the built-in memory. Thus, complex structures can be modeled fast and accurately.

IMST GmbH,
Kamp-Lintfort, Germany +49 2842 981 0, www.empire.de.
Booth 1746 ***RS 253***

LDMOS RF Power Transistors

This family of LDMOS RF power transistors is targeted to GSM/EDGE applications in the 920 to 960 MHz and 1805 to 1880 MHz frequency

NEW WAVES

bands. These new transistors feature 50 W average output power at 920 to 960 MHz and 45 W average output power at 1805 to 1880 MHz. These products feature a thermally-enhanced open cavity plastic package with copper flanges with less than 10 micro inches of gold plating. This eases the soldering process by eliminating the costly de-golding step from the PCB assembly process providing significant savings.

Infineon Technologies,
Milpitas, CA (877) 465-3667,
www.infineon.com.
Booth 1216 **RS 254**

RF and Microwave Amplifier Systems

This versatile amplifier system can be tailored to meet any customer's requirement and application. The RS1802-1KW-500 is an ideal integrated system for EMC applications. This system includes the company's SMCC-1000, 1000 W amplifier for 200 MHz to 1 GHz as well as its 500 W amplifiers for 1 to 18 GHz (1 to 2.5 GHz, 2.5 to 7.5 GHz and 7.5 to 18 GHz). It is a versatile state-of-the-art design that can be tailored to meet customers' specific requirements for frequency range and RF output power levels. These systems can include any combination of pulse, CW or gridded amplifiers in compact solutions.

Instruments for Industry Inc.,
Ronkonkoma, NY (631) 467-8400,
www.ifi.com.
Booth 2007 **RS 255**

Attenuators

These cost effective 0404 size thick film on alumina attenuators are available in –1 to –10 dB attenuation values in 1 dB increments with attenuation accuracy starting at ±0.3 dB. Operating frequency for the IMS2479 is DC to 3 GHz with a rated power of 40 mW. These attenuators are especially suited, but are not limited to, RF and microwave applications.

International Manufacturing Services Inc.,
Portsmouth, RI (401) 683-9700,
www.ims-resistors.com.
Booth 1808 **RS 256**

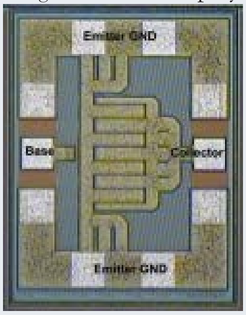
Synthesized Local Oscillator

The WaveCor Synthesized Local Oscillator (SLO) is the next step in the evolution of digital synthesizers and features a frequency range of 50 MHz to 20.48 GHz, switching speed of 10 µs, and a tuning resolution of 1 kHz in a compact 6" × 6" × 2.75" package. Continuing WaveCor's tradition of low phase noise and spurious performance, the WaveCor SLO is a low-cost alternative to YIG-based synthesizers.

ITT Microwave Systems,
Lowell, MA (978) 441-0200,
www.ittmicrowave.com.
Booth 1917 **RS 257**

Power Amplifier Design Library

This Power Amplifier (PA) Design Library is designed for the company's 0.18 micron SiGe BiCMOS process, reducing design cycle time by providing validated PA cells ready for use with a custom power cell design flow. Combined with Jazz's rich library of high quality passive devices including thick inductors and high density MIM capacitors, complete PA design is enabled. The PADL delivers a full PA design flow from schematic to layout including device models characterized over DC, temperature, small-signal and large-signal load pull measurements.



Jazz Semiconductor,
Newport Beach, CA (949) 435-8181,
www.jazzsemi.com.
Booth 416 **RS 258**

Surface-mount Cavity Filter

K&L Microwave has developed TEM-mode cavity filter 6FV-7500/E500-SMT, and its associated family of filters to be soldered on RO-4003 12-mil printed wiring board (PWB). The design maximizes available Qu within the low profile of 0.3" and offers the flexibility of low loss, leadless construction and simplified electronic PWB stuffing, while maintaining RF matching. In addition, this family of filters can be hermetically sealed.

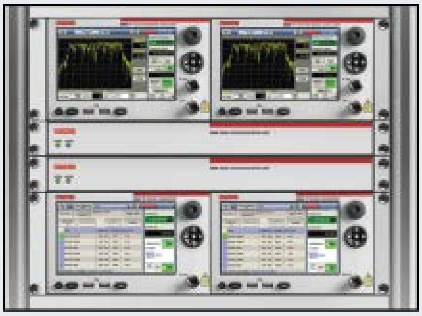
K&L Microwave,
Salisbury, MD (410) 749-2424,
www.klmicrowave.com.
Booth 1506 **RS 259**

High Performance Frequency Synthesizer

This WiMAX Fractional-N synthesizer in IBM 7WL process delivers a –116 dBc/Hz phase noise performance and –90 dBc spurious response at 6 GHz output. High phase noise and spurs can cause tremendous problems for system designers. Error vector magnitude (EVM) is a tight requirement for OFDM systems such as WiMAX. Phase noise causes a jitter in the EVM, whereas spurs cause EVM offsets. This leads to unacceptable packet error rates or low data throughput rates.

Kaben Wireless Silicon Inc.,
Ottawa, Ontario, Canada (613) 596-6646,
www.kabenwireless.com.
Booth 2230 **RS 260**

MIMO System



Keithley simplifies MIMO testing with its model 2820 RF signal analyzers and model 2920 RF signal generators, designed to the requirements of 802.11n WiFi and 802.16e WiMAX multi-input, multi-output communications (MIMO) standards. The model 2895 MIMO synchronization unit provides precise, stable alignment between instruments. The model 280111 MIMO signal analysis software has an extensive measurement suite for analyzing up to 16 signals of an 802.11n WLAN device with 4×4 MIMO channels.

Keithley Instruments Inc.,
Cleveland, OH (800) 588-9238,
www.keithley.com.
Booth 727 **RS 261**

Ultra-fine Resolution CRFM

The CRFM-9041 is a wide bandwidth, ultra-fine resolution Coherent Radio Frequency Memory (CRFM). Sampling at 2200 MHz, the CRFM captures, stores and replays RF signals, delaying the signal up to 7.5 ms with 1 ns resolution. The CRFM is a multi-functional test asset for development of EW, radar, seeker and communication systems. Up to 1 GHz instantaneous bandwidth is available with –45 dBc spurs. Highly configurable for any combination of ECM, radar envi-

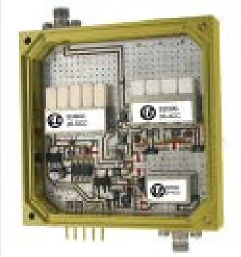
New Waves

ronment and arbitrary waveform (exciter) signal generation. Latest DSP technology performs amplitude/phase modulation and fine resolution Doppler. The CRFM fits into a 5-slot 6U VME card cage, and is supplied with single board computer, master oscillator, power supply and either a desktop or rack mount enclosure.

KOR Electronics,
Cypress, CA (714) 898-8200,
www.korelectronics.com.
Booth 2110 **RS 262**

Switch Filter Amplifier

This switch filter amplifier (SFA) series is available in both ceramic and lumped element configurations.



The SFA series offers wide frequency of 100 to 3000 MHz and bandwidth ranging from 1 to 40 percent, with a typical return loss of 18/14 dB. The noise figure of 1.5 to 5 dB combined with 300 ns switching speed, 10 to 40 dB gain and bias of +10 VDC, +5 VDC make the SFA series ideal for receiver applications and improvement of overall system performance.

Lark Engineering Co.,
San Juan Capistrano, CA (949) 240-1233,
www.larkengineering.com.
Booth 532 **RS 263**

X-band BUC

The model UB61000-040 is an X-band, 10 W miniature BUC. This unit is designed for in-

door or outdoor use in commercial or military and military Manpack miniature SATCOM systems. This unit can be mounted on the antenna for maximum efficiency of operation or can also be supplied without heatsinks for ease of system integration. The company provides LNAs, SSPAs and converter products for a variety of communication needs.

Locus Microwave Inc.,
Boalsburg, PA (814) 466-6275,
www.locusmicrowave.com.
Booth 504 **RS 264**

PCS/AWS Cavity Combiner

Lorch Commercial and Wireless (LCW) offers WP-D00002, a combiner that provides a solu-

tion for utilizing a single antenna for the full personal communication system (PCS) and advanced wireless services (AWS) frequencies. The combiner exhibits less than 0.25 dB of insertion loss across the passbands of 1850 to 1990 MHz and 1710 to 1755/2110 to 2155 MHz while providing greater than 80 dB of isolation. The unit measures 11" × 7.5" × 2.3" and is available from stock. Other mechanical configurations are available.

Lorch Microwave,
Salisbury, MD (410) 860-5100,
www.lorch.com.
Booth 1529 **RS 265**

Power Measurement Kits

The MECA MFK-PMK-1 power measurement kit replaces high power attenuators as a

means of reducing RF signal levels into sensitive power meters. Directional couplers have low insertion loss and high directivity so the sampled power is extremely stable and isolated from changes as power levels increase. Rugged, hard-shell case with form-fitting foam insert. Delivery: stock to four weeks. Product is made in the USA.

MECA Electronics,
Denville, NJ (973) 625-0661,
www.e-meca.com.
Booth 714 **RS 266**

Drop-in Isolators and Circulators

MESL Microwave has launched a range of space-qualified package drop-in and substrate

drop-in isolators and circulators. These devices are available with either MIC, tab or coaxial interfaces and are initially for C-, X- and Ku-band applications with other frequencies to follow. These devices have 0.5 dB insertion loss, 23 dB isolation and 21 dB return loss over a temperature range of –20° to +80°C.

MESL Microwave Ltd.,
Edinburgh, UK +44 131 333 2000,
www.meslmicrowave.com.
Booth 436 **RS 267**

Drop-in Isolators and Circulators

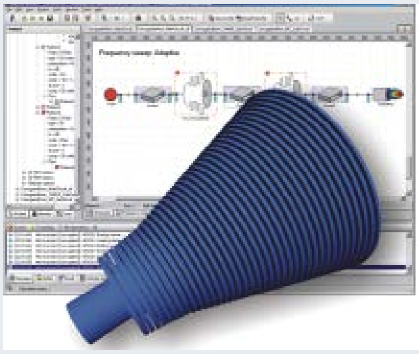
MICA Microwave, a division of Micronetics, introduces its newest stripline drop-in isolator

and circulator family, the SMD product line. The SMD series is a small and durable 0.50 diameter × 0.24 thick true surface-mount package. It has been designed to cover frequency requirements between 4 to 15 GHz in bandwidths up to 20 percent. The unique surface-mount launching construction allows for direct placement onto a PC board without adding counter-bored receptacles. Typical performance of the unit is 20 dB isolation, 0.5 dB insertion loss and 1.25 VSWR with forward power levels up to 20 W.

MICA Microwave Corp.,
Manteca, CA (209) 825-3977,
www.mica-mw.com.
Booth 516 **RS 268**

NEW WAVES

EM-software Tool



Version 6.6 of the EM-software tool µWave Wizard™ includes a set of new elements that have been developed for the radiation library that exploit the body of revolution (BOR) symmetry of circular waveguide horn antennas. The elements coincide with the specifications for various horn profiles, like vertically and axially corrugated horns, profiled smooth wall, ring loaded and Potter horn profiles. This eases the setup of the entire horn geometry since the process is now carried out automatically inside the element and accelerates the computation for multi-mode and tracking mode applications due to utilization of the BOR symmetry with the mode-matching method. Calculated electromagnetic fields within these elements can either be visualized in longitudinal cuts or the maximum values can be plotted versus frequency. This allows a faster evaluation of power handling capabilities for such structures.

Mician GmbH,
Bremen, Germany +49 (421) 16899351,
www.mician.com.
Booth 1045 **RS 269**

Coaxial Attenuators

These blind-mate, high reliability coaxial attenuators offer amazing performance in a small footprint. Available in both standard and temperature variable versions these attenuators work up to 18 GHz and are available in ½ dB increments.

Micro-Mode Products Inc.,
El Cajon, CA (619) 449-3844,
www.micromode.com.
Booth 1752 **RS 270**

Highpass Filter

The model HMBC-150HJ is a highpass filter with a passband from 0.5 to 18 GHz. This miniature device discriminates a desired band of frequencies from all unwanted RF signals below a specified bandpass. The HMBC filter has uses in many types of military applications, including: EW, radar and communications systems, as well as aerospace and weather satellite systems. The main advantages of the Microphase-designed and engineered HMBC highpass filter are its small size and excellent RF performance with extended stopbands. This filter has a cut-off frequency of 0.5 GHz with a passband to 18 GHz.

Microphase Corp.,
Norwalk, CT (203) 866-8000,
www.microphase.com.
Booth 602 **RS 271**

Coaxial Terminations

The model TNM-114 is a Type N termination that operates in a frequency range from DC to 2.5 GHz. Also available in SMA models, large volumes of these terminations are kept in stock and priced for quick delivery.

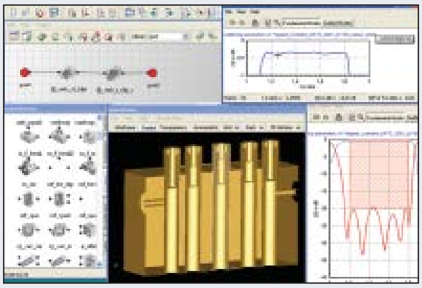
Microwave Communications Laboratories Inc.,
Saint Petersburg, FL (727) 344-6254,
www.mcli.com.
Booth 2026 **RS 272**

Multiplexer

The model 16866 is a multiplexer that offers three operating bands over a wide range of frequencies (30 to 90 MHz, 115 to 400 MHz and 450 to 2000 MHz). This unit is ideal for commercial or military applications that require a compact design and reliable isolation due to the co-location of the three transmission sources. MFC is an ISO9001:2000 registered company.

Microwave Filter Co. Inc.,
East Syracuse, NY (315) 438-4700,
www.microwavefilter.com.
Booth 2014 **RS 273**

Fast EM CAD and Optimization Tool

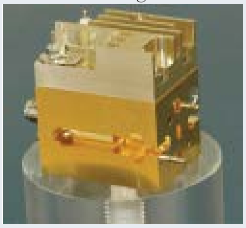


WASP-NET® ends the quest of microwave design engineers for high simulation speed by its unique hybrid MM/FE/MoM/FD CAD engine, which yields EM precision in seconds. The new releases of WASP-NET will, among other things, provide a new graphical user interface (GUI), utilizing all modern operational and user-defined conveniences for highest user-friendliness, combined with a new quality of EM CAD and optimization efficiency by improved algorithms. WASP-NET application examples include: fast optimization of all types of waveguide components and aperture antennas/arrays; full-wave synthesis of waveguide and combline filters; cross-coupled and LTCC filters; dielectric resonator filters; dielectric loaded horns; shaped subreflectors; squarax and stripline elements; and large-sized structures, e.g. slot arrays, reflectors and antennas with radomes.

Microwave Innovation Group (MiG) GmbH & Co. KG,
Bremen, Germany +49 421 223 7966 0,
www.mig-germany.com.
Booth 709 **RS 274**

Active Multipliers

The AMC series of full-band active multipliers extends the range of coaxial signal sources from 8 to 20 GHz to the complete millimeter-wave spectrum from 18 to 140 GHz in all common waveguide bands. The AMC series features high output power, low power dissipation, built-in bias protection, optional multiplication configurations and rugged packaging. Outputs are available in eight waveguide bands from WR-42 to WR-08. Watch for a high power (13 dBm) full-band WR-10 version and a full-band WR-06.



Millitech Inc.,
Northampton, MA (413) 582-9620,
www.millitech.com.
Booth 1522 **RS 275**

Low Noise Amplifier

This GaAs MMIC low noise amplifier (LNA) is offered in an RoHS compliant, standard 3×3 millimeter QFN plastic package, covering 20 to 38 GHz. This LNA, identified as XL1010-QT, delivers 3 dB noise figure and 17 dB small-signal gain and is well suited for multiple receiver applications that require broadband performance with simple bias requirements. The XL1010-QT also includes on-chip ESD protection structures and DC bypass capacitors to ease implementation and volume assembly. Samples are available today from stock, along with production quantities in six to eight weeks.

Mimix Broadband Inc.,
Houston, TX (281) 988-4600,
www.mimixbroadband.com.
Booth 1423 **RS 276**

Ceramic Hermetically-sealed RF Switches

On land, sea and in the air, demanding critical applications call for a switch that is a cut above the rest. Mini-Circuits' rugged CSWA2-63DR+ ceramic RF/microwave SPDT switch is that switch. From 0.5 to 6 GHz this switch operates in the absorptive mode (good output VSWR in off state) and from 0.3 to 500 MHz in the non absorptive mode (output ports reflective in off state). The CSWA2-63DR+ at only 4 × 4 × 1.2 mm handles tight spaces; provides protection against high moisture environments and offers outstanding performance. For tough RF/microwave switch requirements in commercial, industrial or military applications, think Mini-Circuits' new ceramic switch. Price: from $4.95 each (Qty. 10 to 49).

Mini-Circuits,
Brooklyn, NY (718) 934-4500,
www.minicircuits.com.
Booth 1937 **RS 277**

New Waves

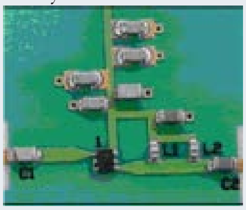
Miniature Digital SP5T Switch

The model SW5-005180AI3NF-S0001 is an absorptive single-pole five-throw (SP5T) switch that operates in a frequency range from 500 MHz to 18 GHz with a minimum of 60 dB isolation and VSWR of 2:1 maximum. The four-bit input control word is TTL compatible and commands switching time from 50 percent control input to the 10 to 90 percent settling within 100 ns. Rise/fall time is < 20 ns typical. The power handling capability is 20 dBm. This model measures 1.7" across (including connectors) and is 0.37" thick. Weight: 19 grams.

MITEQ Inc.,
Hauppauge, NY (631) 436-7400, www.miteq.com.
Booth 1108 **RS 278**

CLR Library™

This upgraded version of Modelithics capacitor-inductor-resistor model library adds scalable 01005, 0201, 0402 and 0603/0604 sized capacitor and inductor Global Models from vendors like AVX, Murata, Taiyo-Yuden, Coilcraft, Toko and TDK. Version 5.02 is currently shipping for Agilent's ADS, AWR's Microwave Office and Agilent/Eagleware's Genesys EDA software. CLR Library models are part-scalable, substrate-scalable, with a number of advanced features now offered in many models such as pad-scalability, pad-removal and orientation (H/V) selection. For ADS and MWO users, this library includes a new feature with which the layout geometry for pad-scalable models will now be automatically updated to match user-specified values for the pad dimension parameters. Versions of the CLR Library are also available for Ansoft Designer and Cadence Spectre RF.



Modelithics Inc.,
Tampa, FL (813) 866-6335, www.modelithics.com.
Booth 746 **RS 279**

WiMAX Cavity Filter

Utilizing a re-configurable platform fully modeled in EM simulation software and tested with a stringent design verification process, the WiMAX cavity filter series covers the 2.3 to 2.7 GHz frequency range with emphasis on low loss narrowband applications. WiMAX cavity products features include: passband center frequency from 2.3 to 2.7 GHz, suited for mobile and fixed WiMAX, WiBro and Wi-Fi applications; 0.04 to 0.2 percent 1 dB bandwidth available; and use as an Rx and/or Tx filter. Duplexers can be developed using the same re-configurable platform.

MtronPTI,
Yankton, SD (605) 665-9321, www.mtronpti.com.
Booth 2000 **RS 280**

48 V DC-DC Converters

This MPD7D06*S 48 V input isolated DC-DC converter series is developed to provide optimal power selection flexibility. The new device allows engineers to easily scale from low to high power and vice-versa in the design stage. This saves valuable time and money during the board layout and presents the opportunity to add new features or make changes without altering said layout. This ability is especially appealing to router, computer server, optical backbone, FTTx, Public Branch Exchange (PBX) and fixed wireless access applications. The increased scalability is enabled by the MPD7D06*S's parallel operation feature and footprint compatibility with the 10 W MPD6D10*S series and the 15 W MPD6D11*S series DC-DC converters.

Murata Electronics North America,
Smyrna, GA (770) 436-1300, www.murata.com.
Booth 1103 **RS 281**

New Waves

Microwave Integrated Circuit Design

Narda Microwave-East will showcase its innovative approach to microwave integrated circuit design at IMS 2008. The company's techniques deliver unprecedented levels of analog, microwave and digital integration, along with extensive use of FPGAs for high speed signal processing and temperature compensation. The result is compact, multifunction modules that can be produced at lower cost in high volumes with high levels of performance.

Narda Microwave-East,
Hauppauge, NY (631) 231-1700, www.nardamicrowave.com/east.
Booth 1600 ***RS 282***

Temperature-compensated Crystal Oscillator

The NT2520SA series is an SMD temperature-compensated crystal oscillator (TCXO) measuring 2.5 × 2.0 mm with a height of only 0.8 mm maximum and weighing just 0.013 g. Exhibiting tight frequency stability of ±0.5 ppm over the broad operating temperature range of –30° to +85°C makes this oscillator ideal for GPS, PND and cellular phone handset applications. It is available in frequencies ranging from 13 to 38.4 MHz and GPS frequencies of 13, 16.368, 16.369, 16.8, 19.2, 24.5535, 26, 27.456 and 38.4 MHz. Delivery for the NT2520SA series is 12 weeks ARO. Price for 10,000 pieces of the NT2520SA packaged tape and reel is approximately $1.65 each.

NDK America Inc.,
Belvidere, IL (815) 544-7900, www.ndk.com.
Booth 909 ***RS 283***

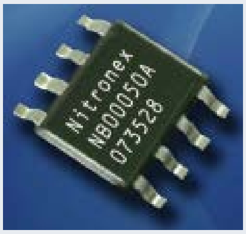
High Speed Receiver and Beam Controller

The Panther 9000 series high speed receiver is now available for high performance antenna testing. The Panther 9000 collects multi-port, multi-frequency data at up to 300,000 measurements per second and includes an integrated beam controller to free the measurement application software from stringent timing requirements. The Panther 9000 supports CW or pulsed measurements and transfers the amplitude and phase data directly to the host computer through a LAN interface.

Nearfield Systems Inc.,
Torrance, CA (310) 525-7000, www.nearfield.com.
Booth 2012 ***RS 284***

GaN-on-Si Power Transistor

The model NPT1004 is a gallium nitride high electron mobility transistor (HEMT) that delivers 45 W at 28 V for high peak to average ratio (PAR) and pulsed applications. Designed using Nitronex's patented SIGANTIC® NRF1 process, the NPT1004 combines a broadband DC to 4 GHz high power density GaN-on-Si HEMT with a cost-effective thermally-enhanced plastic package to offer an optimized solution for light thermal load power applications. The NPT1004 delivers 5 W average power for 2.5 to 3.5 GHz WiMAX applications (single carrier OFDM



NEW WAVES

64-QAM ¾, 10.3 dB peak to average, 10 MHz channel bandwidth) and 4.5 W for 3.3 to 3.5 GHz WiMAX applications (single carrier OFDM 64-QAM ¾, 10.3 dB peak to average, 3.5 MHz channel bandwidth).

Nitronex,
Durham, NC (919) 424-9100,
www.nitronex.com.
Booth 2108 **RS 285**

RF IC

NXP's TFF1003HN is a new RF IC designed for use in Ku-band linear block upconverter for VSAT systems. This IC features HVQFN24 packaging and is manufactured in SiGeC technology. The TFF1003HN is an integrated VCO-PLL, and converts a 204 MHz signal into a 13.05 GHz, phase noise, integrated from 5 kHz to 10 MHz, < 0.7° RMS. This model offers 100 kHz phase noise density at –100 dBc/Hz. The TFF1003HN will be volume production at the end of 2008.

NXP Semiconductors,
San Jose, CA (415) 593-8422,
www.nxp.com.
Booth 523 **RS 286**

Drop-in Circulators and Isolators

These two miniature sized drop-in type circulators and isolators are designed for the 33 GHz frequency range. Dimensions of the circulators/isolators are 4 × 4 × 3.5 mm. The pattern is printed on a ferrite plate by sputtering, and the connection to the circuit board is made by bonding wire or ribbon. Loss is 1 dB maximum, VSWR is 1.7 maximum, isolation is 15 dB minimum and power handling is 0.25 W maximum.

Orient Microwave Corp.,
Higashiomi, Shiga, Japan
+81-749-45-8121,
www.orient-microwave.com.
Booth 1649 **RS 287**

Bandpass Filter

The model PTF-2BP30512-ES is a continuously tunable bandpass filter for JTRS and SDR RF front-end applications. This filter operates in a frequency range from 30 to 512 MHz and provides an easy-to-use, self-contained compact package that facilitates filter performance demonstrations and integration for RF front-end application testing. The 6 percent bandwidth filter has insertion loss of 5.5 dB, IIP3 of 43 dBm and can handle up to 2 W of RF power for use in Tx/Rx applications.

Paratek Microwave Inc.,
Columbia, MD (301) 575-0900,
www.paratek.com.
Booth 2111 **RS 288**

Rectangular GPS Antenna

This rectangular antenna (linear polarization) is designed to perfectly fit into a slim type of navigation application and GPS receiver. It has a square antenna merit that features low noise as well as a chip antenna with good antenna gain. This antenna is smaller, superior and also offered in a variety of sizes that include: 25×7.4×2T, 25×10×4T, 25×13×4T and 35×17×4T according to customers' needs. The company is in progress of obtaining patents for Korea (10-20060100021-1) and overseas (PCT/KR2007/002291).

Partron Co. Ltd.,
Hwaseong-si, Gyeonggi-do, Korea
+82-31-201-7770, www.partron.co.kr/eng.
Booth 2152 **RS 289**

Portable Frequency Standard

This high precision frequency standard called 7370 is a cost effective and fully portable GPS synchronized frequency standard, which will continue to operate for up to eight hours without the connection of its GPS and power. The instrument is compact and lightweight (weighs only 2.6 kg), and has fully automatic battery recharging and oscillator calibration overnight, using optional fixed antenna, or while travelling (via in-car charger lead and magnetic base GPS antenna). The 7370 retains accurate time and frequency during long periods of field use, due to calibration via GPS and high quality internal oscillator.

Pendulum Instruments Inc.,
Oakland, CA (510) 428-9488,
www.pendulum-instruments.com.
Booth 344 **RS 290**

Digital Step Attenuators

This new line of UltraCMOS™ 7-bit digital step attenuators feature an unprecedented serial-addressable control interface and best-in-class linearity, superior noise immunity and no gate lag. These 50 Ω DSAs have a frequency range up to 6 GHz, and offer superior attenuation accuracy, lower current drain and exceptional ESD. The attenuators work with any combination of 3 V and 5 V logic on supply and control pins, making them ideal for next-generation communication and ATE systems.

Peregrine Semiconductor Inc.,
San Diego, CA (858) 731-9400,
www.psemi.com.
Booth 1606 **RS 291**

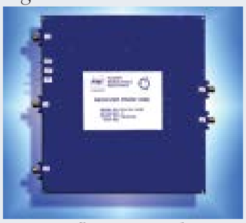
Microwave Synthesizer

These microwave frequency synthesizers are based on a phase-refining technology that provides a unique combination of low phase noise, fast switching speed and cost characteristics. The FSW-0210 model operates in a frequency range from 2 to 10 GHz with 0.001 Hz steps, microseconds tuning speed and instrument-grade spectral purity. A built-in processor supports SPI/RS-232/USB interfaces and features including output power calibration and control, external ALC input and various modulation options. The USB connection and customer-friendly interface enable instant deployment of the synthesizer.

Phase Matrix Inc.,
San Jose, CA (408) 428-1000,
www.phasematrix.com.
Booth 450 **RS 292**

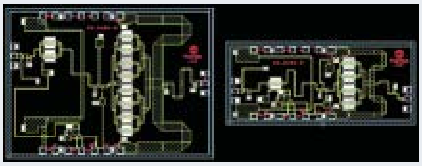
Direction Finding Receiver Front-end

The model RFE-218-70-BB is a direction finding receiver front-end that operates in a frequency range from 2 to 18 GHz. The minimum dynamic range of this subsystem is –60 to +5 dBm, while the input VSWR is 3.0 and the frequency flatness at the outputs is ±3 dB maximum. The Log slope is 50 mV/dB (±10 percent), the Log linearity is ±2.25 dB maximum and the TSS is –63 minimum. The rise time is 30 ns maximum and the recovery time is 350 ns maximum. The typical gain is +3 dB and the isolation between the outputs is 24 dB minimum.



Planar Monolithics Industries Inc.,
Frederick, MD (301) 631-1579,
www.planarmonolithics.com.
Booth 912 **RS 293**

X-band PA MMICs



Plextek has recently completed the design of 2 and 4 W X-band (8 to 12 GHz) power amplifier MMICs for a UK client. These are available as bare die, packaged components or connectorized modules. As fabrication also takes place outside the US, these parts will not be subject to ITAR restrictions.

Plextek Ltd.,
Great Chesterford, Essex, UK
+44 (0) 1799 533200, www.plextek.com.
Booth 2016 **RS 294**

Precision "N" Cable Connector

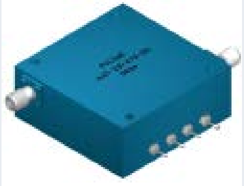
New Waves

This precision Type N connector is available for 0.300 diameter low-loss cables. Using solder/clamp cable termination with a soldered center contact the connector performs from DC to 18 GHz. The design has a dielectric loaded solid outer conductor that is compatible with all N female interfaces and has a robust internal captivation. Other unique features include a convenient knurl/hex coupling nut and an extended tail grip designed to retain SAE-AMS-DTL-23053/4 dual wall heat shrink in hi-flex applications. Additionally, the connector has moisture resistant front and rear seals and is thermally rated from –55° to +170°C.

Precision Connector Inc.,
Franklin, IN (317) 346-0029,
www.precisionconnector.com.
Booth 413 **RS 295**

Linearized Pin Diode Attenuator

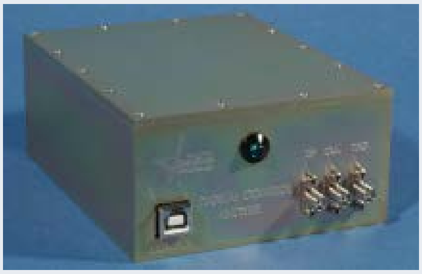
The model AAT-28-479A/5S is a linearized pin diode attenuator that supplies up to 32 dB of



attenuation in the frequency range from 6 to 16 GHz with 4 dB insertion loss and a control voltage of 0 to +4 V. The DC power required is +15 V at 100 mA and –15 V at 50 mA. Outline dimensions are 2" × 2" × 0.8" and SMA female removable connectors are utilized. Other units are available to 18 GHz.

Pulsar Microwave Corp.,
Clifton, NJ (973) 779-6262,
www.pulsarmicrowave.com.
Booth 1548 **RS 296**

Digitally-controlled Exciter



This digitally-controlled exciter is a turnkey solution designed for FMCW radar applications. Using one master clock, the exciter provides the coherency of frequency and timing in RF output, radar synchronizer clock, receiver data acquisition sampling clock and trigger. The DDS-based exciter posses high linearity and low phase noise characteristics meeting extreme accuracy requirement in generating agile programmable waveforms such as sawtooth, triangle and gated FMCW. The standard RF output frequency is set at 11.7 GHz with up to 1.2 GHz bandwidth. It is then multiplied into Ka-band, V-band and W-band to generate desired millimeter-wave frequencies.

QuinStar Technology Inc.,
Torrance, CA (310) 320-1111,
www.quinstar.com.
Booth 1905 **RS 297**

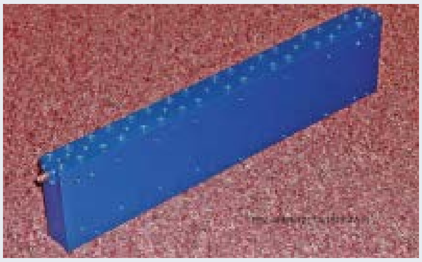
RF Passive Components

R&D Microwaves introduces new low PIM RF passive components for wireless, featuring a new high power combiner. The unit includes a unique integrated high power termination. The combiner assembly operates in a frequency range from 800 to 2500 MHz, with less than 160 dBc PIM. The combiner is supplied with 7-16 DIN connectors and is IP-65 sealed for outdoor or indoor applications. "No PIM" has increasingly become a hot topic in wireless systems applications.

R&D Microwaves LLC,
East Hanover, NJ (908) 212-1696,
www.rdmicrowaves.com.
Booth 951 **RS 298**

New Waves

L1 and L2 Dual GPS Notch Filter



Reactel part number 4PR7-12274/1575.4-S11 is a dual GPS band notch filter with 45 dB notches centered at 1227.4 and 1575.4 MHz. This unit features 3 dB bandwidths of 15 MHz and insertion loss of less than 0.8 dB.

Reactel Inc.,
Gaithersburg, MD
(301) 519-3660,
www.reactel.com.
Booth 1722 **RS 311**

GaN Ultra Broadband Power Amplifier

The model GA0538-4540-M amplifier is designed with wideband gap GaN device technology, resulting in ultra broadband frequency range and high output power. This product is 10 W output power over 0.5 to 3.8 GHz that features 42 dB gain. Current draw is 2500 mA from +32 V DC. Connectors are SMA(F). A bench top type model, GA0538-4540-R, is also available that features a cooling fan and 100 to 240 V AC.

R&K Co. Ltd., Seki Technotron USA,
Santa Clara, CA (408) 986-9190,
www.sekitech.com.
Booth 1712 **RS 299**

Electro-mechanical Switch

The SPDT latching switch offers a height reduction of 40 percent over standard models.

This sub-miniature latching switch maintains all of the electrical characteristics of its standard models. The switch operates in a frequency range from DC to 18 GHz, features low insertion loss and high isolation, high power handling capability and a life of 2,000,000 cycles minimum. Size: 1.25 × 1.34 × 0.5.

Renaissance Electronics Corp.,
Harvard, MA (978) 772-7774,
www.rec-usa.com.
Booth 1800 **RS 312**

2 W InGaP Amplifier

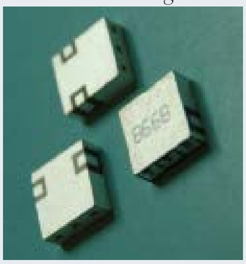
RFMD's SZP5026Z delivers the ideal combination of low cost and high performance. The

SZP5026Z is a high-linearity, single-stage class AB heterojunction bipolar transistor (HBT) amplifier housed in a proprietary surface-mountable encapsulated package. Specifically designed as a flexible final PA for 802.16 and 802.11 equipment in the 4.9 to 5.9 GHz bands, the on-chip active bias circuitry allows operation from a single +3 to +5 V bias without the use of complicated negative gate bias circuitry.

RFMD,
San Jose, CA (408) 493-4300,
www.rfmd.com.
Booth 1235/1311 **RS 313**

RFID Filters

Sangshin Elecom announces its line-up of RFID filters. Sangshin has developed a complete line of



monoblock filters for RFID applications. These filters are designed for US, European, Japanese and Korean RFID applications and have the same package size and footprint for all four frequencies allowing for a single board layout. These filters offer excellent performance and stability in a small, cost-effective package.

Sanghin Elecom, RFMW Ltd.,
San Jose, CA (877) 367-7369,
www.rfmw.com.
Booth 651 **RS 314**

Line Card

The 2008 line card is designed for the company's RF, wireless and power conversion division, which designs and distributes components, modules and assemblies used in RF and wireless infrastructure, networks, digital broadcasting, defense and power conversion. The dual-format line card features the most up-to-date listing of Richardson Electronics' suppliers. Featuring 77 of the industry's leading global suppliers, the new line card includes 11 new suppliers. Suppliers featured in the line card have access to key global customers as it will be distributed by local sales engineers at customer visits and tradeshows. The expanded line card will also help customers searching for products by category.

Richardson Electronics,
LaFox, IL (630) 208-3637,
www.rell.com.
Booth 1626 **RS 315**

Surface-mount Switches

This series of QPL single-pole, double-throw (SPDT) surface-mount switches are qualified to MIL-DTL-3928. The switches are identified as part numbers MIL-DTL-3928/29-01 through -12 on the QPL listing. This new line of SPDT surface-mount switches reflects the high quality and reliability of QPL switches, as well as other electro-mechanical switches manufactured by RLC.

RLC Electronics Inc.,
Mount Kisco, NY (914) 241-1334,
www.rlcelectronics.com.
Booth 415 **RS 316**

50 GHz Four-port VNA

The new R&S ZVA50 is the world's first four-port network analyzer with measurement coverage to 50 GHz. Its two sources allow it to perform measurements on multiport and balanced components using a single instrument. With a measurement bandwidth of 15 MHz, high sampling rates and time resolution of 12.5 ns, the R&S ZVA50 is well suited for pulse profile measurements of radar and satellite signals. Dynamic range is 130 dB, output power is +13 dBm and measurement speed is 3.5 µs/point.

Rohde & Schwarz,
Columbia, MD (410) 910-7800,
www.rohde-schwarz.com.
Booth 623 **RS 317**

High Frequency Coaxial Connectors

These two unique products improve productivity in test applications. The SMA Quick-Lock™ provides a unique locking mechanism to replace threaded SMA male connections. The SMA Push-On™ offers a faster slide on connection. Both work with any SMA female connector. These products are offered as test cables in various sizes, cable types and configurations and provide excellent electrical performance to 18 GHz.

Rosenberger of North America LLC,
Lancaster, PA (717) 290-8000,
www.rosenbergerna.com.
Booth 1517 **RS 318**

New Waves

Quad-band CMOS PAs

The model SEM4001 is a GSM/GPRS quad-band CMOS PA module that meets the 3GPP standards. By using SEM's module technology, SEM4001 achieves power-added efficiency levels that are among the highest in the GSM PA industry. SEM's patented PA techniques allow the power amplifier core and the power controller to be implemented in a single die with a standard silicon CMOS process technology bringing the cost advantage of true CMOS integration. The integrated 50 Ω input and output matching circuitry in the standard 5×5 leadless plastic package enables customers to significantly minimize the bill of material. Samples are available upon request.

Samsung Electro-Mechanics (SEM),
Suwon, South Korea
(404) 385-7557,
www.sem.samsung.com.
Booth 1157 ***RS 319***

7/16 Panel Receptacle

The 7/16 panel receptacle consistently delivers intermodulation levels of –175 dBc. This receptacle is especially suited for up-link communications. It ensures high grade transmission by delivering VSWR < 1.03 (PCS) and PIM of –175 dBc. It is weather sealed and is delivered with an enhanced 0.232 interface that results in improved mating characteristics and reduction of mating torque. In addition to improved on/off mating, the enhanced 0.232 interface also offers higher signal integrity and therefore protection of communications equipment.

San-tron Inc.,
Ipswich, MA (978) 356-1585,
www.santron.com.
Booth 1042 ***RS 320***

Voltage-controlled Oscillator Synthesizer

The SKY73117 voltage-controlled oscillator (VCO) synthesizer is a fully integrated, high performance signal source for high dynamic range transceivers. The device provides a fast switching speed and low phase noise performance for 2G, 2.5G and 3G base station transceivers. In addition, the synthesizer provides an integrated, internal shield for the complete module that reduces electromagnetic interference (EMI) and radio frequency interference (RFI). Therefore, external EMI/RFI shielding is not required, which reduces PCB layout and shortens product development time.

Skyworks Solutions Inc.,
Woburn, MA
(781) 376-3000,
www.skyworksinc.com.
Booth 1617 ***RS 321***

End Launch Connectors

These enhanced end launch connectors provide an improved clamping mechanism that securely holds the connector in place for board thickness up to 0.110" (2.80 mm) and renders soldering the pin to your trace optional. Connectors are available in SMA (27 GHz), 2.92 mm (40 GHz) and 2.40 mm (50 GHz). Connectors ship fully assembled.

Southwest Microwave Inc.,
Tempe, AZ (480) 783-0201,
www.southwestmicrowave.com.
Booth 2043 ***RS 322***

NEW WAVES

Nonmagnetic Variable Trimmer Capacitors

These high voltage nonmagnetic variable capacitors, designated the SGNM series, feature durable high purity ceramic dielectrics. High purity ceramics are a new concept to the industry and provide significant advantages over the currently available devices using polytetrafluoroethylene (PTFE) dielectric including increased performance, durability, mechanical and electrical stability. The design can be sealed to 40 lbf/in^2 (276 kPa), or used for cryogenic applications as low as 4 K. The series is easily modified with specification options enabling the design to meet many unique project requirements. The SGNM series offers models with capacitance ranges starting with 1 to 10 pF, and increasing (in 5 pF increments) to 10 to 180 pF. DC working voltage ranges from 1.5 kV up to 7.5 kV (DC withstanding voltage from 3 to 15 kV).

Sprague-Goodman Electronics Inc.,
Westbury, NY (516) 334-8700, www.spraguegoodman.com.
Booth 1553 **RS 323**

Ceramic Trimmer Capacitors

These ceramic trimmer capacitors are designed for telecom and microwave projects requiring miniature components. Designated the SGC3S series, these super thin surface mounted devices measure 0.126" × 0.177" × 0.059" and are RoHS compliant. They are constructed with high temperature liquid-crystal polymer housings for superior durability and low dielectric loss. The housing is constructed to resist penetration by dust and flux, and is colored to make each of the five available capacitance ranges easily identifiable. The parts are ideal for designs requiring minimal capacitance drift over the operating temperature range of –25° to 85°C.

Sprague-Goodman Electronics Inc.,
Westbury, NY (516) 334-8700, www.spraguegoodman.com.
Booth 1553 **RS 324**

Multi-pin Connectors

These hermetic miniature dual-lobed multi-pin connectors are offered with 0.025" contact centers. The connectors are mating interface compliant with MIL-DTL-32139. Designed to laser weld into higher level assemblies and provide reliable hermeticity (1×10^{-9} or better) in hostile environments. Connectors are available in several shell configurations and materials, including aluminum, stainless steel and titanium. They can be supplied with insulated wire, formed leads or flat pin terminations to facilitate wirebonding.

SRI Hermetics Inc.,
Melbourne, FL (321) 254-4067, www.srihermetics.com.
Booth 1436 **RS 325**

Copper-plated Submount Technology

This copper-plated submount technology is designed in support of today's "P" side down, edge-emitting high power laser diode mounting applications. Submount features include: planarized copper metalization (up to 75 µm thick) capable of efficient, high thermal transfer unmatched by today's other standard metallization techniques; high thermally conductive ceramics: AlN (up to 230 W/mK Tc), BeO (up to 320 W/mK min Tc); greatest thermal conductivity/price ratio amongst metallizations currently available; excellent flatness and parallelism; straight walls; and dead sharp radii (5 µm typ).

Stellar Industries Corp.,
Millbury, MA (508) 865-1668, www.stellarind.com.
Booth 2001 **RS 326**

Contacts for 38999 Connectors

To meet the requirements of customers looking to simplify system level interconnect, SV Microwave introduces a new family of high frequency contacts for series 1 and 3 MIL-DTL-38999 connectors. Based on SV's proven blindmate technology to accommodate misalignment during mating, the product line consists of size 8 contacts with the option of 18 or 40 GHz performance and size 12 contacts operating to 65 GHz, all of which fit into standard cavities and are fully removable using standard extraction tools. Designs are available for common cable sizes: custom versions can be produced for special cables and PCB mount applications.

SV Microwave,
West Palm Beach, FL (561) 840-1800, www.svmicrowave.com.
Booth 801 **RS 327**

High Resolution Synthesizer

This high performance, high resolution synthesizer operates in a frequency range from 5 to 5.3 GHz and is housed in a small connectorized package measuring 20 × 12 × 3 cm. The step size in the 300 MHz operating bandwidth is 1 Hz with maximum phase noise of –105 dBc/Hz at 1 kHz, –120 dBc/Hz at 10 kHz, –120 dBc/Hz at 100 kHz and –120 dBc/Hz at 1 MHz offset. Non-harmonic spurious suppression is –60 dB typical with RF output power of +10 dBm over the specified operating band. Additional features include support for locking with external GPS 1 PPS source for long-term stability and manual field adjustable frequency tuning.

Synergy Microwave Corp.,
Paterson, NJ (973) 881-8800, www.synergymwave.com.
Booth 900 **RS 328**

NEW WAVES

Non-reinforced Prepreg

*fast*Rise™27, a multilayer, non-reinforced prepreg material is designed to eliminate skew in differential transmission lines and eliminate Dk fluctuations caused by fiberglass in filter and coupler applications. *fast*Rise27 is a low temperature thermosetting prepreg based on ceramic, thermoset and PTFE. It is ideal for use with Taconic's standard low loss laminates like TSM-29. The low 0.0017 Df at 40 GHz enables the production of mm-wave multilayer PWBs. The low 420°F lamination temperature enables sequential laminations to be performed at lower temperatures than those normally used for FEP and PFA in military constructions.

Taconic,
Petersburgh, NY (518) 658-3202,
www.taconic-add.com.
Booth 637 **RS 329**

4 kW IFF Pulsed Amplifier/Transmitter

The model 1172 is a pulsed amplifier/transmitter designed primarily for IFF applications.

Maximum output power is 4000 W (66 dBm) and is adjustable in three increments. The unit operates in IFF Modes 1, 2, 3/A and 4 and Mode S. Optionally, the model 1172 is available as a transmitter with the addition of an internal RF source. Standard features of the amplifier include DPSK and PPM modulation, pulse shaping circuits, sample ports (forward power) and protection circuitry.

Technical Services Laboratory Inc.,
Ft. Walton Beach, FL (850) 243-3722,
www.tslinc.com.
Booth 515 **RS 330**

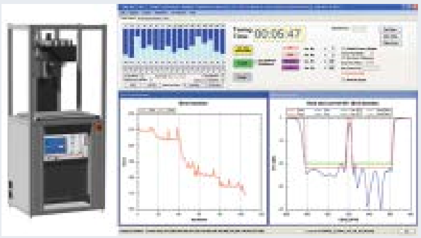
DPDT Ultraminiature Relays

This series of DPDT ultraminiature relays delivers RF performance over a bandwidth from

DC to 8 GHz. The new RF312 exhibits high repeatability and is capable of transmitting signal integrity up to 12 Gbps data rates. The RF312 family of relays also exhibits excellent isolation between pole-to-pole. The new relays are available as through-hole (RF312) or surface-mount (GRF312). Both versions are RoHS compliant.

Teledyne Relays,
Hawthorne, CA (800) 284-7007,
www.teledynerelays.com.
Booth 823 **RS 331**

Intelligent Automatic Filter Tuning Tool



This Intelligent Automatic Filter Tuning Tool (IAFTT) allows producers of high performance RF and microwave filters to save a significant amount of time and money, due to its capability to set adequate filter characteristics automatically, up to several times faster and more accurately than manually. IAFTT makes filters and duplexers production planning easier. Production processes are much more foreseeable and there is no need of high experienced human filter tuners.

TeleMobile Electronics Ltd.,
Gdynia, Poland, +48 58 7351186,
www.iaftt.eu.
Booth 2115 **RS 332**

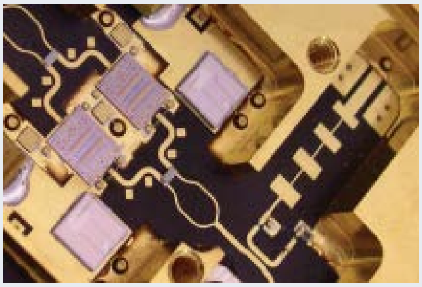
D-sub and Circular Assemblies

HDRFI® assemblies use high frequency low loss coax and a unique patented interconnect

system to transfer high frequency/data through a planar connection system, using a z-axis elastomer. High frequencies transfer with minimal loss through the connector interface. Features include: standard pin and socket power contacts, no moving parts, 40 GHz RF contacts, frictionless, high bandwidth, low compression mating force, small form factor, zero extraction force, scalable and customizable for multiple configurations.

Tensolite,
St. Augustine, FL (800) 458-9960,
www.tensolite.com.
Booth 1637 **RS 333**

Millimeter-wave Components



This wide range of millimeter-wave components is designed to support various military and commercial/industrial applications. These components are the basis for custom millime-

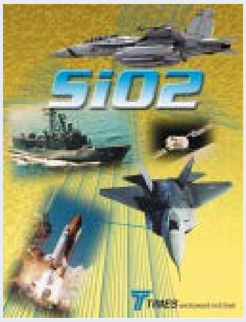
NEW WAVES

ter-wave subsystems for radar, sensor and communications applications. System tradeoff studies are performed in cooperation with the customer to achieve optimum performance levels. Fast prototyping can then be performed using standard Terabeam/HXI components. A transition to production can take place using advanced integration techniques to reduce the size and cost of the hardware.

Terabeam/HXI,
a Division of Terabeam Corp.,
Haverhill, MA (978) 521-7300,
www.terabeam-hxi.com.
Booth 403 ***RS 334***

Cable Assemblies

SiO2 cable assemblies are a major advancement in silicon dioxide technology. Advanced



equipment and materials result in a low loss, high velocity dielectric with excellent phase and loss versus temperature as well as excellent consistency. SiO2 cables have exceptionally low hysteresis, with phase and loss values returning to the same values. Hermetically sealed intermediate sections allow use of virtually all TMS connectors including replaceable and non-replaceable and connectors have a crack-free, fired glass seal for optimum microwave performance.

Times Microwave Systems,
Wallingford, CT (203) 949-8400,
www.timesmicrowave.com.
Booth 1000 ***RS 335***

Ku-band GaN FET

The model TGI1414-50L is a gallium nitride (GaN) Ku-band power field effect transistor (FET) that operates in a frequency range from 14 to 14.5 GHz and achieves high output power of 50 W. The primary application of the new transistor will be earth stations for satellite microwave communications, which carry high capacity signals, including high definition broadcasts. The TGI1414-50L is now in mass production.

Toshiba America Electronic Components Inc.,
Irvine, CA (949) 623-2900,
www.toshiba.com/taec/.
Booth 1701 ***RS 336***

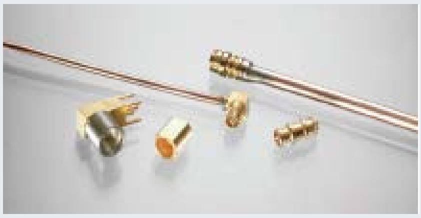
Solid-state Programmable Attenuator

The model SPA-53095-1S-5V-TTL-R is a high performance programmable attenuator that

features a dynamic range of 95 dB in 1 dB steps over a wide frequency range of 400 to 3000 MHz. Attenuation accuracy is ±0.4 dB or 2.5 percent over the entire range. VSWR is 1.5 maximum and insertion loss is 5.5 dB maximum. Switching speed is < 100 ns and the operating temperature range is 0° to 70°C. The control protocol is TTL and via a 10 pin connector. The RF connectors are SMA female. This programmable attenuator is an ideal solution where high reliability, fast switching speed and flexible configurations are required. Delivery: stock to six weeks.

Trilithic Inc.,
Indianapolis, IN (317) 895-3600,
www.trilithic.com.
Booth 1836 ***RS 337***

40 GHz RF Connectors

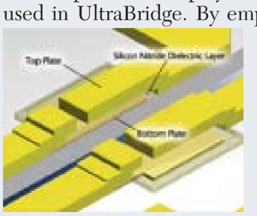


These new SMPM microminiature RF connectors offer the same performance and convenience as the proven SMP connectors, but in a form factor that is 30 percent smaller. With a low VSWR through 40 GHz, SMPM connectors offer a versatile solution for high density packaging, allowing center-to-center spacing of 0.135". The 50 Ω connectors are available with either a smooth bore or fully detented interface to provide insertion forces of either 2.5 or 4.5 pounds. The interface design complies with MIL-STD-348A. The connectors are designed for rugged environments, where harsh mechanical shock and vibrations are found.

Tyco Electronics Corp.,
Harrisburg, PA (800) 522-6752,
www.tycoelectronics.com/aerospace/.
Booth 1723 ***RS 338***

UltraCapacitor™

UltraCapacitor™ employs the same technology used in UltraBridge. By employing the silicon



nitride as the dielectric layer between the upper and lower electrodes, UltraSource is capable of integrating capacitor elements from 2 pF to 250 pF directly into thin film circuit designs. Spaces as small as 1 mil (25.4 microns), controlled to tolerances of 2.5 microns, can be achieved. With capacitance designed in, the door is open to a variety of other component integration ideas.

UltraSource Inc.,
Hollis, NH (603) 881-7799,
www.ultrasource.com.
Booth 1900 ***RS 352***

NEW WAVES

Free-run Mode Jitter Attenuators

The VFJA402 and VFJA430 jitter attenuators, integrated clock/PLL timing solutions are designed for 1G/10G/100G synchronous Ethernet applications. The VFJA402 provides two LVPECL outputs from 10 to 200 MHz. The VFJA430 has two LVCMOS outputs from 10 to 200 MHz. Two select inputs [S1,S0] allow the user to select 1 of 3 preset input frequencies from 8 kHz to 200 MHz or free-run mode for both jitter attenuators. The VFJA402 and VFJA430 offer ultra-low output jitter (0.20 ps RMS 12 kHz to 20 MHz). The devices operate from a +3.3 V DC power supply and typically consume 150 mW. Both are available in a 19.5 × 15.5 mm surface-mount package and are RoHS 6/6 compliant.

Valpey Fisher Corp., Hopkinton, MA (508) 435-6831, www.valpeyfisher.com.
Booth 1449 ***RS 339***

Oven-controlled Crystal Oscillators

The EX-620 series evacuated miniature oven-controlled crystal oscillator (EMXO) was specifically developed to achieve OCXO performance while significantly lowering power consumption and reducing package size (13.21 × 13.21 mm). The smaller size and low power consumption makes the EMXO ideal for portable and battery powered applications. The ruggedized hybrid thick film construction also makes the EX-620 ideal for harsh environment applications.

Vectron International, Hudson, NH (888) 328-7661, www.vectron.com.
Booth 1501 ***RS 340***

Transistor Tool

SWAP-X402 is an innovative yet affordable tool for characterizing microwave power transistors. SWAP-X402 can be used as an add-on to any tuner system. Next to providing load pull information such as power gain, the SWAP-X402 measures the time domain waveforms of voltages and currents at the transistor terminals under realistic operating conditions. The additional time domain data result in an unprecedented insight in transistor behavior and are needed for validating large signal models, designing amplifiers and studying reliability.

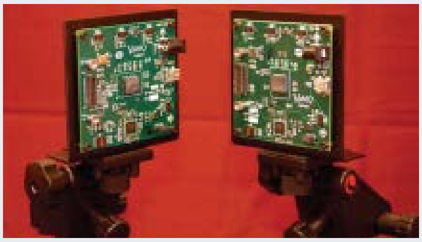
Verspecht-Teyssier-DeGroote s.a.s., Brive, France +33 5 55 86 73 01, www.vtd-rf.com.
Booth 851 ***RS 341***

Silicon NPN Phototransistors

These wide-angle phototransistors in a PLCC-2 surface-mount package are compatible with lead (Pb)-free soldering. Devices in the VEMT series serve as pin-to-pin and functional equivalents for the current TEMT series of phototransistors, enabling simple and quick migration to meet lead (Pb)-free soldering requirements. Vishay's current TEMT series of phototransistors are lead (Pb)-free PLCC-2 devices, but they require lead (Pb)-based solder. The new VEMT series of phototransistors feature the same specifications as the TEMT series devices, but are compatible with lead (Pb)-free reflow soldering processes according to JEDEC-STD-020D.

Vishay Intertechnology Inc., Malvern, PA (619) 336-0860, www.vishay.com.
Booth 1013 ***RS 342***

60 GHz Integrated Radio Solution



This 60 GHz integrated radio solution enables commercial, government and academic institutions to utilize the unlicensed 57 to 64 GHz band for application development. Vubiq's tiny radio modules (patent pending), packaged in a 10 mm BGA, combine 60 GHz transmitters and receivers with integrated antennas, and are available in a cost-effective development system. Vubiq's development system includes a 60 GHz transmitter board and 60 GHz receiver board, each with a USB controller. Embedded control firmware and a simple GUI interface are included, easing setup and operation.

Vubiq Inc., Aliso Viejo, CA (949) 226-8482, www.vubiq.com.
Booth 311 ***RS 343***

Phase-locked Oscillator

The phase-locked oscillator (PLO) series provides a variety of input and output options, ensuring optimal phase noise during locked and unlocked conditions. The PLO series is based on low noise SC-cut crystal oscillator, phase lock loop and also includes an internal frequency doubler option. Noise floors are typically –172 dBc/Hz, and inputs can be specified from 1 to 30 MHz. These parts are useful for system synchronization, radar systems, coherent sources, phase noise cleanup and test equipment.

Wenzel Associates Inc., Austin, TX (512) 835-2038, www.wenzel.com.
Booth 2139 ***RS 344***

New Waves

3D Electromagnetic Solver

WIPL-D Pro is a 3D electromagnetic solver that provides fast and accurate analysis of arbitrary metallic and dielectric/magnetic structures. Method of Moments based numerical engine offers efficient simulations and yield high precision results: current distribution, near field, far field and circuit parameters. Application areas include: 3D antennas/arrays, transmission lines/waveguides, multi-layered MW circuits, 3D scatterers and EMC problems.

WIPL-D d.o.o.,
Belgrade, Serbia +381 11 2124 656,
www.wipl-d.com.
Booth 853 **RS 345**

Coaxial Terminations and Fixed Attenuators

Continuing the proud tradition of Omni Spectra, XMA Corp. announces two new high performance 40 GHz products: the Omni Spectra 4801-6XXX-XX family of coaxial terminations and the Omni Spectra 4882-6XXX-DB family of coaxial fixed attenuators. These products offer superior specifications, including low VSWR, a 1 W power rating, and a durable stainless steel construction–competitively priced and designed to meet the toughest demands of military, aerospace and communications applications.

XMA Corp.,
Manchester, NH (603) 222-2256,
www.xmacorp.com.
Booth 218 **RS 346**

Miniature Variable Attenuator

This miniature variable attenuator provides attenuation that can be varied continuously or by step and a wide frequency range from DC to 3, 6 and 10 GHz is available. Attenuation range from 3 to 60 dB is available. These attenuators are available in SMD, SMA/N connector types, feature small size and are lightweight. US utility patent. Applications include: 2.4G RFID, wireless LAN, mobile communications, GPS and satellite communications.

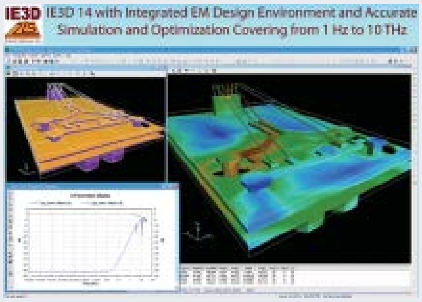
Yantel Corp.,
Shenzhen, Guangdong, China
+86-755-8355 1878, www.yantel-corp.com.
Booth 745 **RS 347**

S-band Oscillator

The model CLV2593A-LF is a lead-free, RoHS compliant oscillator in S-band (2496 to 2690 MHz) featuring ultra low phase noise performance of –105 dBc/Hz at 10 kHz offset. This unique design offers superior harmonic suppression of –24 dBc and a typical tuning sensitivity of 20 MHz/V. This VCO is designed to operate at 8 V DC supply while drawing 22 mA (typical) over the extended operating temperature range of –40° to 85°C. CLV2593A-LF is ideally suited for applications that require good harmonic suppression and ultra low phase. CLV2593A-LF comes in an industry-standard mini package measuring 0.50" × 0.50" × 0.13". Delivery: stock to four weeks.

Z-Communications Inc.,
San Diego, CA (858) 621-2700,
www.zcomm.com.
Booth 1908 **RS 348**

EM Design Tools

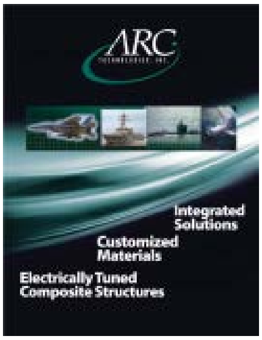


Zeland offers high performance EM design tools for MMIC, RFIC, RFID, antennas, signal integrity, RF MEMS, SoP, SiP and other high frequency applications. The latest IE3D 14 features integrated layout editing, full-wave EM simulation and optimization, S-parameters, current, near and far field visualization and processing, accurate full-wave EM simulation from 1 Hz to 10 THz. IE3D also features real-time full-wave EM tuning and optimization, Boolean enabled object oriented layout parameterizations. IE3D is linked to Cadence layout tools and Microwave Office.

Zeland Software Inc.,
Fremont, CA (510) 623-7162,
www.zeland.com.
Booth 1622 **RS 349**

NEW LITERATURE

CAPABILITIES BROCHURE



This brochure outlines the company's capabilities as a leading developer of microwave-absorbing materials and electrically tuned composite structures for use in commercial and defense applications. The six-page brochure showcases ARC Technologies' extensive capabilities and processes; expertise in advanced materials for both functional and material property requirements; in-house testing and analytical methodologies; and advanced equipment.

ARC Technologies,
Amesbury, MA (978) 388-2993,
www.arc-tech.com.

RS No. 200

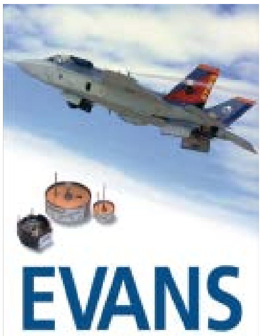
FAST PULSE TEST SOLUTIONS

This four-page web guide and short form catalog 17S outlines the company's large family of high speed, high current and high voltage pulse generators, drivers and amplifiers for research lab and production testing applications. Pulsed laser diode and discrete semiconductor device switching time applications are extensively highlighted along with 10 other application areas.

Avtech Electrosystems Ltd.,
Ottawa, Ontario, Canada (613) 226-5772,
www.avtechpulse.com.

RS No. 201

HYBRID CAPACITORS CATALOG



This catalog features the company's Hybrid® Capacitors that have been specified in numerous systems throughout the F-35 Joint Strike Fighter. Hermetically sealed, tantalum hybrid capacitors have more than 4× the energy density of other military-style capacitors. These capacitors are found in laser targeting, communications modules, controls, cockpit displays, phased-array radars, fire control systems and elsewhere on many advanced commercial and military aircraft.

Evans Capacitor Co.,
East Providence, RI (401) 435-3555,
www.evanscap.com.

RS No. 202

DESIGNER'S GUIDE

The 13th edition Designer's Guide catalog for 2008 includes 152 new digital, mixed-signal, RF, microwave and millimeter-wave product data sheets, as well as quality/reliability, application and packaging/layout information. Full specifications are provided for 633 products across 16 product lines including: amplifiers, attenuators, data converters, frequency dividers/detectors, frequency multipliers, high speed digital logic, mixers, demodulators/modulators, passives, phase shifters, power detectors, sensors, switches, synthesizers, VCOs/PLOs and VGAs.

Hittite Microwave Corp.,
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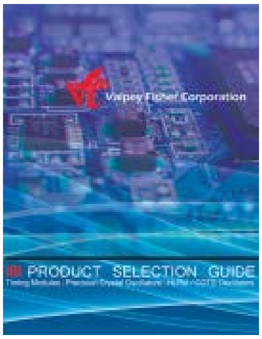

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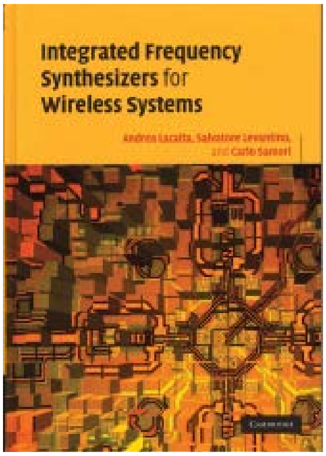

A. Lacaita, S. Levantino and C. Samori
Cambridge University Press • 246 pages; $120, £65
ISBN: 978-0-521-86315-5

The phase-locked loop (PLL) concept is about 70 years old and a wealth of literature is already available on the subject. Why another book about PLLs? The first reason is related to the specific application considered, namely the silicon integration of frequency synthesizers. Classical texts do not deal in depth with issues related to the design of frequency synthesizers in modern transceivers. In particular, the design guidelines and the performance of some important building blocks and their impact on the whole system are sometimes barely mentioned. The attempt in this book has been instead to provide a broad description of the most typical circuit topologies of voltage-control oscillators, frequency dividers and phase and frequency detectors, and to discuss their performance in terms of power consumption, phase noise, spurs, etc. The second reason is that the book attempts to provide an alternative approach to PLL theory and design. The book starts with three chapters addressing the PLL as a system. Chapter 1 points out the typical requirements of the frequency synthesizer in RF systems. Chapter 2 covers some PLL basics. It does not deal with the whole PLL theory, which is analyzed in depth in many classical books. It highlights only the concepts needed for understanding the subsequent topics. Chapter 3 analyzes fractional-division PLLs, which are seldom discussed in other texts. Chapters 4 to 9 are devoted to discussing in detail the design issues related to the PLL building blocks. Chapters 4 to 7, for example, deal with voltage-controlled oscillators and their practical implementations in bipolar and CMOS technologies, including resonator design and layout. Chapters 8 and 9 are focused on the design of programmable dividers and phase-comparison circuits, including issues related to nonlinearities.

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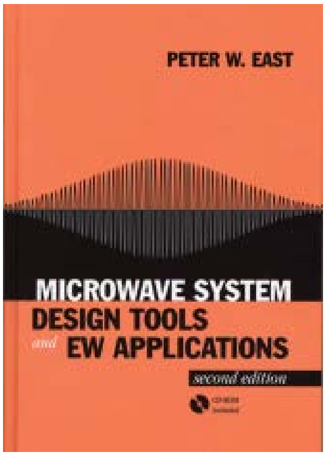
Microwave System Design Tools and EW Applications: Second Edition



Peter W. East
Artech House • 248 pages; $119, £66
ISBN: 978-1-59693-256-2

The original aims of the software e-book are maintained in this second edition. The book is intended to support microwave system designers and offers an alternative approach for the accurate design and specification of microwave components and systems for electronic warfare (EW) equipment. This edition combines a conventional technical textbook with a complementary interactive electronic book on a CD-ROM. While the book stands alone as a practical microwave system design reference, the CD-ROM runs on a personal computer and contains a number of independent small software applications paralleling and building on the topics covered in the text. The software applications or applets, written in Sun Microsystems Java 1.1 programming language, are intuitive, interactive tools, which apply the design theory outline in the book to produce accurate target models. The principal aims of this method of information presentation are to simplify microwave system design and to speed up the user understanding and learning process. The topics and applets have been selected to cover technical requirements likely to be met in the microwave radar and EW system design fields. The book restructures and expands the technical manual provided in the first edition software package into nine chapters. All the original applets have been improved and nine applets added. The range of toolbox topics is sufficient to design a modern EW system, and many, because of their complexity, have not been published before in an easily assimilated form. In summary, the book covers all the main microwave components and subsystems used in EW systems in a practical manner and examines many new characteristics and performance issues. The CD-ROM contains a simple user interface to select and run the applets and operates with all Microsoft Windows operating systems and browsers.

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Career Corner

Shortage in RF Engineers and Offshoring: Conflict, Risk and Challenge

Offshoring has been occurring in engineering professions for several years now. Figures indicate an increasing rate of engineering among jobs shifted to other regions in the world. Dr. Ron Hira of RIT stated in his presentation on this topic back in 2005 "Global Outsourcing of Jobs Exacerbates US Engineering Unemployment." Much more was written in this context, and recent figures are reason for concern. The current shortage in RF engineers in the US induces a false sense of stability.

The outsourcing phenomenon is inevitable and is also healthy. It is an evolutionary process, challenging nations around the globe with opportunities as well as risks. To survive this process, a society must adjust and maintain core technologies and those jobs that carry the ingenuity to lead the future.

Microwave engineering is core technology and will soon become essential infrastructure in many industry sectors (retail, communications, medical, automotive, etc.). We are now in the midst of a race for next generation technologies laying microwave infrastructure in all those markets. Extensive R&D efforts occurring now across the globe are also drawing a new map of global technology powers.

Education systems and governments now have a primary role in the global race for future technology dominance.

Unlike low-level jobs, where the competition is on labor cost only, RF engineers are not available everywhere and it takes time to build up local training. Supporting evidence is given in an article by Sramana Mitra, comparing offshoring in India and China. The article specifically identifies India's difficulty to leverage its current outsourcing heaven to capture higher-level jobs. India's education system is apparently unable to supply the growing demand. Although things may not be as bad in other offshoring destinations such as Eastern Europe, education is the soft spot of offshoring engineering jobs. You can build a production plant in six months, but it takes years to train the engineers. Recognizing this fact can direct us to the areas where we can and should take measures, adjust and respond.

The education system in North America is better spread and equipped to support this challenge than its counterparts in many other regions of the world. In addition, microwave engineering involves scientific disciplines, heavily relies on accumulated experience and requires large capital investments in anechoic facilities and test instrumentation. The United States education system is a major resource to be used to reduce the offshoring effect.

Nations who will succeed in steering up their education system to respond to these global trends will get a piece of future world economy.

What is the forum to work with projections of demand in various fields of engineering and provide the education system with goals to meet, while working with corporations to commit to domestic R&D centers? Would anyone dare go as far as federal subsidies for preferred fields of expertise?

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