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RF & Microwave Systems

IMS 2012 SPECIAL ISSUE

May-June 2012

RF FRONT-END INTEGRATION DRIVEN BY LOW POWER

WILL FIWI BE THE ENDGAME OF BROADBAND ACCESS?

ANALOG VENDORS EYE EXPANSION DESPITE MARKET LULL

TRENDS IN ANALOG AND RF IC SIMULATION

WIRELESS IP GROWS IN SURPRISING WAYS

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From the Publisher of Chip Design
Tools, Technologies & Methodologies

AWR 2011: EXPLORE THE FUTURE OF HIGH-FREQUENCY DESIGN

To explain, let's use the design of a typical MMIC amplifier as an example. To design it, you'll need to perform die-level analysis, physical layer management, and EM simulation of every independent element. A specification or performance change has to be applied to every single element. With the new EM-centric features in **AWR 2011**, functions run concurrently, dramatically reducing wait time and merging die designs into modules as the design progresses to resolve conflicts on the spot. The initial design is simulated while asynchronous EM simulation solvers run in the background as soon as new details emerge, reducing chip design time significantly.

ADVANCED EM SIMULATION

With **AWR 2011**'s new approach to asynchronous EM simulation (Figure 1) there's no waiting for EM analysis to finish or EM results to be reintegrated into the design. Just keep working while EM analyses run transparently on multiple CPUs on the same computer. Swept parameter simulations of fully parameterized EM models are executed in parallel, including parameterized materials and geometries using techniques like AWR's unique extraction approach or the software's new graphical geometry parameterization.

Simulation State Management (SSM)

SSM is a new approach to managing simulation results within the design environment for both synchronous and asynchronous simulation data. It efficiently manages the large amount of simulation results from optimization runs, swept simulations, or Monte Carlo analyses. All of a designs EM data (structures, meshes, currents, yield analysis, and optimization results) is intelligently managed for all stages of the process. You can plot and view results on top of other results for every simulator in AWR's product portfolio, from EM to harmonic balance and transient analysis, providing early insight into design behavior. Additionally, **AWR 2011**'s process-aware geometry processing algorithm automatically converts mask-ready geometries to EM-ready layouts, and automates operations like via creation and de-featuring that typically required manual modifications.

EM Yield and Optimization

EM yield analysis within **AWR 2011** efficiently automates design for manufacturing (DFM) in RF and microwave design so you don't have to manually perform EM yield analysis, sweeps, optimization, and DFM. With **AWR 2011**, they're all an integrated part the design process. Arbitrary shapes and geometries and user-defined layers quickly account for manufacturing-related effects such as mask alignment and etch tolerance. Combined with the capabilities of SSM, **AWR 2011** lets you track variants like finding corner cases (Figure 2), sweeping manufacturing-related parameters, and monitoring performance of circuit simulations in linear, harmonic balance, or the time-domain.

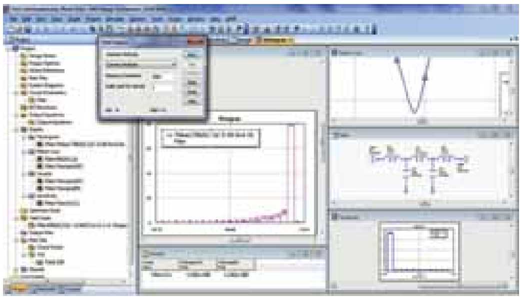

Figure 2: Yield analysis is faster and more comprehensive in AWR 2011.

USER-DEFINED PARAMETERIZED MODELS

AWR 2011 uses the parameterized models you've created along with EM schematics and parameterized cells (pCells) or static shapes to define an EM parameterized model (Figure 3). Shape manipulation includes Booleans, resizes, and other operations that go a lot further than simply making a shape bigger or changing a polygon's aspect ratio. You can define the parameterized model and simulate it on demand to create a model that can be used in tune-mode or for fast circuit-based optimization.

CIRCUIT ENVELOPE SIMULATION

With **AWR 2011**, Microwave Office and Visual System Simulator™ (VSS) now cooperate to enable circuit envelope simulation (Left page, Right monitor), which significantly improves the ability to design broadband, highly linear, efficient 3G and 4G amplifiers. It simulates complex higher-order modulation schemes faster than stand-alone time-domain and frequency-domain simulators by combining the advantages of both. That is, it processes modulation data in the time-domain and carrier signals in the frequency-doma and gives you access to the amplitude and phase of every harmonic of the signal. That means you can analyze waveforms with greater accuracy and focus early on EVM and ACPR while simultaneously optimizing matching networks for both circuit and system metrics. Your Microwave Office circuit flows seamlessly into the system-level environment of VSS such that circuit envelope simulation monitors voltage and current waveforms in seconds rather than the minutes or hours required by transient solvers.

And there's more to **AWR 2011** than can fit on this page. A few more highlights worth noting include:

- Subcircuit Parameterization: Nonlinear circuits in Microwave Office software can now share the same hierarchical parameter-passing as blocks within VSS software, revealing how metrics such as resistance value or inductor Q impact the overall system-level design.
- AWR Connected™ for CapeSym SYMMIC: Explore the relationships between thermal and electrical properties to deal with thermal hotspots in RF power devices amplifiers (Left page, Left monitor).
- RF Aware Short/Open Checker: Eliminate wiring and layout errors earlier in the design flow.

To learn more about **AWR 2011** and the breadth of new features and capabilities available to MMIC, MIC, RF PCB and module designers, visit www.awr-2011.com or www.awrcorp.com/tryAWR to register to download your free 30-day trial copy today.

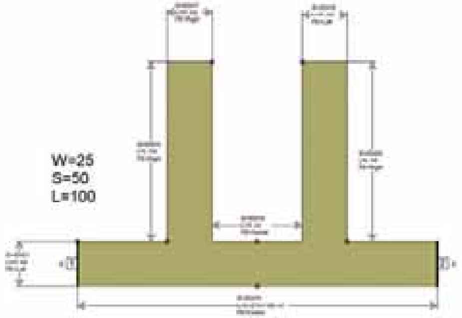

Figure 3: EM schematics include parameterized cells (pCells) or static shapes that can be manipulated to define an EM parameterized model.

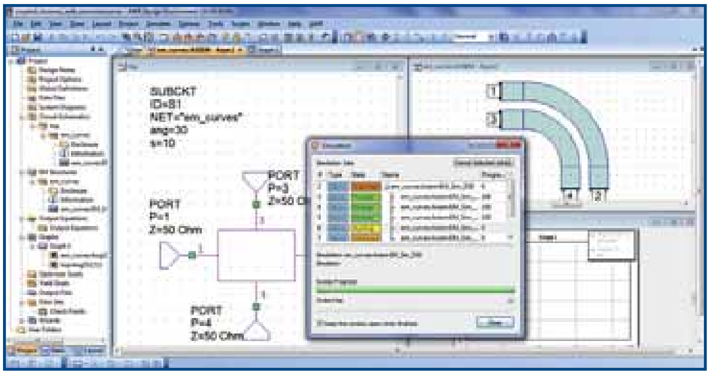

Figure 1: With AWR's asynchronous EM simulation you won't be waiting for an analysis to finish or EM results to be reintegrated into the design.

RF & Microwave Systems

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Focus on IMS

IMS 2012

- IMS2012 is off to a Record Breaking Start!
- Take Advantage of the Lowest Rates Available, Register for IMS2012 Today!
- Don't Miss Your Chance to be a Part of the Premier RF and Microwave Conference!
- IEEE Microwave Theory and Techniques Society to celebrate 60th Anniversary at IMS2012!

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CST and Delcross Announce Distribution Agreement for North America
Framingham, MA, and Champaign, IL, May 14, 2012, CST of America, Inc. (CST) and Delcross Technologies (Delcross) have signed a distribution agreement to make CST an authorized reseller

30MHz to 1.4GHz Wideband I/Q Demodulator with IIP2 Optimization & DC Offset Cancellation Improves Zero-IF Receiver Performance

RFaxis Will Launch the World's First and Only Patented, Pure CMOS, Fully Integrated, 5GHz Single-Chip/Single-Die RF Front-End Integrated Circuit at Computex Taipei 2012

Freescale Introduces Baseband-to-Antenna Reference Design for Multi-Standard Small Cell Base Stations

Helic's VeloceRF in Nanoradio's arsenal

Maxim's Highly Integrated Femtocell Transceivers Simplify Compact Radio Designs

ANADIGICS Powers NEC MEDIAS

Updates in IPC-6018B Help Engineers Design High-reliability Boards

New IPC Survey to Measure Impact of On-Shoring in the Electronics Industry

TriQuint Wins New $12.3M GaN DARPA Contract To Develop Ultra-Fast Power Switch Technology

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- LTE-Advanced Signal Generation and Measurement Using SystemVue
- High-Speed, Real-Time Recording Systems Handbook

Featured Articles

Fast and New Method for Cycle Slip Analysis in PLL: Part 1
This article presents a fast and new approach to analyzing cycle slip in a phase-locked loop (PLL) with a saw tooth phase detector. PLL cycle slip analysis is a nonlinear and mathematical hand calculation is perceived to be complex. In most cases, powerful CAD software, such as Agilent Technologies' Advanced Design System (ADS), is relied on to do the simulation, as it outputs accurate and reliable data. However, this article will elaborate on how cycle slip occurs and what actually happens during cycle slip. Linear analysis, such as Laplace and inverse Laplace transform, are used to analyze the time domain response between cycle slipping. One caveat is that strict conditions must be applied for the analysis to be accurate. Although this is the case, this analysis will give new perspective and thus will help one achieve a more intuitive, solid understanding as to why and what happens during cycle slip. Analysis results from this simple approach with different input conditions will be compared with accurate output from ADS.

Make the Most of MCU Sleep Modes
Predict how well an MCU will perform over its lifetime on a single battery charge, and make intelligent architecture choices. The advent of inexpensive, energy-efficient embedded processors

How Low Can You Go?
Ultra-low-power microcontroller technologies may revolutionize new designs. VDC Research embedded hardware team analysts left Embedded World 2012 with the impression that this is the

Capacitive Proximity Sensing
Remote interaction with user interface offers new opportunities for product differentiation. Capacitive touch technology is still all the rave in the user-interface space, as it rightfully

MEMS and Packaging Hold Keys to Radio Connectivity
A fully mobile and connected world full of "rich" user experiences won't exist until radios can operate at ultra-high speed and ultra-low power in both existing 6-GHz and future 60-GHz spectrums.

A View from the Floor at IMS 2011
This year's International Microwave Symposium introduced new GaN suppliers, rugged LDMOS transistors, and tighter integration between design and test.

Official Guide to the 2011 IEEE MTT-S International Microwave Symposium (IMS)
Things to Note for Your Ultimate Microwave Week Experience!

Differentiation and Co-existence in WiMax and LTE
In his article "The Era of Wireless Broadband," EECatalog editor Cameron Bird compares expectations and realities of WiMax and LTE deployments. While forecasts ebb and f low, a

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- Wireless Backhaul Video

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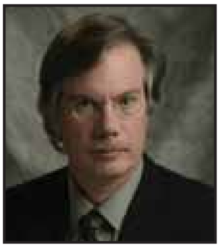
True Circuits IP...
the truth is in the silicon

By John Blyler, Editor-in-Chief

Wireless IP Grows in Surprising Ways



While growing, analog and wireless IP usage may face challenges in manufacturing preferences at lower nodes and emerging LTE technology trends.

Does it even need to be stated that mobile data rates are growing at amazing rates? In-Stat's reports a doubling of mobile data every year, like Moore's Law on steroids.

An Internet Minute - courtesey of Intel.

Interactions that were once measured in weeks or months now occur in an Internet minute via YouTube, Google, Facebook, Twitter, LinkedIn and other social media applications. This accelerated connectedness is all thanks to the rise of mobile devices. In fact, IHS iSuppli recently notes that shipments of Internet-based consumer devices are expected to exceed those of traditional PC platforms for the first time in 2013.

This unprecedented growth in mobile "everything" translates to a huge potential market for analog and wireless IP in both front-end mobile devices and back-end platforms that service them. For the designers of both ends, the challenge is to provide greater bandwidth at lower power and for faster deployment cycles.

Chris Rowen, the founder and CTO of Tensilica, sees this trend taking an interesting turn in 2012 – (quote from David Manner's blog):

"High-bandwidth and low cost help LTE wireless make it a strategic alternative outside of traditional cellular networks – to DSL, cable and broadcast for living room platforms, for home/business femtocells, and for machine-to-machine networking, for example in smart meters."

Mobile data usage is affected by the proximity of a device to a cell tower. Small cells are needed where additional large cell towers (macrocells) would be impractical. In-Stat reports that there will be, "160.3 million active small cells, and the retail value of small cell shipments will reach $14 billion by 2015."

These numbers have not gone unnoticed by SoC and semiconductor IP vendors. For example, Intel's latest Crystal Forest technology announcement is aimed squarely at the back-end telecommunication manufacturers, operators and service providers. The Sandybridge-based processor chip of Crystal Forest is set at the 22 nm node, while the second chip containing the IO, memory controller and accelerators lies at a 32nm geometry.

[Sidenote: Manner's examines the manufacturing process node imbalance at Intel concerning digital verses wireless ICs.]

ARM – Intel's competitor in the mobile space – claims to have 95% of the worldwide LTE baseband designs. ARM partners, like Qualcomm, Renesas Mobile, Broadcom and even Intel Mobile (Infineon?) contribute to the analog and wireless portion of the ecosystem.

From in-home cells to LTE front- and back-end technology, analog and wireless IP vendors will have a busy future.

John Blyler can be reached at: jblyler@extensionmedia.com

IMS2012
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IEEE MTT-S

2012 Official Guide to the 2012 IEEE MTT-S International Microwave Symposium

17–22 JUNE 2012 • MONTRÉAL, QUÉBEC, CANADA

Yes indeed, we are all very much excited about IMS2012, which is finally coming to Montréal. It is only the second time since its inception that this Symposium has been held outside the United States. This Symposium is poised to be a truly international event with the historic 60th anniversary celebration of MTT-S, and of course, unforgettable personal memories. Microwave Week, with IMS as its centre piece together with the RFIC and ARFTG conferences as well as the largest commercial exhibition of its kind, will add a special flavour to Montréal's beautiful summer decorated by its well-known festivities. This year, you can see a number of fine-tuned programs and innovations, which are summarized in the section "What's New". You will find a wealth of useful and important information in this Program Book, which facilitates your Microwave Week attendance and your Montréal stay.

Founded in 1642, Montréal has been recognized as one of the most romantic, welcoming, artistic, innovative, and culturally diverse cities in the world. The city offers everything to everyone with easy access to everywhere.

Our motto "MICROWAVES WITHOUT BORDERS" or "MICRO-ONDES SANS FRONTIÈRES" not only reflects our unique international destination, French heritage and culture in North America but also the international cooperation and spirit of our community. The IMS2012 Steering Committee and our colleagues of IEEE Meeting & Conference Management and MP Associates have been working selflessly for you and for our IMS events around the clock to make sure this year's Microwave Week will be a unique success. In spite of the worldwide economic turmoil, but encouraged by early indications, we are expecting to experience one of the most attended Microwave Weeks in history. We have already broken historic IMS records including an all-time record number of technical paper submissions, an all-time record number of received MicroApps presentation proposals, and there have never been before so many commercial exhibit booth reservations at such an early date.

The opening ceremony highlights the presentation of our plenary speaker, Mr. Steve Mollenkopf, President and Chief Operating Officer of Qualcomm. He provides a keynote address on "3G/4G Chipsets and the Mobile Data Explosion." This year's closing session features a presentation of our keynote speaker, Professor Thomas H. Lee of Stanford University. He talks about "The Fourth Age of Wireless and the Internet of Everything."

On behalf of the IMS2012 Steering Committee and the City of Montréal, I feel privileged and honoured to invite you, your family and friends to take part in this unparalleled event and explore the friendly atmosphere of Montréal. To plan your trip, visit and stay, you can find useful information on the city of Montréal at http://www.tourism-Montréal.org/ about our famous international festivals and happenings like the world famous Formula 1 racing, the International Fireworks competition at the amusement park La Ronde (of the Six Flags family), and the international Jazz Festival, all for your enjoyment right before and after Microwave Week.

Please prepare your attendance to ensure a memorable time and experience that you cannot afford to miss. You should go to http://ims2012.mtt.org/ or download our mobile apps for information and the latest news on IMS2012 and Microwave Week. I promise that you will discover a world of colourful ethnicity, rich culture, multiple languages, new ideas, international cuisines, and of course, the warm camaraderie and sheer joie de vivre to be found all united in one place, our unique Montréal. A bientôt! See you soon!

Ke Wu

PLENARY SESSION TALK

3G/4G Chipsets and the Mobile Data Explosion
Monday, 18 June 2012
1730 - 1900
Room 710

Plenary Speaker: Steve Mollenkopf

The Plenary talk will be given by Steve Mollenkopf, President and Chief Operating Officer of Qualcomm. From his leadership role in Qualcomm, one of the greatest and most successful global telecommunication corporations, as well as pioneer of Code Division Multiple Access (CDMA) technology, Mr. Mollenkopf is ideally positioned to provide an acute and authoritative perspective on microwave technology and business which should be in the interest of all the attendees of the IMS. His talk will be entitled "3G/4G chipsets and the mobile data explosion."

Abstract of the talk

The rapid growth of wireless data and complexity of 3G and 4G chipsets drives new design and deployment challenges for radio and device manufacturers along with carriers. This talk will provide a perspective on the problem from the point of view of a large, worldwide manufacturer of semiconductors and technology for cellular and connected consumer electronics devices. The increase in device and network complexity will result in significant business opportunities for the industry.

Biography of the Speaker

Steve Mollenkopf serves as president and chief operating officer of Qualcomm, leading the company's business operations, product and worldwide sales groups. In this role, Mr. Mollenkopf also serves as president of Qualcomm CDMA Technologies (QCT). Moreover, he is a member of Qualcomm's Executive Committee, helping to drive Qualcomm's overall global strategy.

Since 2008, Mr. Mollenkopf led QCT and served as executive vice president and group president of Qualcomm, driving growth and providing critical technical and operational leadership. QCT, the company's semiconductor business, is the world's largest wireless chip supplier and fabless semiconductor company, in terms of revenue.

A published IEEE author, Mr. Mollenkopf holds patents in areas such as power estimation and measurement, multi-standard transmitter system and wireless communication transceiver technology. He serves on the Board of Directors for the Semiconductor Industry Association and serves as a Board Member and is on the Board Executive Committee and CEO Council for the Global Semiconductor Alliance.

Mr. Mollenkopf holds two electrical engineering degrees, a bachelor of science in electrical engineering from Virginia Tech and a master of science in electrical engineering from the University of Michigan at Ann Arbor.

CLOSING CEREMONY TALK

The Fourth Age of Wireless and the Internet of Everything

Thursday, 21 June 2012

1600 - 1730

Room 710

Closing Speaker: Thomas H. Lee

The Closing talk will be given by Thomas H. Lee, Professor at Stanford University. Prof. Lee is well known as a prolific writer, a pioneer scholar and an outstanding speaker. He will close the symposium by presenting his vision on the future of key aspects of microwave and internet technology.

Abstract of the talk

"Making predictions is hard, particularly about the future". The patterns of history are rarely discernible until they're obvious and perhaps irrelevant. Wireless may be an exception, at least in broad outline, for the evolution of wireless has been following a clear pattern that tempts us to extrapolate. Marconi's station-to-station spark telegraphy gave way to a second age dominated by station-to-people broadcasting, and then to today's ubiquitous people-to-people cellular communications. Each new age was marked by vast increases in value as it enlarged the circle of interlocutors. Now, these three ages have covered all combinations of "stations" and "people," so any Fourth Age will have to invite "things" into the mix to provide another stepwise jump in the number of interlocutors. This talk will describe how the inclusion of multiple billions of objects, coupled with a seemingly insatiable demand for ever-higher data rates, will stress an infrastructure built for the Third Age. Overcoming the challenges of the coming Fourth Age of Wireless to create the Internet of Everything represents a huge opportunity for RF engineers. History is not done.

Biography of the Speaker

Thomas H. Lee received the S.B., S.M. and Sc.D. degrees in electrical engineering, all from the Massachusetts Institute of Technology in 1983, 1985, and 1990, respectively. His graduate work at MIT resulted in the world's first RF CMOS IC in 1989.

Since 1994, he has been a Professor of Electrical Engineering at Stanford University, where his research focus is on silicon RFIC technology. He has received several "Best Paper" awards, at ISSCC and CICC, and is a Packard Foundation Fellowship recipient.

He served for a decade as an IEEE Distinguished Lecturer of the Solid-State Circuits Society, and has been a Distinguished Lecturer of the Microwave Society as well. He holds 57 U.S. patents and authored "The Design of CMOS Radio-Frequency Integrated Circuits" and "Planar Microwave Engineering" and co-authored four additional books on RF circuit design. He also cofounded the memory company Matrix Semiconductor (acquired by Sandisk in 2006) and Ayla Networks. He is currently on leave from Stanford to serve as Director of the Microsystems Technology Office at DARPA.

In 2011, Dr. Lee was awarded the Ho-Am Prize in Engineering (colloquially known as the "Korean Nobel") for his RF CMOS work.

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MICROWAVE WEEK AT A GLANCE

SUNDAY

0800 - 1200 AM Workshops & Short Courses	1200-1320 Panel Session
WSA: Unconventional Power Amplifier Architecture with High Efficiency (Cont. in PM)	
WSB: Modern Techniques for Tunable and Reconfigurable RF/Microwave Filter Development (Cont. in PM)	
WSC: 3D Integrated Circuits (Cont. in PM)	
WSD: RF & mmW PAs: Linearization and Power Challenges (Cont. in PM)	
WSE: Towards Watt-Level mm-Wave Efficient Silicon Power Amplifiers (Cont. in PM)	
WSF: Wide-Band (Multi-Octave), Fast-Settling, RF Frequency Synthesis (Cont. in PM)	
WSG: RF and Modem Techniques for Multi-standard Radios Coexistence (Cont. in PM)	
WSH: RF and Analog ICs for Biomedical Applications	
WSI: RF at the Nanoscale	
WSJ: RF Spectrum Sensing and Signal Feature Detection Circuits	
WSK: Recent Development in CMOS Mixer Design and Application (Cont. in PM)	
WSL: Recent Developments of High-Speed Wireline Transceivers	
SC-1: Graphene and RF Applications (Cont. in PM)	

Registration: 0700-1800 • **RFIC Plenary:** 1740-1900

MONDAY

0800 - 1200 AM Workshops & Short Courses	1200-1320 Panel Session
WMA: Introduction to Advanced Dielectric Measurement Techniques (Cont. in PM)	**THz Integrated Circuits:** Do future markets support highly integrated silicon-based IC development?
WMC: Advanced Techniques for Electromagnetic-Based Model Generation (Cont. in PM)	
WMD: Wireless Positioning and Tracking in Indoor and Urban Environments (Cont. in PM)	
WME: THz devices and systems based on nanotechnology (Cont. in PM)	
WMF: Wireless energy transfer and scavenging techniques (Cont. in PM)	
WMG: Broadband PAs for Wireless Communications (Cont. in PM)	
WMH: GaN's Destiny: Reliable CW Operation at Power Densities Approaching 40 W/mm - Can it Be Fulfilled (and When)? (Cont. in PM)	
WMI: Towards Development of Smarter Substrate Integrated Waveguide Components and Advanced Fabrication Methodologies (Cont. in PM)	
WMJ: Emerging Technology and Technological Challenges in Low Phase Noise Oscillator Circuit Designs	
WMK: Analytic Concepts and Design Techniques for Low-Noise and Low-Distortion Mixers	
WML: Measurement, Design, and Linearisation Techniques for High-Efficiency Amplifiers	
SC-3: Theory and Design of Frequency Synthesizers (Cont. in PM)	
SC-4: Nonlinear Microwave Circuits — Their Dynamics, Bifurcation, and Practical Stability Analysis/Design (Cont. in PM)	
SC-5: Dielectric Resonator Antennas, Theory, Design and Applications with Recent Advancement (Cont. in PM)	

Registration: 0700-1800 • **RFIC Symposium:** 0800-1720 • **IMS Plenary:** 1730-1900

TUESDAY

0800 - 0940 Early AM Technical Sessions	1010 - 1150 Late AM Technical Sessions	1200-1320 Panel Session
TU1A: Novel Devices, Waveguiding Structures and Analysis Methods	**TU2A:** Time-Domain Modeling: Advances and Applications	**RF scaling:** Can it keep up with digital CMOS? Should it?
TU1B: Ferroelectric, Ferrite and Acoustic-Based Resonators and Filters	**TU2B:** New Implementations of Couplers and Hybrids	
TU1C: Advances in RF MEMS Ruggedness and Reliability	**TU2C:** Nonlinear Device Modeling	
TU1D: Millimeter-Wave Power Amplifiers	**TU2D:** Applications of Carbon-Based RF Nanotechnology	
		RF MEMS for Defense and Aerospace

RFIC Interactive Forum: 1330-1550

Registration: 0700-1800 • **RFIC Symposium:** 0800-1140 • **Exhibition:** 0900-1700 • **MicroApps:** 0905 to 1750 • **IMS Student Paper Competition and IMS Student Design Competition**: 1330-1550

WEDNESDAY

0800 - 0940 Early AM Technical Sessions	1010 - 1150 Late AM Technical Sessions	1200-1320 Panel Session
WE1A: Semiconductor-Based Integrated Passives	**WE2A:** Circuits for Systems at W-band and Beyond	How will LDMOS and III-V device technologies play in cellular infrastructure future markets?
WE1B: Silicon and Indium Phosphide MMICs Achieve New Performance Milestones for Radiometers in Earth Remote Sensing	**WE2B:** Silicon RF and Microwave Circuits	
WE1C: New Developments in Multi-Band Planar Filters	**WE2C:** Tunable Filters I: Tunable Filters with Narrow Bandwidths	
WE1D: Packaging for Microwave and Millimeter-Wave and Radiating Integrated Systems	**WE2D:** Retrospective and Outlook of Microwave CAD	
WE1E: Industrial Microwave Power Applications: Systems and Process Development	**WE2E:** Digital Pre-Distortion and Behavioural Modeling of High-Power Amplifiers	
WE1F: Novel Mixed Mode Circuits for High-Speed Communication up to 100 Gbps	**WE2F:** RF Devices for Wireless Health Care Applications and Biosensing	
WE1G: Passive Feeds and Arrays	**WE2G:** State-of-the-Art of CMOS Low-Noise Technologies	
WE1H: A Retrospective of Field Theory in Microwave Engineering	**WE2H:** Microwave Components for Space: Trends and Developments	
	WE2J: Emerging Systems and Applications	

IMS Interactive Forum: 1330-1550

Registration: 0700-1800 • **Exhibition:** 0900-1800 • **MicroApps:** 0905 to 1900

THURSDAY

0800 - 0940 Early AM Technical Sessions	1010 - 1150 Late AM Technical Sessions	1200-1320 Panel Session
TH1A: Rectifiers for Microwave Wireless Power Transmission	**TH2A:** Nonlinear Measurement Techniques	The Mathematics and the Physics of MIMO (Multi-input-multi-output) Systems
TH1B: HF, VHF and UHF Power Amplifiers and Applications	**TH2B:** Novel Transmission-Line and Guided-Wave Structures	
TH1C: High Performance non-Planar Filters Technologies 1	**TH2C:** Novel Technologies and Components	
TH1D: Advanced Transceiver Architectures for Wireless Communication Systems	**TH2D:** GaN-Based Power Amplifiers	
TH1E: Unconventional RFIDs	**TH2E:** 60 GHz CMOS	
TH1F: Biomedical Imaging	**TH2F:** RF-MEMS Capacitive Switches and Circuits	
TH1G: Advanced Low Noise Circuits	**TH2G:** Advances in Sensors and Sensor Systems	
TH1H: Tunable FBARs	**TH2H:** The Evolution of Some Key Active and Passive Microwave Components	

IMS Interactive Forum: 1330-1550

Registration: 0700-1600 • **Exhibition:** 0900-1500 • **MicroApps:** 0905 to 1435 • **Closing Ceremony:** 1600-1730

FRIDAY

0800 - 1200 AM Workshops & Short Courses
WFA: Integration and Technologies for mm-wave Sub-systems (Cont. in PM)
WFB: White Space Technologies Future Emerging Technology Needs (Cont. in PM)
WFC: Emerging Technology of Terahertz Imaging Systems, Devices, and Algorithms (Cont. in PM)
WFD: High-Efficiency Transmitters with Dynamic Supplies (Cont. in PM)
WFE: Gallium Nitride for Low Noise Amplifier Applications
WFF: Advances in Reconfigurable RF Systems and Materials
WFG: RF Coils and Components for MRI Receiving Applications
WFH: RFID-Based Low-Cost Smart Sensor Networks for Challenging Environments
WFJ: A World Survey of the State-of-the-Art in RF MEMS
WFK: Advanced RF, Microwave and MMW Technology for Nuclear, Chemical and Biological Detection Systems
SC-6: Microwave Filters and Multiplexing Networks for Communication Systems (Cont. in PM)
SC-7: A Look at Some of the Principles of Wireless Communications from a Maxwellin Viewpoint
SC-2: EMI/EMC Fundamentals for RF & Microwave Engineers

ARFTG Interactive Forum: 1000-1050 and 1520-1600

Registration: 0700-0900 • **ARFTG Conference:** 0800-1700

http://ims2012.mtt.org

17 June 2012

1300 -1700 PM Workshops & Short Courses

- **WSA:** Unconventional Power Amplifier Architecture with High Efficiency (cont. from AM)
- **WSB:** Modern Techniques for Tunable and Reconfigurable RF/Microwave Filter Development (cont. from AM)
- **WSC:** 3D Integrated Circuits (cont. from AM)
- **WSD:** RF & mmW PAs: Linearization and Power Challenges (cont. from AM)
- **WSE:** Towards Watt-Level mm-Wave Efficient Silicon Power Amplifiers (cont. from AM)
- **WSF:** Wide-Band (Multi-Octave), Fast-Settling, RF Frequency Synthesis (cont. from AM)
- **WSG:** RF and Modem Techniques for Multi-standard Radios Coexistence (cont. from AM)
- **WSK:** Recent Development in CMOS Mixer Design and Application (cont. from AM)
- **WSM:** Advances in Noise Analysis for RF Circuits
- **WSN:** Short-Range Near-Field Communications (NFC)
- **WSO:** Advancements in Front End Modules for Mobile and Wireless Applications
- **WSP:** Digital transmitters and PAs for wireless applications.
- **SC-1:** Graphene and RF Applications (Cont. from AM)

Social Events

RFIC Reception (Palais des Congrès, Level 7- Room 710a): 1900-2100

18 June 2012

1300 -1700 PM Workshops & Short Courses

- **WMA:** Introduction to Advanced Dielectric Measurement Techniques (Cont. from AM)
- **WMB:** Device Model Extraction based on Vectorial Large-Signal Measurements
- **WMC:** Advanced Techniques for Electromagnetic-Based Model Generation (Cont. from AM)
- **WMD:** Wireless Positioning and Tracking in Indoor and Urban Environments (Cont. from AM)
- **WME:** THz devices and systems based on nanotechnology (Cont. from AM)
- **WMF:** Wireless energy transfer and scavenging techniques (Cont. from AM)
- **WMG:** Broadband PAs for Wireless Communications (Cont. from AM)
- **WMH:** GaN's Destiny: Reliable CW Operation at Power Densities Approaching 40 W/mm - Can it Be Fulfilled (and When)? (Cont. from AM)
- **WMI:** Towards Development of Smarter Substrate Integrated Waveguide Components and Advanced Fabrication Methodologies (Cont. from AM)
- **SC-3:** Theory and Design of Frequency Synthesizers (Cont. from AM)
- **SC-4:** Nonlinear Microwave Circuits — Their Dynamics, Bifurcation, and Practical Stability Analysis/Design (Cont. from AM)
- **SC-5:** Dielectric Resonator Antennas, Theory, Design and Applications with Recent Advancement (Cont. from AM)

IMS2012 Welcome Reception: (Palais des Congrès, Viger Lobby): 1900-2030

Chapter Chair's Meeting and Reception (Hyatt, Grand Salon): 2000-2200

19 June 2012

1350 - 1530 Early PM Technical Sessions	1600 - 1720 Late PM Technical Sessions
TU3A: Optimization of Microwave Circuits Through Nonlinear Analysis	**TU4A:** New Modeling and Simulation Techniques for Periodic Structures
TU3B: Metamaterial Transmission-line Structures	**TU4B:** Coupled Multi-Physics Modeling of High-Power and High-Frequency Electronic Devices
TU3C: Space-Mapping-Based Modeling and Design	**TU4C:** Advances in Broadband Communication Systems
TU3D: Novel Packaging Technology and Techniques	**TU4D:** Terahertz Imaging
TU3E: Globalization of Engineering Education and Research: Opportunities and Challenges	**TU4E:** Advances in PLL and Oscillator Technology
TU3F: Frequency Conversion and Control Circuits	**TU4F:** Power Harvesting Related to Communication Systems
TU3G: SiGe/CMOS for Phased Array Applications: A World Perspective	**TU4G:** Active Arrays and Power Combiners
TU3H: Novel Planar Filter Structures	**TU4H:** GaN Power Amplifiers Exploiting Harmonic Enhancement

Women in Microwaves Reception (Pointe A Callière Museum): 1800-1930

Ham Radio (Hyatt Hotel, Soprano Room): 1830-2130

Student and GOLD Receptions (Pub St-Paul): 1930-2130

Rump Session: Human Aspects of Communication and Persuasion: First Impressions and Subtext (Westin, St. Antoine AB): 1700-1900

20 June 2012

1350 - 1530 Early PM Technical Sessions	1600 - 1720 Late PM Technical Sessions
WE3A: Unprecedented Microwave Devices Based on Nano-materials	**WE4A:** Terahertz Communication Technology
WE3B: High Power Wideband Technologies	**WE4B:** Advancements in Passive Technologies
WE3C: Advances in CAD Algorithms	**WE4C:** Tunable Filters II: Filters with Broad Tuning Bandwidth
WE3D: Unconventional Measurement Techniques	**WE4D:** RFID Technologies and Applications
WE3E: Millimeter-Wave CMOS Signal Sources	**WE4E:** High Power GaN Amplifiers
WE3F: Advances in Silicon-based Millimeter-wave and Terahertz Integrated Circuits and Systems	**WE4F:** Advances in Ohmic Switches
WE3G: Short-Range Radar and Positioning Systems	**WE4G:** Biomedical Sensors
WE3H: A Tribute to Rüdiger Vahldieck	**WE4H:** Tunable Systems: Enabling Future Handset Technologies
WE3J: Multi-Mode Resonator and Wideband Planar Filters	**WE4J:** Novel Periodic Structures and Metamaterials

Industry Hosted Cocktail Reception (Palais des Congrès, Level 2- Exhibition Hall): 1700-1800

MTT-S Awards Banquet (Palais des Congrès, Level 7- Room 701): 1800-2200

21 June 2012

1350 - 1530 Early PM Technical Sessions

- **TH3A:** Linearizability of GaN from Device, Circuit to System Levels
- **TH3B:** Novel III-V MMIC Techniques
- **TH3C:** High Performance non-Planar Filters Technologies 2
- **TH3D:** Efficiency Enhancing Techniques for Linear Power Amplifiers
- **TH3E:** Microwave Photonic Systems and Techniques
- **TH3F:** Frequency-Domain Electromagnetic Analysis
- **TH3G:** Multi-port Technology for Radio and Radar Applications
- **TH3H:** Remembering Roger Pollard

MTT-S Student Awards Luncheon (Le Westin Hotel, Level 9- Fortifications Ballroom): 1200-1400

NVNA Users' Forum to Thursday Night (Fortifications Ballroom, Westin): 1600-1730

IMS2012 Closing Reception (Palais des Congrès, Viger Lobby): 1730-1830

22 June 2012

1300 -1700 PM Workshops & Short Courses

- **WFA:** Integration and Technologies for mm-wave Sub-systems (Cont. from AM)
- **WFB:** White Space Technologies Future Emerging Technology Needs (Cont. from AM)
- **WFC:** Emerging Technology of Terahertz Imaging Systems, Devices, and Algorithms (Cont. from AM)
- **WFD:** High-Efficiency Transmitters with Dynamic Supplies (Cont. from AM)
- **WFI:** The Development of Precision GPS Solutions in 4G
- **WFL:** System, MMIC and Package Design for a Low-Cost, Surface- Mountable Millimeter-Wave Radar Sensor
- **SC-6:** Microwave Filters and Multiplexing Networks for Communication Systems (Cont. from AM)

Technical Track Key:

- General Interest
- Emerging Technical Areas
- Systems & Applications
- Active Components
- Passive Components
- µwave Field & Circuit Techn.

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EXHIBITION COMPANY LISTING

IMS2012 EXHIBITING COMPANIES AS OF 20 MARCH 2012:

Exhibit hours have been scheduled to provide maximum interaction between conference attendees and exhibitor personnel:

Tuesday, 19 June	0900 to 1700
Wednesday, 20 June	0900 to 1800
Thursday, 21 June	0900 to 1500

= First-time exhibitor
525 total exhibitors and 42 first-time exhibitors!

2COMU
3G Metalworx Inc.
A-Alpha Waveguide Co.
A.J. Tuck Co.
A.T. Wall Company
AA-MCS
Accumet Engineering Corp.
ACEWAVETECH, Inc.
ADMOTECH Co.Ltd
AdTech Ceramics
Advance Reproduction Corp.
Advanced Chemical Company
Advanced Circuitry International
Advanced Research Systems, Inc.
Advanced Switch Technology
Advanced Test Equipment Rentals
AdvanSys Electronix
Aeroflex Inc.
Aethercomm Inc.
Agilent Technologies
AI Technology, Inc.
Aldetec, Inc.
Aliner Industries, Inc.
Alliance Corp.
AMCAD Engineering
Amcom Communications Inc.
AMCrf
American Beryllia, Inc.
American Microwave Corp.
American Standard Circuits, Inc.
American Technical Ceramics
Ametek HCC Industries
Amphenol Printed Circuits
Amplical Corp.
AmpliTech Inc.
AMT Solutions Co.,Ltd.
ANADIGICS
Analog Devices, Inc.
Anapico Ltd.
Anaren, Inc.
Anatech Electronics
Anoison Electronics
Anritsu Co.
ANSYS, Inc.
APA Wireless Technologies
Apollo Microwaves Ltd.
Applied Thin-Film Products (ATP)
AR RF/Microwave Instrumentation
ARC Technologies, Inc.
Arlon Tech. Enabling Innovation
Artech House
ASB Inc.
Aselsan
Association of Old Crows/Naylor Pub.
Astrolab, Inc.
ATE Systems, Inc.
Auriga Microwave
Aurora Software & Testing, SL
Avago Technologies
Averna
AVX Corp.
AWR Corp.
Axiom Test Equipment, Inc.
B&Z Technologies
Barry Industries, Inc.
BEEcube, Inc.
Besser Associates, Inc.
Bliley Technologies, Inc.
Bonding Source
Bowei Integrated Circuits Co., Ltd.
BSC Filters Ltd.
C W Swift
Cadence Design Systems, Inc.
Cambridge University Press
CAP Wireless Inc.
CapeSym, Inc.
Carlisle Interconnect Technologies
Cascade Microtech, Inc.
Centellax, Inc.
Centerline Technologies, LLC
Century Seals Inc.
Cernex & Cernexwave
Channel Microwave
Charter Engineering, Inc.
Chengdu Omicron Microwave Tech. Co., Ltd.
Chengdu Seekon Microwave Comm. Co., Ltd.
Chengdu Tiger Microwave Tech. Co., Ltd.
Chin Nan Precision Electronics Co., Ltd.
Ciao Wireless, Inc.
Cirexx International, Inc.
Cobham
Coilcraft, Inc.
Coleman Cable Systems, Inc.
Coleman Microwave Co.
Colorado Microcircuits
COM DEV Ltd.
Communication Power Corp. (CPC)
Communications & Power Industries
Compex Corp.
Component Distributors Inc.
Constant Wave
Continental Resources, Inc.
Corning Gilbert Inc.
Corry Micronics Inc
Crane Aerospace & Electronics
Crane Polyflon
Cree, Inc.
Crystek Corp.
CST of America, Inc.
CTT Inc.
Cuming Microwave Corp.
Custom Cable Assemblies, Inc.
Custom Interconnects
Custom Microwave Components, Inc.
Custom MMIC Design Services, Inc.
Daa-Sheen Technology Co., Ltd.
Daisy RS
dBm
Delta Electronics Mfg. Corp.
Delta Microwave Inc.
Design Workshop Technologies Inc.
Diamond Antenna & Microwave Corp.
Dielectric Laboratories, Inc.
Diemat, Inc.
DITF Thin Film
DiTom Microwave Inc.
Dong Jin Technology Innovation Co., Ltd.
Dow Key Microwave Corp.
Ducommun LaBarge Technolgoies, Inc.
DuPont Electronic Technologies
Dyconex AG
Dynawave Inc.
Dyne-Tech Co., LTD
e2v aerospace and defense Inc
EADS North America
Eclipse Microwave, Inc.
EE-Evaluation Engineering
Elbit Systems EW & SIGINT-Elisra
Elcom Technologies Inc.
Elcon Precision, LLC
Electro Rent Corp.
ElectroMagneticWorks Inc.
Elliptika
EM Research, Inc.
EM Software & Systems - FEKO
EMC Technology/Florida RF Labs
Emerson & Cuming Microwave Products
Emerson Connectivity Solutions
Empower RF Systems
Empowering Systems, Inc.
EMSCAN
ENS Microwave, LLC
Epoxy Technology, Inc.
ETL Systems
ETS-Lindgren
EuMW2012/Horizon House Publ. Ltd.
Excalibur Engineering Inc.
EZ Form Cable Corp.
F&K Delvotec, Inc.
Farran Technology Ltd.
Ferrite Microwave Technologies
Ferro-Ceramic Grinding
First Level Inc.

EXHIBITION COMPANY LISTING

IMS2012 EXHIBITING COMPANIES AS OF 20 MARCH 2012:

Flann Microwave
Flexco Microwave Inc.
Focus Microwaves Inc.
Fotofab
Freescale Semiconductor
Frontlynk Technologies Inc.
FTG Corp.
G-Way Microwave/G-Wave Inc.
Gap Wireless Inc.
Geib Refining Corp.
Gel-Pak
Gerotron Communication GmbH
GGB Industries, Inc.
GigaLane Co., Ltd.
GigOptix, Inc.
Global Communication Semiconductors, LLC
Gova Advanced Material Technology Co.,Ltd
Gowanda Electronics
Greenray Industries Inc.
GuangShun Electronic Tech. Research Inst.
Harbour Industries, Inc.
HEI Inc.
Herley Industries
Herotek Inc.
Hesse & Knipps Inc.
High Frequency Electronics
Hirose Electric Co., Ltd.
Hittite Microwave Corp.
Holzworth Instrumentation Inc.
Hong Kong Sun Fung Co., Ltd.
HRL Laboratories, LLC
Huada Intl. Electronics & Tech. Co., Ltd.
Hughes Circuits Inc.
Hunter Technology
IBM Corp.
IEEE Microwave Magazine
IEEE Xplore Digital Library
IHP GmbH
IKE Micro
IMST GmbH
In-Phase Technologies, Inc.
Infineon Technologies
Infinite Graphics
Innertron, Inc.
Innovative Fabrication
Instek America Corp.
Integra Technologies Inc.
Integrand Software, Inc.
Intercept Technology Inc.
International Manufacturing Services Inc.
Intertronic Solutions Inc.
inTEST Thermal Solutions
Ion Beam Milling, Inc.
IPDiA
IQD Frequency Products Inc.
Ironwood Electronics
Isola
ISOTEC Corp.
ITF Co., Ltd.
iTherm Technologies
ITT Exelis Microwave Systems
IW Insulated Wire Microwave Products Div.
JFW Industries, Inc.
Johanson Manufacturing Corp.
Johanson Technology Inc.
JQL Electronics Inc.
Jye Bao Co., Ltd.
K&L Microwave Inc.
Kaben Wireless Silicon Inc.
KCB Solutions
Keragis Corp.
KEYCOM Corp./Sales Dept.
Krytar Inc.
KVG Quartz Crystal Technology GmbH
Kyocera America, Inc.
LadyBug Technologies LLC
Lake Shore Cryotronics, Inc.
LanJian Electronics
Lark Engineering Co.
Laser Process Mfg.
Laser Processing Technology, Inc.
Laser Services
LCF Enterprise
Leader Tech. Inc.
Liberty Test Equipment
Linearizer Technology, Inc.
Linwave Technology Ltd.
Litron Inc.
Logus Microwave
Lorch Microwave
LPKF Laser & Electronics
M/A-COM Technology Solutions
M2 Global Technology Ltd.
Marcel Electronics International
Marki Microwave, Inc.
Massachusetts Bay Technologies
Materion
MathWorks
Maury Microwave Corp.
McGraw-Hill Professional
MCV Technologies, Inc.
MECA Electronics, Inc.
Mega Circuit Inc.
MegaPhase
Meggitt Safety Systems, Inc.
Mercury Computer Systems, Inc.
Mersen
Mesuro
Metropole Products Inc.
Micable Inc.
Mician GmbH
Micreo Limited
Micro Communications, Inc.
Micro Electronic Tech. Development
Micro Lambda Wireless, Inc.
Micro Systems Engineering GmbH
Micro-Coax Inc.
Micro-Mode
MicroApps
MicroAssembly Technologies, Inc.
MicroFab Inc.
Micronetics Inc.
Microsemi Corp.
Microtech, Inc.
Microwave Applications Group
Microwave Communications Labs, Inc.
Microwave Development Labs Inc.
Microwave Dynamics
Microwave Engineering Europe
Microwave Journal
Microwave Product Digest
Microwave Technologies Co., Ltd.
Microwave Technology, Inc.
Microwavefilters S.R.L
Microwaves & RF/Penton Electronics Group
MIG Microwave Innovation Group
Millitech Inc.
Mini-Systems Inc.
MITEQ, Inc.
Mitsubishi Electric & Electronics
Modelithics, Inc.
Modular Components National Inc.
Molex RF/Microwave Business Unit
Momentive Performance Materials
Morion, Inc.
Mosis
MPDevice Co., Ltd.
MtronPTI
Murata Electronics
Nanjing Jiexi Technologies Co., Ltd.
NARDA
National Instruments
NDK
NEL Frequency Controls, Inc.
Networks International Corp. (NIC)
Nitronex Corp.
Noise XT
NoiseWave Corp.
Norden Millimeter Inc.
Northrop Grumman
NSI
Nuhertz Technologies, LLC
Nuvotronics
NuWaves Engineering
NXP Semiconductors
OEwaves Inc.
OML, Inc.
OMMIC
ON Semiconductor
OPHIR RF Inc.
Orient Microwave Corp.
P/M Industries Inc.
P1dB, Inc.
Paciwave, Inc.
Palomar Technologies
Paricon Technologies Corp.
Pascall Electronics Ltd.
Passive Plus Inc.
Peregrine Semiconductor Corp.
PHARAD, LLC.
Photo Sciences Inc.
Pickering Interfaces, Inc.
Piconics Inc.
Pivotone Communication Tech., Inc.
Planar
Planar Monolithics Industries, Inc.
Plansee Thermal Management Solutions

EXHIBITION COMPANY LISTING

IMS2012 EXHIBITING COMPANIES AS OF 20 MARCH 2012:

Plextek Ltd.
Pole/Zero Corp.
Polyfet RF Devices
Ponn Machine Cutting Co.
Power Module Technology
Precision Connector, Inc.
Precision Manufacturing Group
Presidio Components, Inc.
Presto Engineering, Inc.
Q Microwave, Inc.
Q3 Laboratory
Qingdao Xingyi Electronic Equipment Co.
Quest Microwave Inc.
Quik-Pak
QuinStar Technology, Inc.
QWED Sp. z o.o
R&K Company Ltd.
Radant MEMS, Inc.
Reactel, Inc.
RelComm Technologies Inc.
Remcom, Inc.
Remtec, Inc.
Renaissance Electronics Corp.
Res-Net Microwave, Inc.
Resin Systems Corp.
RF Depot Inc.
RF Globalnet
RF Industries
RF Logic
RF Morecom Corea
RF Technology International
RFcore Co., Ltd.
RFHIC Corp.
RFMD
RFMW, Ltd.
RFS Ferrocom Ferrite Division
RH Laboratories, Inc.
Richardson RFPD
RIV Inc. - Precision Printing Screens
RJR Polymers Inc.
RLC Electronics, Inc.
Rogers Corp.
Rohde & Schwarz
Rosenberger North America LLC
S3 Group
Sainty-Tech Communications Ltd.
Samtec, Inc.
San-tron Inc.
Sangshin Elecom Co., Ltd.
Sanmina-SCI OMED
Sawnics Inc.
Schmid & Partner Engineering AG
Scientific Microwave Corp.
Scintera, Inc.
SDP Telecom Inc.
Selectron Inc.
Semi Dice Inc.
SemiGen
Semtech Corp.
SGC Technologies Inc.
SGMC Microwave
Shanghai Eagle Industrial Co., Ltd.
Shanghai Huaxiang Computer Comm. Eng.
Shenzhen Atten Electronics Co., Ltd.
Shenzhen Huayang Tech. Development Co.
Shenzhen Yulongtong Electron Co.,Ltd.
Shin-Etsu Chemical Co., Ltd.
Signatone
Silicon Cert Laboratories
Sinclair Manufacturing Co.
SIPAT Co.
Skyworks Solutions, Inc.
Smith Interconnect
Sonnet Software Inc.
SOURIAU PA&E
Southwest Microwave, Inc.
Spanawave Corp.
Spectra - Mat, Inc.
Spectrum Elektrotechnik GmbH
Spectrum Microwave, Inc.
Spinner Atlanta
Sprague Goodman
SRI Connector Gage Company
SRTechnology Corp.
SSI Cable Corp.
State Of The Art Inc.
Stellar Industries Corp.
StratEdge Corp.
Sumida America Components
Sumitomo Electric Device Innovations
SV Microwave Inc.
Symmetricom
Synergy Microwave Corp.
T-Tech Inc.
Taconic
Tahoe RF Semiconductor, Inc.
Tai-Saw Technology Co., Ltd.
TDK-Lambda Americas
TE Connectivity
Tecdia Inc.
Tech Briefs Media Group
Techmaster Electronics, Inc.
Tektronix Inc.
Teledyne Coax Switches
Teledyne Cougar
Teledyne Defence Ltd.
Teledyne Labtech
Teledyne MEC
Teledyne Microelectronics
Teledyne Microwave
Teledyne Relays
Teledyne Scientific
Teledyne Storm Products
Teledyne Technologies, Inc.
Telegartner, Inc.
Telemakus, LLC.
Teseq, Inc.
TestEquipment.com, Inc.
TestEquity LLC
Testforce Systems Inc.
Texas Instruments
Thales Components Corp.
THINFILMS Inc.
Times Microwave Systems
TMD Technologies Ltd.
Toshiba America Electronic Cmpts.
TotalTemp Technologies, Inc.
TowerJazz
TRAK Microwave Corp.
Transcom, Inc.
Transline Technology Inc.
TriQuint Semiconductor
TRM Microwave
TRS-RenTelco
TRU Corporation Inc.
TTE Inc.
TTM Technologies, Inc.
TYDEX
UltraSource Inc.
UMS (United Monolithic Semiconductors)
UTE Microwave Inc.
Vacuum Engineering & Materials Co., Inc.
Valpey Fisher Corp.
Vaunix Technology Corp.
VECTRAWAVE
Vectria Ltd.
Vectron International
Verspecht-Teyssier-Degroote
VidaRF
Viking Tech America Corp.
Virginia Diodes Inc.
Vishay Intertechnology, Inc.
Voltronics Corp./Dover
VTI Instruments Corp.
W. L. Gore & Associates, Inc.
Weinschel Associates
Wenzel Associates Inc.
Werlatone Inc.
West Bond Inc.
WEVERCOMM Co., Ltd.
Wibicom
Wiley-IEEE
WIN Semiconductors Corp.
WIPL-D D.O.O.
Wireless Design & Development
Wireless Telecom Group
WiSpry, Inc.
X-Com Systems
X5 Systems, Inc.
Xi'an Forstar S&T Co., Ltd.
Xi'an Gold Waves S&T Co., Ltd.
Yantel Corp.
Yokowo Co., Ltd.
Yortec Inc.
Z-Communications, Inc.

By Jennifer Burkhardt

Product News

CST AND DELCROSS DEMONSTRATE INTEGRATED SOLUTION FOR COSITE INTERFERENCE ANALYSIS

Orlando, FL, Computer Simulation Technology (CST) and Delcross Technologies (Delcross) will be demonstrating initial integration and capabilities for cosite interference solutions at DoD Electromagnetic Environmental Effects (E3) Program Review, booths # 21 and 22.

Realistic environments containing multiple aggressors (transmitters) and multiple victims (receivers) pose significant engineering challenges with respect to cosite interference. In order to predict cosite interference accurately, a large number of contributing factors have to be taken into account. In particular, the RF performance characteristics of each transmitter (Tx) and receiver (Rx) as well as the wideband coupling/isolation between all antennas must be considered in order to identify and eliminate undesired interference between systems.

AGILENT TECHNOLOGIES ENHANCES FIELDFOX RF ANALYZERS WITH OPTIONS FOR MEASURING TIME DOMAINS AND CHANNEL POWER

Agilent Technologies Inc. (NYSE: A) enhanced its FieldFox RF analyzers with options for time-domain analysis and channel-power measurements. These options give engineers the features they need to more easily and quickly test their RF communications infrastructure.

Agilent will demonstrate its new FieldFox options, along with solutions that cover everything from circuit-level modeling through system verification for general RF, microwave, 4G communications, and aerospace/defense applications at IMS 2012/IEEE MTT-S (Booth 1015), June 19-21, in Montreal, Canada. A range of premier partner solutions will also be available on Agilent Avenue and throughout the event area.

GIGOPTIX ADDRESSES 100G AND BEYOND COHERENT RECEIVERS MARKET WITH THE RELEASE OF NEXT GENERATION TRANSIMPEDANCE AMPLIFIER

GigOptix, Inc. (OTCQX:GGOX), a leading fabless supplier of semiconductor and optical components that enable high-speed information streaming, today announces availability for sampling of its next generation GX3222B dual channel Linear Transimpedance Amplifier (TIA) designed for use in 100Gb/s DWDM optical receivers.

The GX3222B is a high performance, silicon germanium, dual channel 32Gbaud linear TIA with adjustable bandwidth control that enables its use in receiver modules in a number of fiber optic transmission systems such as current generation 100Gb/s DP-QPSK optical systems in addition to future 400Gb/s optical systems. The GX3222B is designed for use in 100G and beyond coherent optical receivers and includes critical functions such as high DC current cancellation, low Total Harmonic Distortion (THD), linear gain over a high dynamic range and low power consumption.

IMS 2012: THE MICROWAVE APPLICATION SEMINARS (MICROAPPS)

The Microwave Application Seminars (MicroApps) are scheduled for the Palais des congrès de Montréal (Montréal Convention Center) June 19-21, 2012, as part of IEEE-IMS/MTT-S. MicroApps are a series of concise "application note" technical presentations given by exhibitors that are distinct and separate yet complementary to the IEEE technical sessions.

MicroApps are engineering topics of interest to the microwave community and cover new products, noteworthy state-of-the-art materials, components, measurement tools, and novel manufacturing and design techniques that incorporate the exhibitor's products and technologies in an application-centric setting.

FREESCALE INTRODUCES BASEBAND-TO-ANTENNA REFERENCE DESIGN FOR MULTI-STANDARD SMALL CELL BASE STATIONS

Solution combines new RF products with QorIQQonvergeSoC to extend Freescale's technology lead in small cell base station markets

Freescale Semiconductor (NYSE: FSL) today announced a new reference design for small office/home office (SOHO) base station applications that is partially powered by two advanced gallium arsenide (GaAs) monolithic microwave integrated circuits (MMICs).

The comprehensive baseband-to-antenna reference design combines the QorIQQonverge BSC9131 base station system-

By Jennifer Burkhardt

on-chip (SoC) with Freescale RF radio boards, and is a multi-protocol solution that scales across a range of cellular bands to ease developers' transition from 3G to 4G LTE. Sourcing the base station SoC and RF devices from the same vendor speeds time to market and helps ensure optimal compatibility and integration.

MAXIM'S HIGHLY INTEGRATED FEMTOCELL TRANSCEIVERS SIMPLIFY COMPACT RADIO DESIGNS

Femtocell transceivers support WCDMA and cdma2000® radio bands, accelerate time-to-market, and ease design with market-leading baseband partners.

Maxim Integrated Products introduces the MAX2550–MAX2553femtocell transceivers for WCDMA (Bands 1 to 6 and 8 to 10) and cdma2000 (Band Class 0, 1, and 10).

The amount of data consumed by smartphones is rising and the increase in data transmission requires more base-station cell sites to receive and transmit the signals. With existing base-station cell sites maxed out on capacity, femtocells are becoming a fast-growing market. Carriers are also moving to femtocell transceivers that reside in a home or office and essentially provide an indoor base station to handle the cellular voice and data needs of an entire dwelling.

RFAXIS WILL LAUNCH THE WORLD'S FIRST AND ONLY PATENTED, PURE CMOS, FULLY INTEGRATED, 5GHZ SINGLE-CHIP/SINGLE-DIE RF FRONT-END INTEGRATED CIRCUIT AT COMPUTEX TAIPEI 2012

RFaxis' RFX5000 is Pin-to-Pin Compatible with Conventional 5GHz Front-End Module

RFaxis, a fabless semiconductor company focused on innovative, next-generation RF solutions for the wireless connectivity and cellular mobility markets, announced it will commercially launch its pure CMOS, RFX5000RF Front-End Integrated Circuit (RFeICTM) designed to enable robust wireless connectivity for next-generation 802.11a/n/p wireless connectivity applications in the 5GHz frequency band at Computex Taipei 2012. The technology will support PCs, ultra-mobile devices, high definition multimedia streaming devices, routers/access points, as well as wireless access in vehicular environments (WAVE).

"We have had an overwhelming demand from leading suppliers in the WLAN ecosystem for our 5GHz pure CMOS RFX5000 RFeIC," stated Mike Neshat, chairman and CEO of RFaxis. "This reinforces that our RFX5000 RFeIC is a crucial link in the WLAN ecosystem to enable our customers to meet demanding market requirements. Based on our customers' requests, we made the RFX5000 pin-to-pin compatible with Skyworks SE5007T Front-End Module. Contrary to extended lead-times and rising prices facing traditional Front-End vendors, we are consistently redefining the RF Front-End market by leveraging the competitive performance of our CMOS RFeICs, our cost competitiveness, and high level of integration, to meet the needs of our customers.

TRIQUINT WINS NEW $12.3M GAN DARPA CONTRACT TO DEVELOP ULTRA-FAST POWER SWITCH TECHNOLOGY

TriQuint's Leadership Developing Highly-Advanced, Mixed-Signal Digital / RF GaN Circuits Led to New Opportunity in MPC Program

TriQuint Semiconductor, Inc. a leading RF solutions supplier and technology innovator, today announced that it has been selected by the Defense Advanced Research Projects Agency (DARPA) to lead a $12.3 million development program focused on ultra-fast gallium nitride (GaN) switch technology for the Microscale Power Conversion (MPC) program. TriQuint's revolutionary new GaN modulator has the potential to enable highly-efficient RF transmitters substantially smaller than current solutions.

TriQuint was selected by DARPA as the prime contractor for MPC Technical Area I, which seeks to develop a high-speed, DC-to-DC switch (modulator) and related process technology based on the company's innovative enhancement-mode GaN transistors. TriQuint's technology aims to improve the integration of power switches with advanced RF amplifiers to facilitate ultra-high efficiency, reduced-size amplifiers for radar and communications applications.

RF MICRO DEVICES® UNVEILS RGAN-HV™ PROCESS TECHNOLOGY FOR POWER DEVICE PRODUCTS AND FOUNDRY CUSTOMERS

RF Micro Devices, Inc., a global leader in the design and manufacture of high-performance radio frequency components and compound semiconductor technologies, today announced the extension of RFMD's industry-leading GaN process technology portfolio to include a new technology optimized for high voltage power devices in power conversion applications.

RFMD's newest GaN process technology – rGaN-HV™ — enables substantial system cost and energy savings in power conversion applications ranging from 1 to 50 KW. RFMD'srGaN-HV delivers device breakdown voltages up to 900 volts, high peak current capability, and ultra-fast switching times for GaN power switches and diodes. The new technology complements RFMD'sGaN 1 process, which is optimized for high power RF applications and delivers high breakdown voltage over 400 volts, and RFMD'sGaN 2 process, which is optimized

By Jennifer Burkhardt

for high linearity applications and delivers high breakdown voltage over 300 volts. RFMD will manufacture discrete power device components for customers in its Greensboro, NC, wafer fabrication facility (fab) and provide access to rGaN-HV to foundry customers for their customized power device solutions.

ANADIGICS POWERS NEC MEDIAS

New NEC MEDIAS Smartphone is Powered by ANADIGICS' HELP™4 Power Amplifier

ANADIGICS, Inc. (Nasdaq: ANAD), a world leader in radio frequency (RF) solutions, announced that the Company is shipping production volumes of its AWT6621 fourth generation High-Efficiency-at-Low-Power (HELP™4) power amplifiers (PAs) to NEC CASIO Mobile Communications for the new MEDIAS IS11N. The NEC MEDIAS smartphone features a 3.6 inch display, 8 megapixel camera, and Android 2.3 Gingerbread operating system.

"The selection of our industry-leading HELP4 power amplifier by NEC CASIO Mobile Communications for the MEDIAS smartphone validates the performance advantages offered by our products," said Michael Canonico, senior vice president of worldwide sales at ANADIGICS. "Our proven high-volume manufacturing capabilities coupled with support centers located around the world allow us to deliver superior service to multiple leading wireless device manufacturers. We are proud to expand our successful relationship with NEC CASIO Mobile Communications and look forward to working together to develop the next-generation of mobile devices."

ANADIGICS' industry-leading HELP4product family uses the Company's exclusive InGaP-Plus™ technology to achieve optimal efficiency across low-range and mid-range output power levels and provides the lowest quiescent current in the industry. The AWT6621 power amplifier delivers industry-leading efficiency to extend battery life in 4G handsets, smartphones, tablets, netbooks, and notebooks.

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ANRITSU VECTORSTAR™ USED BY MODELITHICS TO VALIDATE PERFORMANCE OF BROADBAND DIODE MODELS OPERATING FROM DC TO 125 GHZ

Broadband VNA System Used to Measure Performance of Models Developed for Microwave and Millimeter Wave Designs

Anritsu Company announces that its VectorStar Broadband ME7838A vector network analyzer (VNA) system was used by Modelithics, Inc. to validate the performance of its novel non-linear diode models for W Band Single Anode and W Band ZBD flip chip schottky diodes from Virginia Diodes (VDI), Inc. Two-port series S-parameter measurements were made using the ME7838A and on-board probing with calibration reference at the component pad-stacks to validate the model's performance from DC to 125 GHz.

The ME7838A was used to generate ultra-broadband S-parameter data that was used in combination with DC I-V, RF resistance versus current, and harmonic power measurements made from separate instrument setups to develop and validate state-of-the-art non-linear mm-wave schottky diode models. The ME7838A was selected because of its wide frequency coverage from 70 kHz to 125 GHz, as well as its excellent dynamic range, measurement speed, and calibration and measurement stability.

"We are very excited about the technical advances represented by what we believe to be the broadest band non-linear diode models developed to date. The overall performance of the Anritsu ME7838A VNA system allowed us to acquire the 125 GHz broadband data very efficiently to enable advancement of models that not only fit this broadband data set well, but that also provided excellent agreement to independently obtain non-linear harmonic power validations," said John Fisher, Vice President of Operations at Modelithics.

CST STUDIO SUITE 2012

System Assembly and Modeling

By Dr. Marc Rütschlin

The key challenge facing RF engineers today is to minimize the time taken for the design and optimization of their devices. Their ability to meet this challenge may be impeded by the need to use different electromagnetic simulation tools for different aspects of their design. By embedding state of the art solvers based on different numerical techniques, such as the Finite Integration Technique (FIT), Finite Element Method (FEM) or Method of Moments (MoM), in a single user interface, CST provides engineers with a universal toolbox from which to choose the optimal tool. The optimization of individual components in isolation is important, but their performance within a system might be affected by the interdependence with other components. An optimization in the context of the entire system may be required.

System Assembly and Modeling

The System Assembly and Modeling (SAM) framework, introduced in version 2012 of CST STUDIO SUITE®, provides an environment to simplify the management of simulation projects in many ways.

A single master model with one set of parameters describes the system to be simulated. If the system consists of multiple components (which could be in full 3D, quasi 2D transmission line elements, or circuit components like SPICE models), the electrical links between those components can be defined at a schematic level, while their geometrical relationship is defined by a 3D layout. From this dual description of the model, simulation tasks can be derived as required.

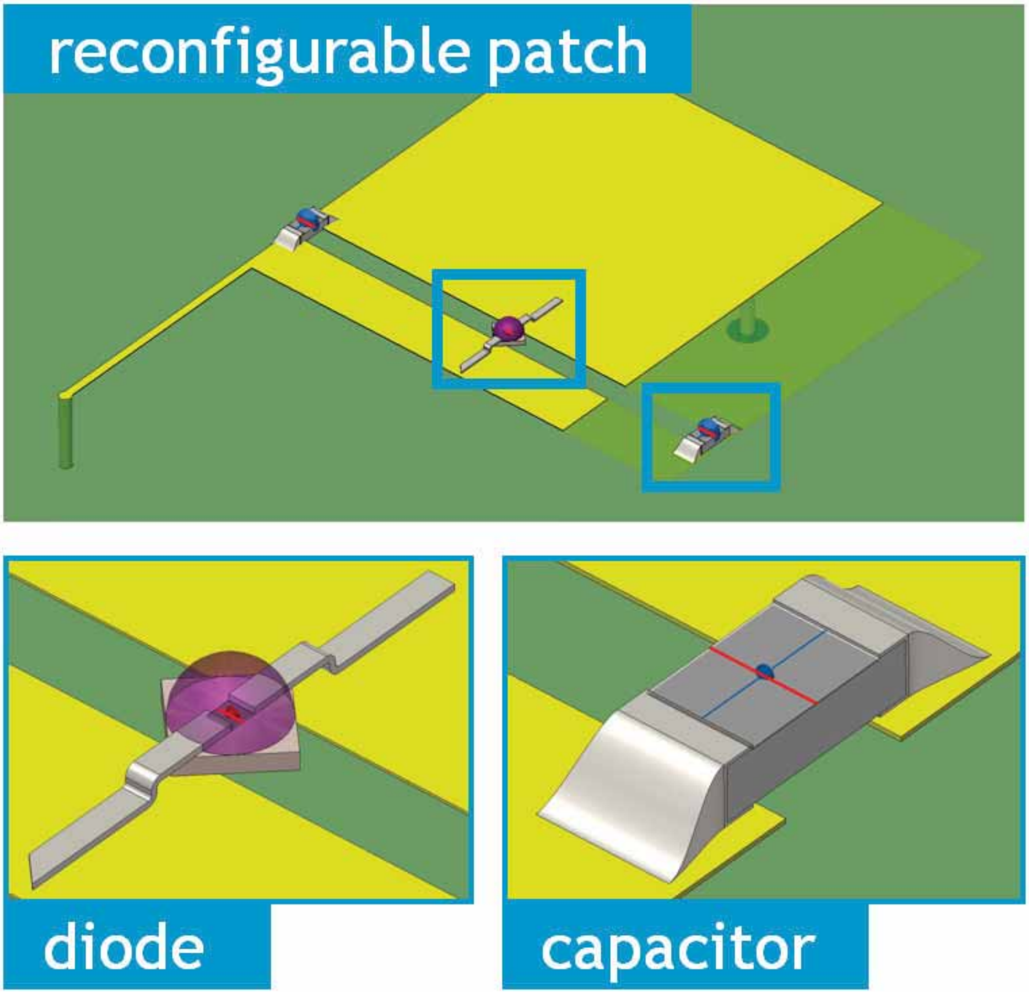

Fig. 1. This reconfigurable patch antenna can be toggled between two operating states by the PIN diode switch which is represented both by its 3D packaging and an equivalent SPICE model. Optimizing this single geometry for correct performance in both states is made easier by SAM.

In the simplest case the model may consist of a single component. SAM may be used to compare the results of different solvers, or to model different configurations within one simulation project. An example of this may be the reconfigurable antenna shown in Figure 1, which can operate in two radiating modes toggled by a switch (e.g. a PIN diode). The antenna has one geometry which has to be optimized for independent operation in its two states. While this sounds simple, it cannot be done easily with a traditional single simulation model.

The user can also set up a linked sequence of solver runs. For example, the electromagnetic analysis of a filter could be followed by a thermal simulation. The filter's resulting mechanical deformation could be determined and used in a second electromagnetic simulation to investigate the detuning effect. All simulations and links can be defined easily in SAM to enable a seamless multiphysics work flow, allowing in this case the optimization of the thermally detuned device.

SAM really comes into its own when a system consisting of multiple parts has to be analyzed or designed. A patch antenna in isolation can be designed and optimized relatively easily. But once it becomes part of an array which with its feed network, is attached to its driving circuitry, is housed in a radome and is installed in its environment (building, aircraft, satellite...), things become much more complex, as shown in Figure 2. We can be faced with a huge problem, both electrically and numerically! Limiting ourselves to a single numerical technique would make the design flow impossible. We need the best approach at each stage of the design, and to be able to combine the best methods as needed. We need to be able to understand how the antenna will perform in its intended environment, and this is exactly what the variety of tools and the SAM framework in CST STUDIO SUITE allows engineers to do.

Three dimensional components could also be represented simply by their S-parameter behavior or by an equivalent field source in the system simulation. This combination of different levels of simulation helps to reduce the computational effort required to analyze a complex model accurately. The user accesses SAM by defining tasks in the familiar CST DESIGN STUDIO (CST DS) interface, which is part of every CST STUDIO SUITE installation. Additional simulation flow control tasks including parameter sweeps and optimizations can be combined as required.

The System Assembly and Modeling approach in CST STUDIO SUITE 2012 is a flexible way of simplifying electromagnetic system simulation by applying innovative simulation and optimization technology to either full EM systems or their components.

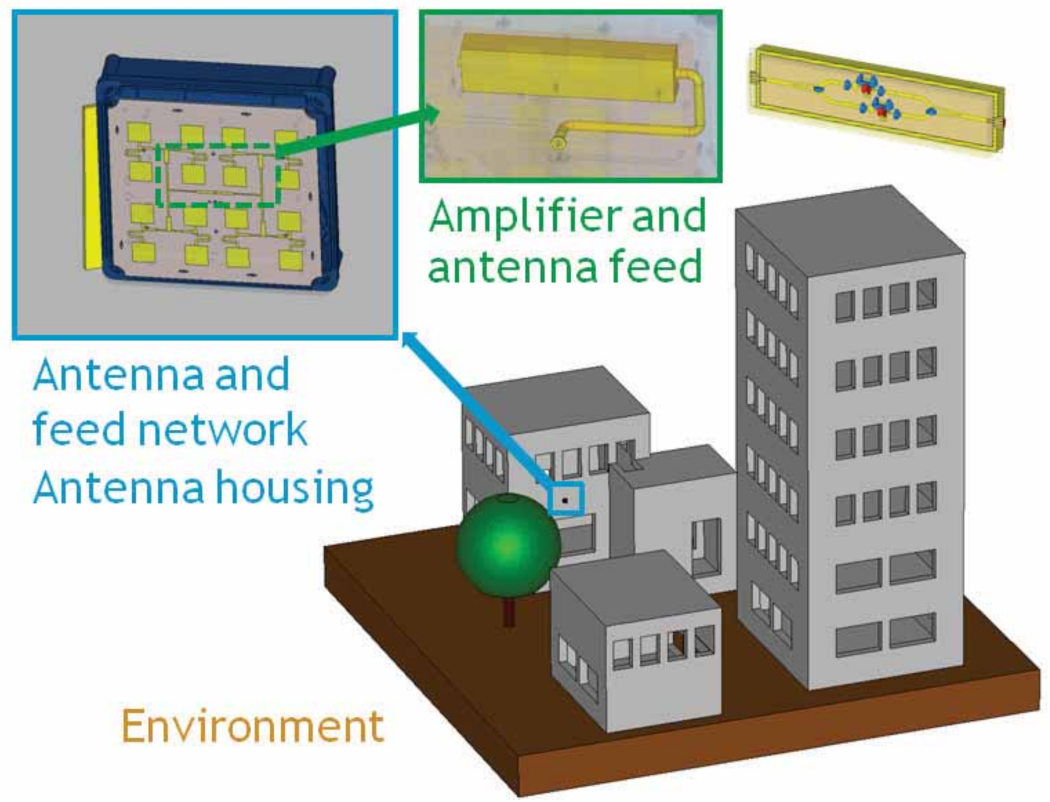

Fig. 2. Configuration of an antenna system in SAM: a) a schematic view defines the electrical connections between an antenna array and its feed network and driving circuitry; b) the 3D layout view defines the geometrical relationship of the antenna with its environment.

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By Mark LaPedus, Contributing Editor

Analog Vendors Eye Expansion Despite Market Lull

The analog chip market is currently in a seasonal lull. But preparing for an eventual upturn in the sector, Infineon, Maxim, On Semi, TI and others are quietly expanding their fab or backend capacities.

Seeking to expand its analog footprint, for example, market leader Texas Instruments Inc. is now converting one fab to larger 200mm wafers and looking at a process shrink within its 300mm plant. In addition, Infineon Technologies AG is moving towards 300mm wafers in select power semiconductor fabs. Rival Maxim Integrated Products Inc. is expanding its internal packaging efforts. And the foundries are also expanding their analog and mixed-signal efforts.

Total global analog revenue remained nearly flat last year, reaching $42.3 billion in 2011, according to Databeans Inc. Like most segments in the semiconductor industry, analog is down but not out right now.


TI's Menon

"A lot of people say analog is yesterday's news," said Venu Menon, vice president of analog technology development in the Technology and Manufacturing Group at Texas Instruments (TI). "Analog is still growing faster than the overall semiconductor market."

Analog still enables "new applications and new markets," Menon said at last week's 13th International Symposium on Quality Electronic Design (ISQED) in Santa Clara, Calif. And unlike digital, analog is "not limited by an industry roadmap. (There are) significant opportunities to differentiate."

Regarding the slowdown in the analog sector, Craig Berger, an analyst with FBR Capital Markets, said the lull is temporary. "The chip sector is at the cyclical trough right now in analog shipments generally, and should ramp as we move through 2012," Berger said in an e-mail. "Some portions of the supply chain are buying chips at well below consumption levels (i.e. China, white goods/appliances and some industrial), which is expected to ease as inventory levels are now at very low levels."

Doug Freedman, an analyst with RBC Capital Markets, said: "For the cycle, I see a slow road to recovery. One market at a time is returning to shipments at demand levels. There will likely be very little inventory rebuild, just an end to an inventory burn."

THE DOWN CYCLE IN ANALOG

In early March, analog chip giant TI cut its guidance for the first quarter, citing soft wireless demand. "Of the company's $100 million revenue cut, the entire shortfall was attributed to wireless shipments, with weaker OMAP sales weighing more heavily than connectivity," FBR's Berger said in a report in early March. OMAP is TI's application processor line for the mobile segment.

"While 4Q11 was an exciting time for new OMAP design wins and initial orders for products like the Amazon Kindle Fire, Barnes & Noble Nook Tablet, Samsung Galaxy S II (GTI9100G), Motorola Bionic, Galaxy Nexus, and others, sales of many of these end products have seasonally decelerated in 1Q '12, while customers also deplete chip and device inventories," he wrote in the report.

"Despite this, we still believe 1Q '12 will be the fundamental revenue trough for the chip sector and for TI, with a 2Q '12 cyclical reacceleration likely," he said. "Stepping back, TI has done a good job of focusing on its analog core, building competitive barriers, and growing scale."

Since 2009, TI has acquired several fabs that could add $9 billion of total analog revenue when fully operational. In 2010, TI acquired Spansion Inc.'s fabs in Japan, and bought Semiconductor Manufacturing International Corp.'s fab in China. The big blockbuster occurred last April, when TI bought National Semiconductor, which itself owned two fabs.

And amid TI's fab acquisition spree, the company continues to ramp up RFAB, its 300mm analog fab in Richardson, Texas. Last year, however, TI also announced plans to close two older 150mm semiconductor manufacturing facilities in Hiji, Japan, and Houston, Texas.

TI's strategy differs from most rivals. The company wants to maintain its leadership in analog and expanding its fab footprint is part of the equation. In contrast, most of TI's analog rivals have not made any recent fab acquisitions. Most analog houses have not even significantly expanded their internal fab capacities, and, in some cases, they outsource some or all of their production to the silicon foundries.

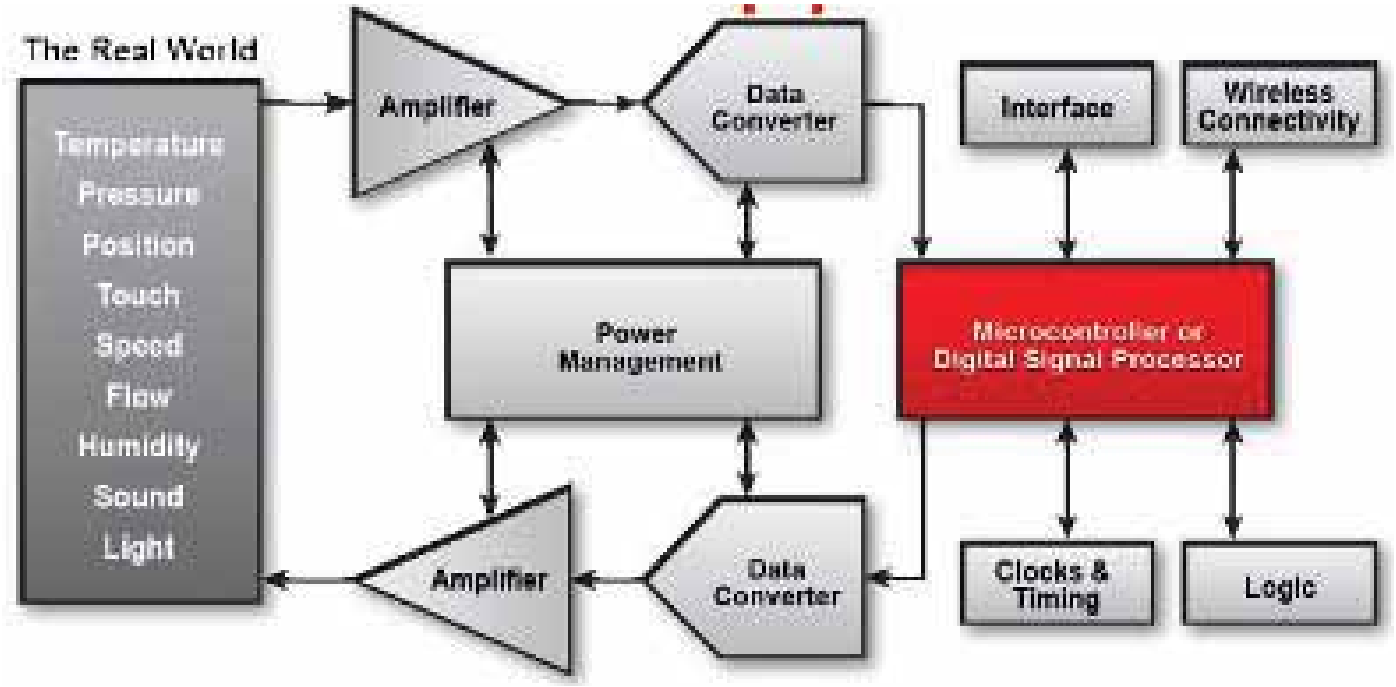
"If you want to excel — and be a big player in all segments — you need the factory horsepower to do that," Menon said in an interview at ISQED.

TI has not acquired any new fabs in 2012, but the company is still expanding its footprint. TI's 300mm RFAB is producing power management devices based on 0.25- and 0.18-micron geometries right now.

The "sweet spot" for analog is 0.25-micron technology, but TI is reportedly looking at finer geometries — and reportedly perhaps 0.13-micron processes — in RFAB. "There are plans to go smaller" in terms of process geometries within RFAB, Menon said, without elaborating.

The former National Semiconductor operation had two fabs, including one in South Portland, Maine and one in Greenock, Scotland. The South Portland fab is a 200mm facility, while Greenock is a 150mm plant. At present, TI is quietly converting the Greenock fab to 200mm capacity, he said. That conversion started prior to TI's move to buy National.

Since the acquisition, there has been some speculation that TI would shutter the National fabs and move the production to RFAB. Asked to comment on that speculation, Menon said: "(National) has capable factories. National has capable high-voltage and high-speed" devices.



TI's view of the analog signal chain (Source: Company)

RBC's Freedman has a slightly different observation. "During the 2009 recovery, TI was not able to keep up with demand," Freedman said. "As a result, they started a pretty major fab expansion plan. I was never a big believer in the thought 'if you build it they will come.' "

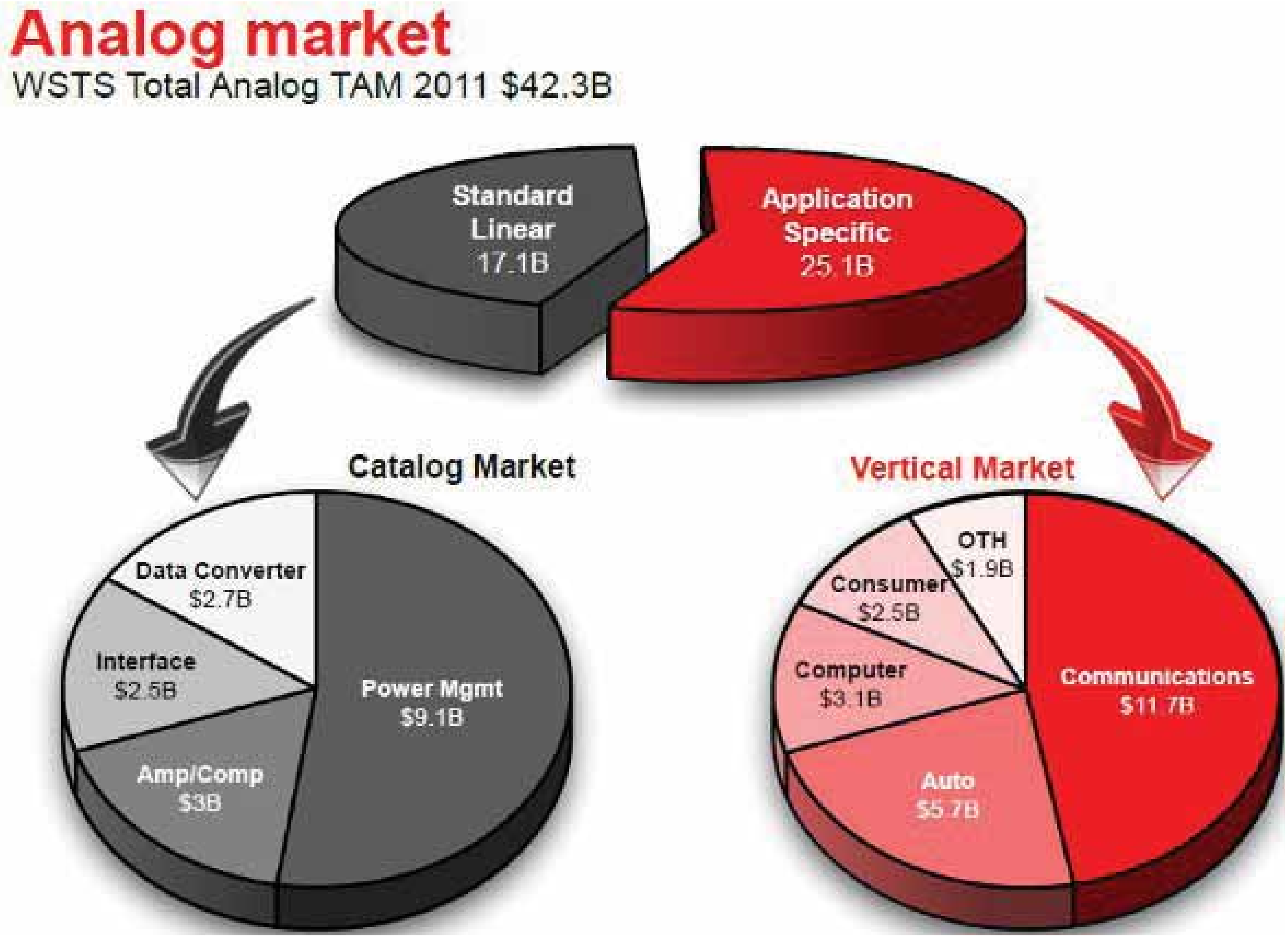
However, Freedman added: "TI should have some excess fab capacity to handle upturns in a 50+ percent gross margin business. While they might have over built in the past, they needed a refresh to the fab footprint, so I'm not surprised by the closure of some older fabs. The National fabs they bought run well and are likely more cost competitive than some older internal facilities."

FBR's Berger said TI's fab expansion program is only part of the analog story. "TI has been an aggressive capacity expander with its 300mm fab, of which only some modules are built out," Berger said. "The firm will clearly see the lowest die costs with this facility, though we note that analog fabs do not see the same volume scale as digital parts, so switching out the different mask sets and taking the resulting yield hit do impact costs. While a slightly lower price is good, we also note that analog business is generally won on performance, price, catalogue product availability, and service – not just price."

OTHERS ARE EXPANDING

Besides TI, others are also making a move on the fab front. In October, Germany's Infineon produced power ICs on 300mm wafers at its Villach, Austria-based pilot line. The high-volume production site for these devices will be at its 300mm fab in Dresden, Germany. In addition, Infineon has also begun construction of a second 200mm fab in Kulim, Malaysia. The current 200mm fab makes power semiconductors.

Meanwhile, rival analog chip maker Maxim Integrated Products Inc. has recently moved towards what it



Source: TI, WSTS

calls a "hybrid manufacturing model." At one time, the company handled its internal fab production, packaging and test in-house.

A large percentage of Maxim's front-end production is still done within its own fabs. Then, in 2010, the company formed a 300mm foundry alliance with Taiwanese DRAM makers Powerchip Semiconductor Corp. Maxim also has a foundry deal with Japan's Seiko Epson Corp.

At one time, Maxim outsourced its entire packaging efforts to the subcontractors. But seeking to develop some of its own capability, Maxim has set up a wafer-level packaging and wafer-bumping plant in Dallas, Texas, said Vijay Ullal, group president for consumer and automotive solutions at Maxim.

Two other analog players in the top 5, STMicroelectronics Inc. and Analog Devices Inc. (ADI), did not respond to repeated press inquiries.

Another player, On Semiconductor, has been on an acquisition spree. But it recently announced plans to close its wafer manufacturing facility located in Aizu, Japan, by the end of June 2012. That fab was previously owned by Sanyo Semiconductor, which was acquired by On Semi. Meanwhile, another emerging analog player, Japan's Renesas Electronics Corp., is said to be merging its chip operations with those from Fujitsu Ltd. and Panasonic, according to reports.

Meanwhile, the silicon foundries are also expanding their analog capacities or processes or both. In September, GlobalFoundries announced it is offering its 180nm BCDlite foundry technology optimized for automotive applications such as power management devices, audio amplifiers, displays and LED driver integrated circuits (ICs).

Mark LaPedus has covered the semiconductor industry since 1986, including five years in Asia when he was based in Taiwan. He has held senior editorial positions at Electronic News, EBN and Silicon Strategies. In Asia, he was a contributing writer for Byte Magazine. Most recently, he worked as the semiconductor editor at EE Times.

Company	2011 Rank	2011 $M	2011 Share	2010 Rank	2010 $M	2010 Share	Y/Y %
Texas Instruments	1	6,524	15.4%	1	6,190	14.6%	5%
STMicroelectronics	2	4,177	9.9%	2	4,291	10.1%	-3%
Analog Devices	3	2,584	6.1%	3	2,482	5.9%	4%
Infineon Technologies	4	2,073	4.9%	5	1,919	4.5%	8%
Maxim Integrated Products	5	2,034	4.8%	4	1,949	4.6%	4%
NXP Semiconductors	6	1,817	4.3%	6	1,810	4.3%	0%
Skyworks Solutions	7	1,477	3.5%	9	1,162	2.7%	27%
Linear Technology	8	1,324	3.1%	8	1,388	3.3%	-5%
ON Semiconductor	9	1,133	2.7%	11	1,115	2.6%	2%
Renesas Electronics	10	1,107	2.6%	10	1,116	2.6%	-1%
Others		18,088	42.7%		18,863	44.6%	-4%
Total		42,338			42,285		0%

TI stays No. 1 in analog chip rankings (Source: Databeans)

By Navid Ghazisaidi

Will FiWi be the Endgame of Broadband Access?

In the near- to mid-term, optical fiber is expected to entirely replace legacy copper-cable installations. The final frontier of optical networks has received a lot of attention, due to its convergence with wireless counterparts. Optical and wireless broadband-access technologies can be thought of as quite complementary. They're expected to coexist over the next decades. The emergence of quad-play services (i.e., voice, video, data, and mobility) leads to the stronger integration of optical and wireless-access networks in order to optimize quality-of-service (QoS) support and avoid replicated networking functions.

Future broadband-access networks will be bimodal. They'll capitalize on the respective strengths of both technologies, smartly merging them in order to realize future-proof Fiber-Wireless (FiWi) broadband-access networks. Those networks will strengthen our information society while avoiding its digital divide.

FiWi networks hold great promise to change the way we live and work by replacing commuting with teleworking.

By combining the capacity of optical-fiber networks with the ubiquity and mobility of wireless networks, FiWi networks form a powerful platform for the support and creation of emerging as well as future unforeseen applications and services (e.g., telepresence). FiWi networks hold great promise to change the way we live and work by replacing commuting with teleworking. This aspect provides more time for professional and personal activities for both corporate and personal benefits. At the same time, it helps to reduce fuel consumption and protect the environment—issues that are becoming increasingly important in our lives.

Hybrid, optical-wireless FiWi networks form a powerful future-proof platform that provides a number of advantages. Introducing optical fiber into broadband-wireless-access networks helps to relieve emerging bandwidth bottlenecks in today's wireless backhaul. Such bottlenecks are due to increasing traffic loads generated by new applications (e.g., iPhone). By simultaneously providing wired and wireless services over the same infrastructure, FiWi networks are able to consolidate (optical) wired and wireless access networks that are usually operated independently of each other. This approach will potentially lead to major cost savings.

FiWi access networks may be viewed as the endgame of broadband access. Currently, many research efforts in industry, academia, and various standardization bodies focus on the design and development of next-generation broadband-access networks. From short-term, evolutionary, next-generation passive optical networks (with coexistence requirements with installed fiber infrastructures—so-called NG-PON1), they range to mid-term, revolutionary, disruptive optical-access network architectures (without any coexistence requirements—also known as NG-PON2) all the way to fourth-generation (4G) mobile-WiMAX and cellular Long Term Evolution (LTE) radio-access networks.

To unleash the full potential of FiWi access networks, emerging optical and wireless-access network technologies have to be truly integrated at the physical, data-link, network, and/or service layers instead of simply mixing and matching them.

Navid Ghazisaidi is with Ericsson Inc., San Jose, CA. He received his PhD degree in Telecommunications from the University of Quebec, INRS, Montréal, QC, Canada, in 2010. Dr. Ghazisaidi is actively researching and contributing on various access networks standardizations in BBF, FSAN, IEEE, and ITU-T. Dr. Ghazisaidi is the co-author of the book "FiWi Access Networks", Cambridge University Press, 2012.

By John Blyler, Editor-in-Chief

Trends in Analog and RF IC Simulation

System-Level Design (SLD) sat down to discuss trends in analog and RF integrated circuit design with Ravi Subramanian, President and CEO of Berkeley Design Automation, during the recent GlobalPress eSummit. What follows are excerpts of that talk.

SLD: What are the trends in analog and RF simulation?

Subramanian: I see two big trends. One is related to physics, namely, the need to bring in physical effects early in the design process. The second trend relates to the increased importance of statistics in doing design work.

Expertise in statistics is becoming a must. One of the strongest demands made on our company is to help teach engineers how to do statistical analysis.

What is required is an appreciation of the Design-of-Experiments (DOE) approach – common in the manufacturing world. Design engineers need to understand what simulations are needed for analog verses digital designers. For example, in a typical pre-layout simulation, you may want to characterize a block with very high confidence. Further, you may also want to do that block extracted in post layout with very high confidence. But what does high confidence mean? How do you know when you have enough confidence?

If you have a normally distributed Gaussian variable, you may have to run 500 simulations to get a 95% probability of confidence in that result. Every simulation waveform and data point has a confidence band associated with it.

> "Physics and statistics are making life difficult for digital designers. But statistical modeling and analysis platforms can help."

SLD: This sounds a lot like the Six Sigma methodology, a manufacturing technique use to find and remove defects from high volume productions – like CMOS wafers. Will design engineers really be able to incorporate this statistical approach into their design simulations?

Subramanian: Tools can help engineers incorporate statistic methods into their works. But let talk about the need for high sigma values. To achieve high sigma, you need a good experiment and a very accurate simulator. If you have a good experiment but you want to run it quickly and give up accuracy, you may have a Six-Sigma setup, but a simulator that has been relaxed so the Six-Sigma data is meaningless. This shows the difference between accuracy and precision. You can have a very precise answer by it isn't accurate.

To summarize; Today's low node processes have associated physical effects that can only be handled by statistic methods. These two trends mean that new types of simulation must be run. Engineers need to give more thought as to which corners should be covered in their design simulations.

Semiconductor chip foundries provided corners that are slow, fast and typical, based upon the rise- and fall-times of flip-flops. How relevant is that for a voltage controlled oscillator (VCO)? In fact, are there more analog specific corners? Yes, there are.

SLD: Statistical analysis, Design-of-Experiments, and corner modes – Designers already hear many of these terms from the yield experts in the foundries. Should they now expect to hear it from the analog and RF simulator communities?

Subramanian: Designers must understand or have tools that help them deal with statistical processes. For example, how do you know if a VCO will yield well? It must have a frequency and voltage characteristics that are reliable over a range of conditions. But if you only test it over common digital corners, you may miss some important analog corners where the VCO performs poorly.

A corner is simply a performance metric, such as output frequency. You want to measure it within a particular confidence level, which is where statistics are needed. It may turn out that, in addition to the digital corners you'll need to include a few analog ones.

SLD: Would a typical digital corner be a transistors switching speed?

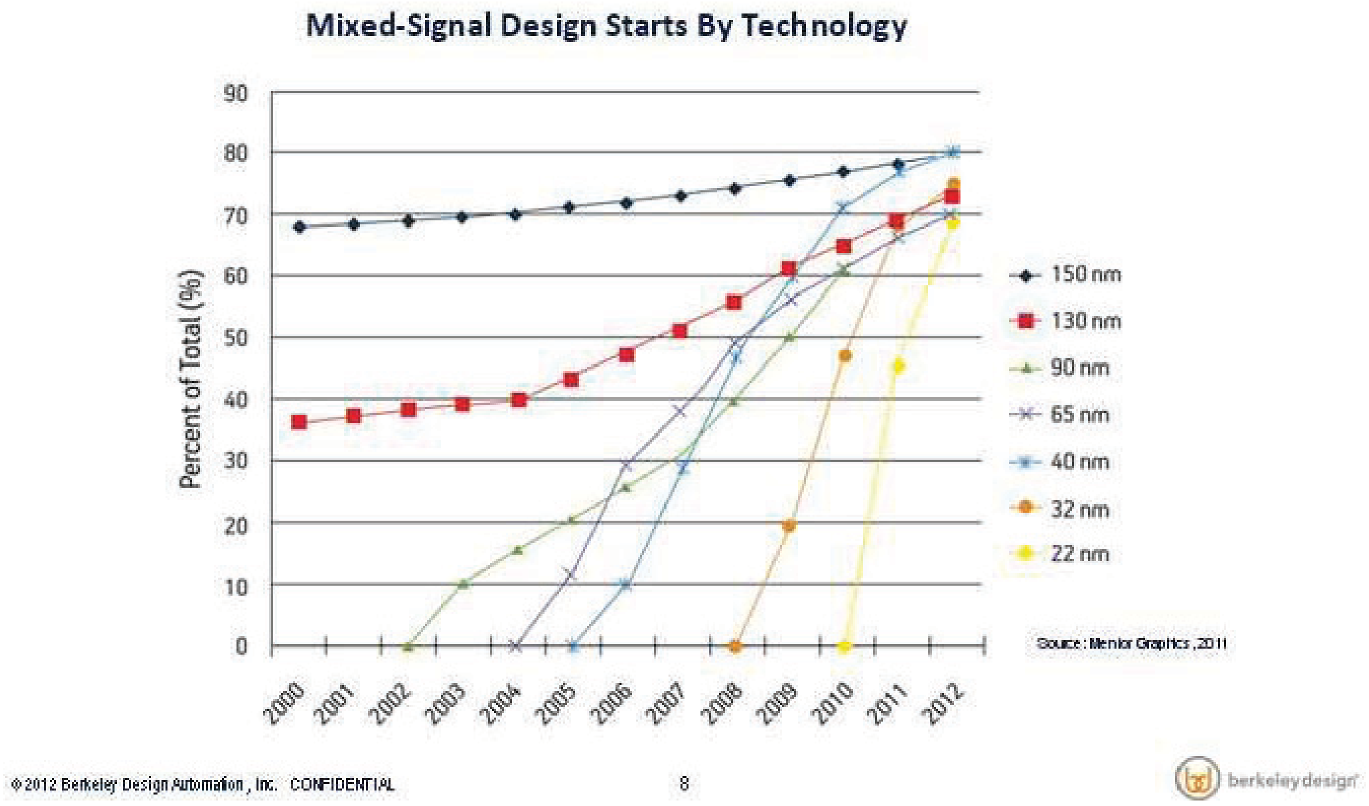
Subramanian: Yes – Foundries parameterized transistors to be slow, typical and fast in terms of performance. The actual transistor model parameters will vary around those three cases, e.g., a very fast transistor will have a fast rise and switching time. So far, the whole notion of corners has been driven by the digital guys. That is natural. But now, analog shows up at the party at the same time as digital, especially at 28nm geometries.

The minimal requirement today is that all designs must pass the digital corners. But for the analog circuits to yield, they must pass the digital and specific analog corners, i.e., they must also pass the condition and variations relevant to the performance of that analog device. How do you find out what those other corners are?

Most designers don't have time to run a billion simulations. That is why people need to start doing distribution analysis for analog corners like frequency, gain, signal-to-noise ratios, jitter, power supply rejection ratio, etc. For each of these analog circuit measurements, a distribution curve is created from which Six-Sigma data can be obtained. Will it always be a Gaussian curve? Perhaps not.

SLD: How will this increase in statistical distribution analysis affect traditional analog electronic circuit simulators like Spice?

Subramanian: Spice needs to start generating these statistically-based distribution curves. I think we are


Mixed-Signal Design Starts By Technology

Source : Mentor Graphics ,2011

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Figure: Mixed-Signal and RF designs are now part of the nanometer SoC design process.

at the early days of that frontier where you can literally see yourself having a design cockpit where you can make statistics simple to use. You have to make it simple to use otherwise it won't happen. I think that is the responsibility of the EDA industry.

SLD: I know that the several of the major EDA tool vendors have recently released tools to make the statistical nature of low process node yields more accessible and useable by digital chip designers. Are their similar tools for the world of analog mixed signal design?

Subramanian: Analog and RF designs are now going through this same process, to move from an art to a science. That's why I say that the nanometer mixed-signal era is here (see figure). Simulation tools are needed, but so are analysis capabilities. This is why our simulation tools have become platforms for analysis. We support the major EDA simulators but add an analysis cockpit for designers.

SLD: Why now? What is unique about the leading-edge 28nm process geometries? I'd have expected similar problem at a higher node, e.g., 65nm. Is it a yield issue?

Subramanian: Exactly – At 65nm, designers were still able to margin their designs sufficiently. But now the cost of the margin becomes more significant because you either pay for it with area or with power, which is really current. At 28nm, with Serdes (high frequency and high performance) and tighter power budgets, the cost of the margin becomes too high. If you don't do power-collapsing, then you won't meet the power targets.

SLD: What are the main analog simulation markets for Berkeley Design Automation (BDA)?

Subramanian: We are oriented around five areas: Connectivity, Application processor, Sensors and Displays, Memory and Power Management.

- Connectivity – Mostly 65nm RF CMOS clock data recovery circuits and such, going to 40nm for high speed 10Gb transceivers. This is a very complex area where you need strong RF and AMS experience to handle the digitally controlled analog design.
- Application processor: This consists of high speed IO interfaces like Serdes. This segment provides half of the company's business, mainly from customers running application processors and CPUs for tablets, smartphones, server CPUs and other.
- Sensors and Displays: When we started in the EDA market, I'd never have thought that image sensors would become such a major area for us, but they have. The reason is that higher resolution image sensors (in smart phones, etc) must maintain good sensitivity and dynamic range with very low power. By sensitivity, I mean; "How black is your black? How white is your white on the iPhone camera?" The platform providers (handset OEMS) must make trade-offs, e.g., using a 13 mega-pixel camera with a quad-core application processor and 12 lanes of Serdes to process movies.
- Power Management: Let everything else, power management is getting more integrated.
- Memory Management: We are making significant investments in that area. Traditionally, memory has had some traditional analog pieces like charge pumps, sensitivity chains and etc. Now, in order to achieve higher and higher memory density, vendors are going to multi-level cells. This allows storage of 2, 4 or 8 bits on a single cell. But to achieve this density you need better voltage resolution between the different bit levels which means you need more accurate simulation to measure the impact of noise. Noise can appear as a bit error when you have tighter voltage margins.

You might wonder if this is really a significant problem. Consider Apple's purchase of Anobit, a company that corrected those types of errors. (http://www.chipestimate.com/blogs/IPInsider/?p=552). If you can design better memory, then you can mitigate the need for error correction hardware and software. But to do that, you need more accurate analog simulation of memory. You cannot use a digital fast Spice tool which uses a transistor table look-up model. Instead, you must use a transistor BSIM (Berkeley Short-channel IGFET Model) model http://en.wikipedia.org/wiki/BSIM]

SLD: Thank you.

John Blyler is the Editorial Director of Extension Media, which publishes Chip Design and Embedded Intel® Solutions magazine, plus over 36 EECatalog Resource Catalogs in vertical market areas.

By John Blyler, Editor-in-Chief

RF Front-End Integration Driven By Low Power

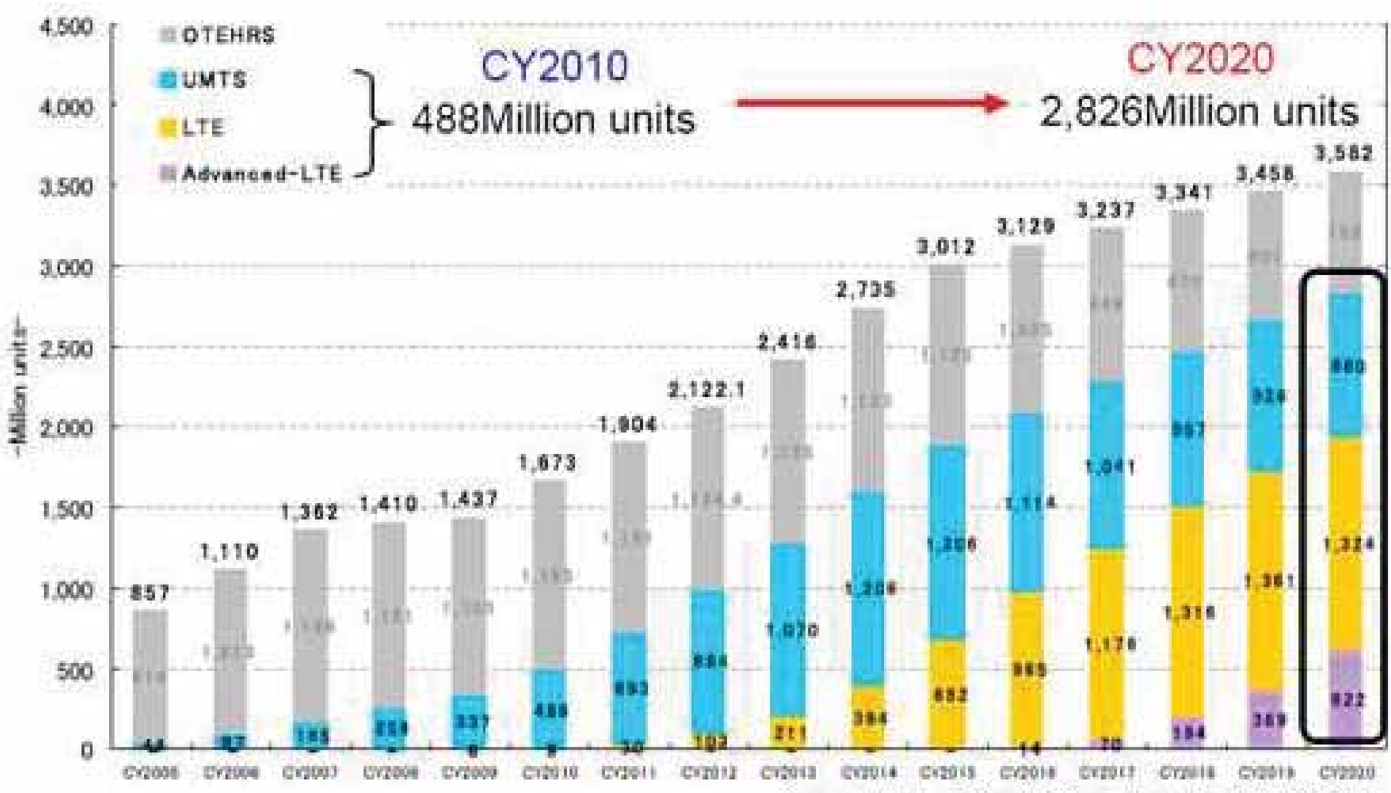
Tunable RF-Front-end MEMS devices built on standard CMOS meet demand for 4G-LTE power efficiency and shrinking handset form factors.

Few doubt the importance of wireless systems in today's globally connected world. But achieving wireless connectivity in ever-smaller and battery sensitive mobile devices means that RF front-ends must become fully integrated into the total system. This is not an easy task.

For reasons of digital scalability thanks to Moore's Law, handset developers traditionally have focused on the processor and transceiver designs. The radio frequency (RF) front-end was seen as a specialty area best left to the black-art world of analog design. But consumers demand ever-smaller, lower-power handsets with increasing feature sets and performance. This means the RF front-end must move away the discrete analog component chains that are needed to support a broad range of carrier frequencies, especially with the advent of 4G and LTE. But what can be done?

Like the digital world, the answer lies in both software and CMOS-based hardware. But instead of transistors as in the digital world, RF front-ends will use micro-electro-mechanical systems (MEMS) as the enabling passive technology. MEMS have been around for several decades. These mechanical structures tend to be oriented to specific products and applications, which meant very customized solution using a very customized fabrication process. This is one reason why MEMS have not been widely adopted.

Today, things are different. Over the last five-plus years, MEMS companies have begun to move away from the



Source: Navian Decade Forecast on Front-End Module

Figure 1: Navian report predicts strong growth for RF front-end modules.

customized development paradigm to a scalable CMOS-based model. In so doing, these companies have taken advantage of the large manufacturing infrastructure enjoyed by the digital CMOS community.

The timing of such a move couldn't be better, with continued strong growth in the global cellular handset. The Navian Market report predicts RF fronts-ends to grow from 488 million in 2010 to 2,826 million units in 2020 – including Advanced LTE, LTE and UMTS systems (see figure 1). Each of these handsets will consist of a chain of discrete RF components for every supported frequency band. Today, the build of material (BoM) for the RF components costs about $8 to $12 US. That amount will rise significantly over the next couple of years with the new frequencies modes require by 4G and LTE operations. Tablets, readers, laptops and other wireless devices will also be affected.

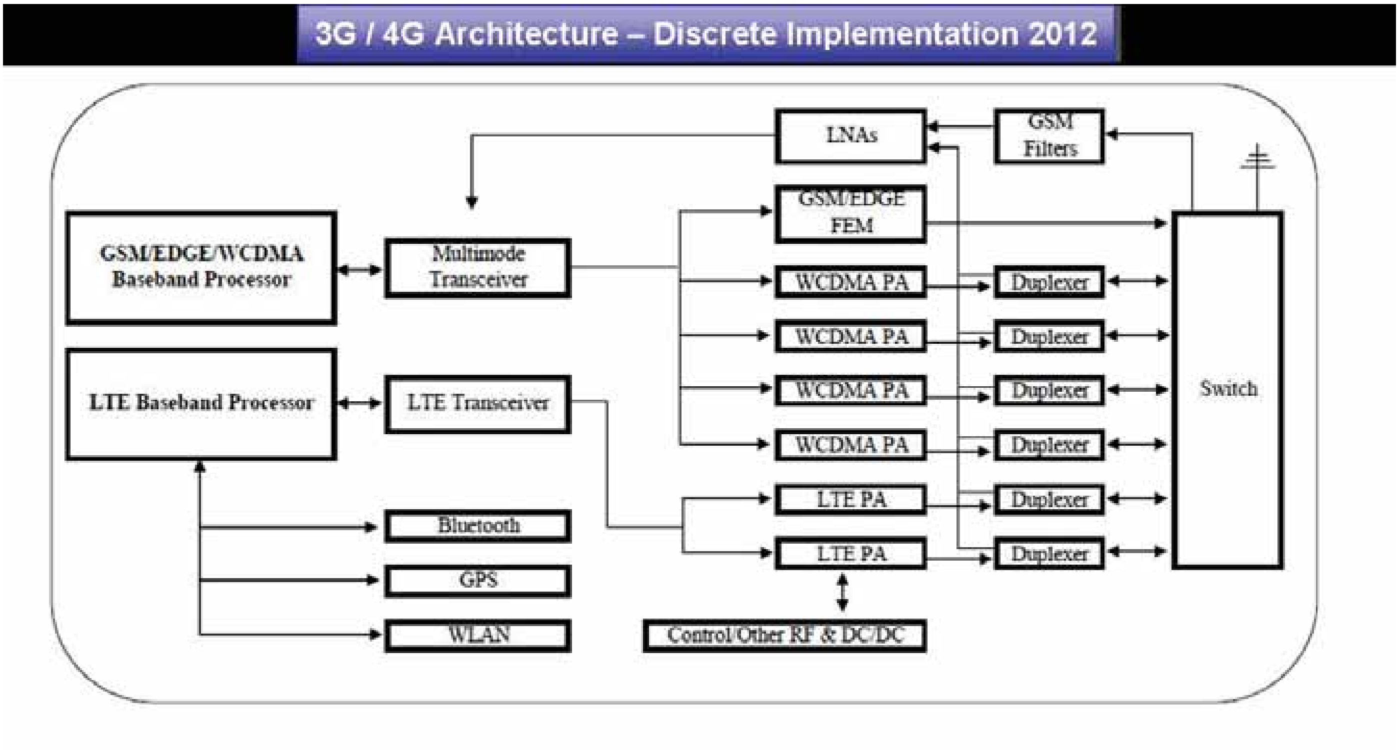
What will be required for RF front-ends to meet the demands of 4G? The increase in component chains must be balanced by shrinking handset sizes. This means that all of the discrete RF components around the transceiver needed to down-convert a wireless signal to the digital baseband domain must be modularized. These components perform functions of power amplification, filtering, impedance matching, and more. Modularizing these analog chains is a complex task that requires trade-offs in RF performance.

Jeff Hilbert - President & Founder

http://www.wispry.com/

"Fast forever to fully employed 4G architectures and theoretically that number will rise to 43 chains in the front-end of every globally-enabled handset," said Jeffrey Hilbert, president of WiSpry. Today's handsets typically have 5 to 8 RF component chains. That's a lot of hardware—too much so for handsets that are continually shrinking in width.

In addition to getting thinner, handsets are becoming dominated by the display. The trend in handset design is to increase the screen size by the bezel and keyboards. While great from a user interface perspective, this trend is bad for RF systems due to antenna placement. For example, removing the keyboard means that the display must be touch screen. But touch screens have metal plates behind them, which interfere with antenna performance.



Source: Oppenheimer & Co.

Figure 2: Typical functional architecture for today's 3G and 4G handsets.

Other problems abound, ranging from handset OEM supply chain issues to special material restrictions in the front-end components.

The traditional answer to most of these challenges has been to integrate more functionality at the board-level. For example, several discrete filters have been packaged into one module so the handset OEM has a smaller BOM and fewer insertions on the board. Moving to module-level integration is a step in the right direction, but even more integration is needed. In today's 3G and even 4G system architectures, there are still separate digital basebands and transceivers components, not to mention numerous structures in the RF front-end (see Figure 2)—from low noise amplifiers (LNA) and power amplifiers (PA) to filters and duplexers.

In the near future, basebands and transceivers will be integrated together as multicores on the same die. A similar consolidation will have to occur on the RF front-end to meet consumer form-factor desires, lower power and 4G-LTE multi-radio operations.

Ever-smaller form factors present real problems for the radio antenna. Today, there is typically less and 1cc of space available for the main antenna in a cell phone. This is particularly challenging from the perspective of electromagnetic design since so many structures can interfere with the antenna's performance. Additionally, LTE deployment in the US will occur in lower frequency bands, which generally require larger antennas. The net result is that antenna design is getting more complex.

This is where MEMS are helping. MEMS are tiny mechanical structures built on the surface of CMOS wafers. They are controlled by software to perform the same analog functions as much larger discrete analog components. For example, WiSpry MEMS are built on a 0.18 micron CMOS process, fabricated on 8-inch wafers by IBM Microelectronics. These devices function as an array of tunable RF passive components (see Figure 3). Each of the individual mechanical elements in the array is separate from the others and is independently addressable. Designers can connect the cells together on the single die or in a package as individual pieces. Arranging these individual cells allows designers to create tunable RF devices used in filters, power amplifiers,

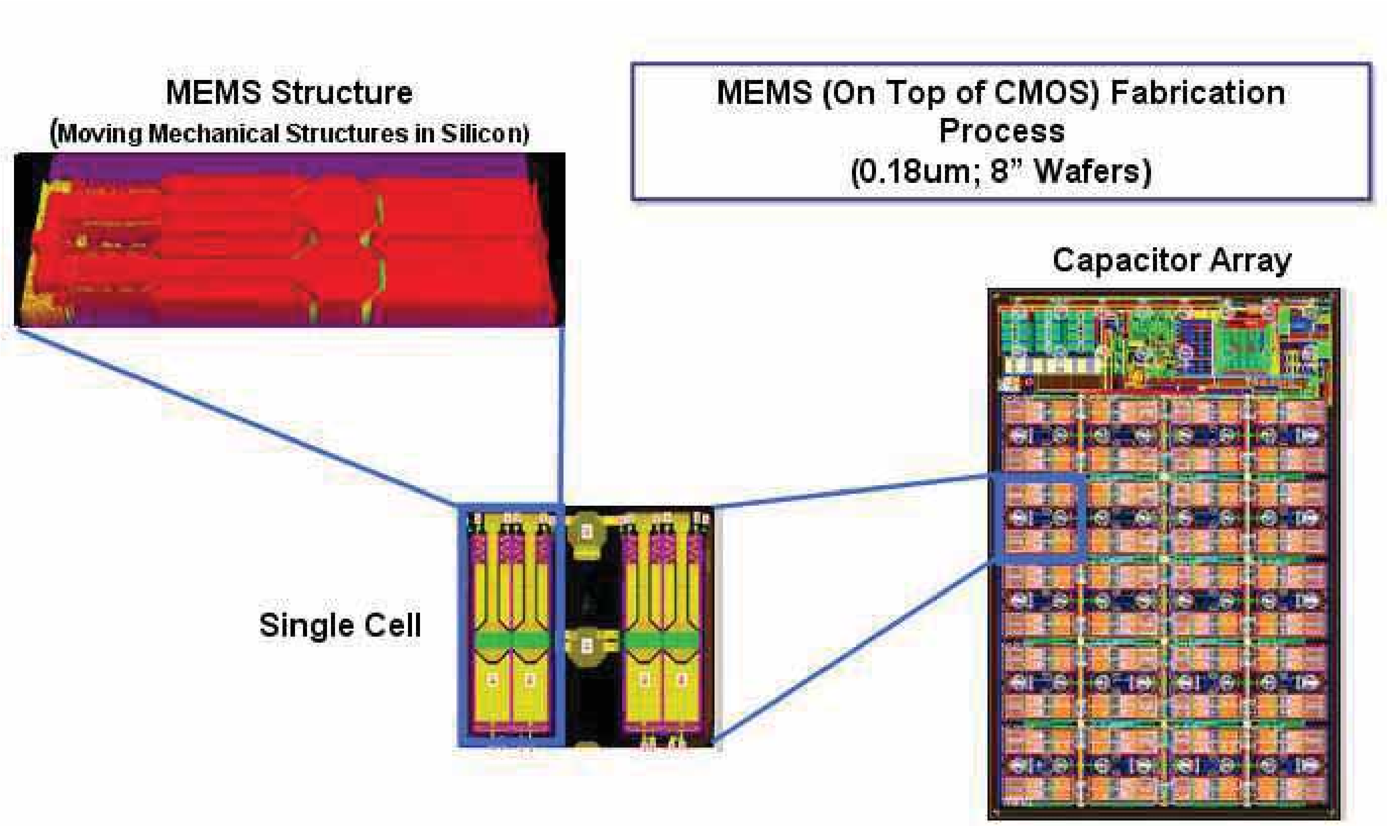


Figure 3: MEMS cells are programmable and can work independently on a die.

antenna tuners, impedance network matching and general purpose capacitors.

CMOS tunable filters will help reduce power consumption by decreasing the number of inactive yet current drawing discrete components. More power will be available to drive the antenna with less power being wasted as heat in components.

In the near future, such MEMS devices will be reconfigured in real time by software running on the baseband processor. Real-time processing is needed to maintain the low latency required to adjust the RF properties of power amplifiers and filters. "In some sense, we will be virtually emulating the hardware components that we've replaced by making these programmable components using the MEMS devices," explained Hilbert. "That is where the RF adaptability comes in." While this goal has been realized in the lab, for now discrete components are implemented in the handset marketplace.

MEMS in CMOS are not without shortcomings, especially in terms of latency. One of the disadvantages of MEMS is they are slow compared to the speed of transistors. For a small fraction of the market applications, this may be a problem.

Where are MEMS being used today? For the most part, in microphones and sensor arrays for motion sensing accelerometers and gyros. These sensors perform the magic that tell the handset to turn off the display to save power when the phone is placed next to the user's head. MEMS gyros are begin to find use in camera stability subsystems and handset pico-projectors.

Where will MEMS be used in the future? For front-end architectures, Hilbert foresees MEMS devices physically attached to the antenna to affect different resonant modes. This will save size and power. Another trend will be the usage in a variety of different filters, from duplexing for Wideband-CDMA to notch and bandpass filters.

Power amplifiers will also be improved with MEMS. Programmable structures will improve the efficiency of power amplifiers and provide impedance matching so less power has to be driven across the handset. This will decrease wasted energy lost as heat.

Figure 4: Tunable RF front-end power amplifier using MEMS technology.

CMOS is not the only approach to creating MEMS. Other technologies include Barium Strontium Titanate (BST) ferroelectric thin films, GaAs-based and Silicon-on-Insulator (SOI). Each technology has its advantages and disadvantages in terms of the key tradeoffs of capacitive change, RF quality factor, and controllability. WiSpry uses CMOS MEMS to create digital capacitors. Partec employs BST technology for analog variable capacitors. Sony uses GaAs-based for its switched passives. Perigrine Semiconductor is an SOI-based implementation of switched passives—using Safire. (see, "Noble Award Honors Low-Power RF Technology" (http://chipdesignmag.com/display.php?articleId=4977)

Choosing the best technology for a given application is tricky. The scale of the RF front-end market is large so potential customers is reluctant to change. The best approach may be to appeal to the entire RF ecosystem, from consumers to carriers and handset OEMS. Each has their own needs. Consumers want longer battery life (lower powered devices), better performances, and global connectivity—all at a cheaper cost.

Carriers want to avoid capital expenditures by lowering their infrastructure costs. One heuristic is the decibel (dB) change. To realize 1 dB change in performance improvement, a carrier's network would require 14% more cell sites. This translates into several million dollars in capital expenditures, which can be a huge cost for the carriers.

Handset OEMS want improved power efficiency and RF performance gain with decrease BOM cost and supply complexity.

Tunable RF (CMOS) MEMS will not solve all of the consumer, carrier and OEM needs. But MEMS does balance many tradeoffs, especially where battery life and form factor are concerned, in next-generation 4G (LTE) wireless systems.

John Blyler is the Editorial Director of Extension Media, which publishes Chip Design and Embedded Intel® Solutions magazine, plus over 36 EECatalog Resource Catalogs in vertical market areas.

By Mark LaPedus, Contributing Editor

Body Area Networking Heats Up in Medical Field

Standards battle brews for wireless chips

For years, chip makers have been waiting for huge growth in the medical market.

So far, though, the medical semiconductor market has yet to see a major boom, but the sector has experienced decent and steady growth. It has become readily apparent that the medical electronics field is complex and fragmented. In medical, chip makers and OEMs alike face long design cycles, funding issues and FDA regulatory headaches.

But one area that is suddenly generating steam — and creating some debate on several fronts — is remote patient monitoring. And seeking to get a piece of the action, Broadcom, IMEC, Qualcomm, TI, Toumaz and others are developing a new class of multi-mode wireless chips for remote monitoring devices. In addition, Intel, Qualcomm and others are backing or developing systems-level products in the arena.

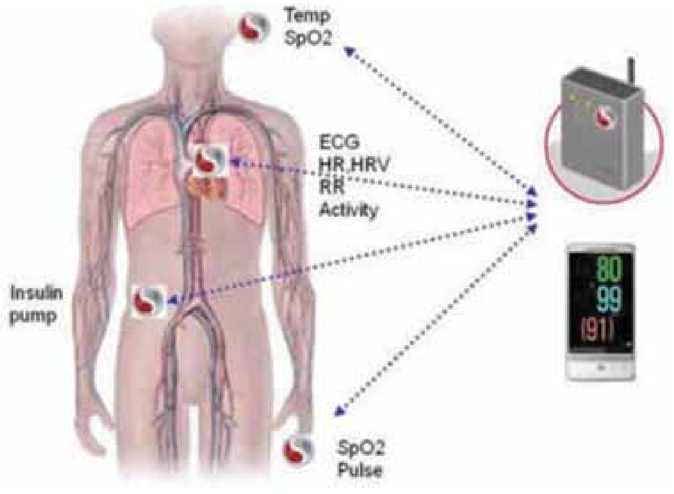
These tiny electronic devices, which can be implanted or worn externally, can remotely monitor the heart, glucose, pulse and other vital data via a PC, and, more recently, through a wireless network. For mobile applications, the wireless chips themselves fall into a loosely defined category called body area networks (BANs). BAN has been talked about for years, but the technology is moving into the limelight.

In fact, as the remote patient monitoring business picks up momentum, there is a wireless standards battle brewing in the BAN arena. The wireless contenders in the BAN field include the emerging IEEE 802.15.6 standard, a low power version of Bluetooth, Wi-Fi and Zigbee. There is no clear-cut winner yet.

“What the (medical) industry is asking for is greater connectivity across different products,” said Ed Hill, director of marketing for the Intelligent Systems Group at Intel Corp. “We believe the industry wants more interoperability — or connected — devices. We also need to make sure these devices are secure.”

For years, Intel has participated in the medical field. In 2006, Intel rolled out the Mobile Clinical Assistant (MCA) reference design, a tablet-like, point-of-care bedside terminal for healthcare. Panasonic and Motion Computing sell products based on the technology.

Intel also has a joint healthcare venture with GE. And Intel also sells its latest embedded processors for imaging gear and other medical equipment. “New compute platforms will open up new algorithms in medicine,” Hill said.



System architecture for wireless body area networks (Source: Toumaz)

GROWTH SEEN IN MEDICAL SEMIS

And it will spur growth in the medical arena. In total, the worldwide medical semiconductor market is expected to increase from $3.8 billion in 2011 to $5.9

billion in 2016, a 9 percent compounded annual growth rate, according to Databeans Inc., a research firm.

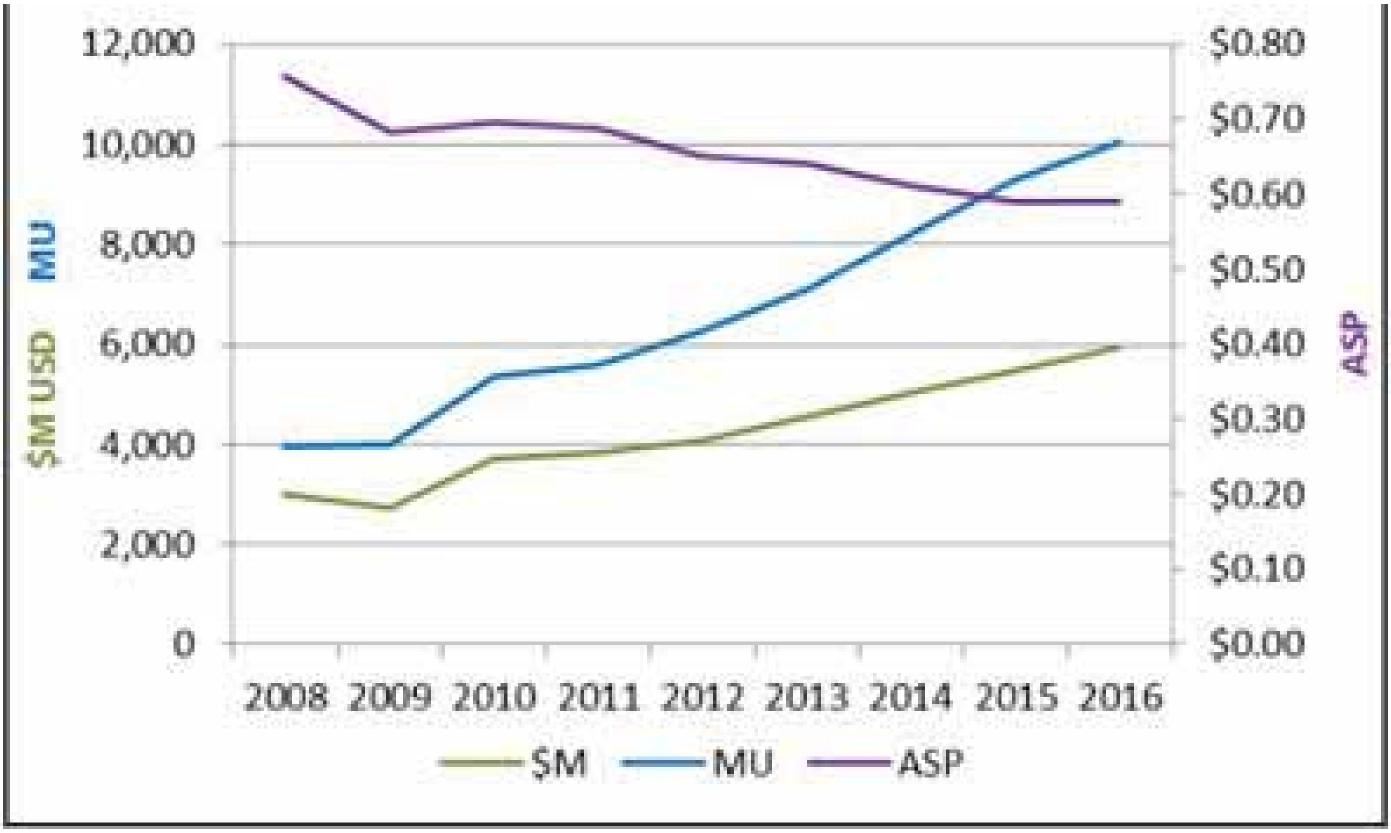
However, in 2012, the medical semiconductor market is projected to see flat growth and reach $4 billion, said Susie Inouye, research director for Databeans. The problem is that “there are excess inventories in the worldwide industrial channels,” Inouye said. “There is also a lot of activity in China. There also are a lot of new design starts in Asia.”

“The medical electronics field is diverse,” added Intel’s Hill. “Medical (electronics) is growing fast, but the growth is less than consumer electronics. And the refresh cycles are quite lengthy.”

There are three major areas in the medical electronics field: clinical, imaging and the home. The clinical electronics segment — the largest medical chip market — includes diagnostic lab equipment and other systems. Meanwhile, imaging — the second largest segment — includes magnetic resonance imaging (MRI) and computed tomography (CT) equipment. Home healthcare is the smallest market, but it is growing the fastest. In the past, the home market was limited to blood pressure monitors, digital thermometers, glucose meters and among others.

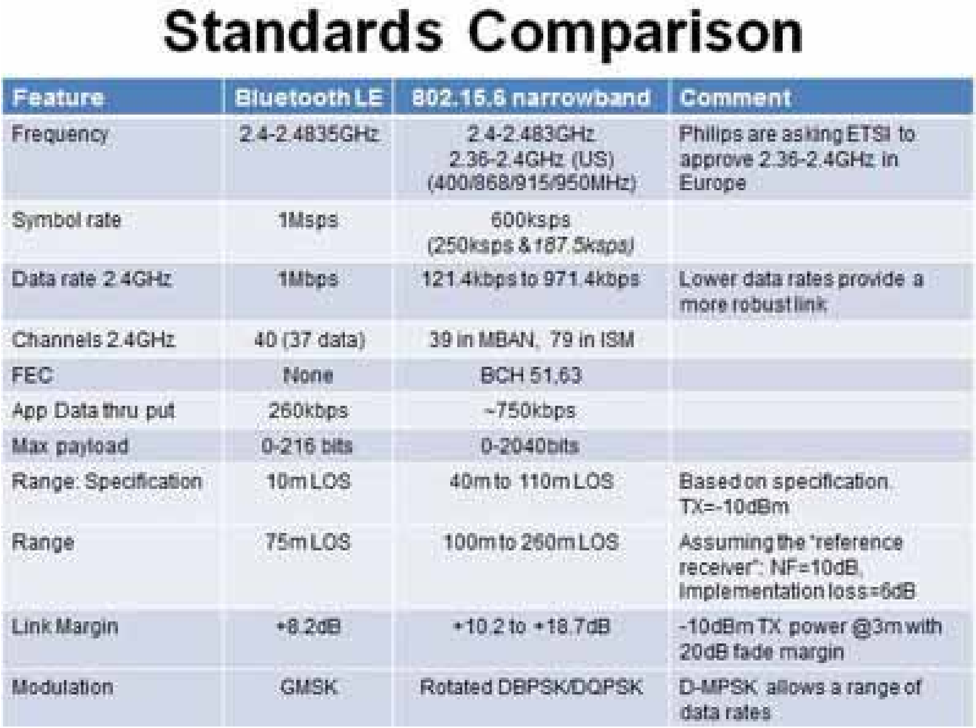
The aging population, combined with soaring healthcare costs, is causing a sea of change in the medical field. To mitigate healthcare costs, there is a movement towards replacing care within hospitals to the patient’s home, said Intel’s Hill. The trend has given rise to remote monitoring. For some time, medical electronics firms have offered small implantable or worn devices that can remotely send data to a health care provider via a PC.

But the buzz in the arena started last June, when Medtronic Inc. launched its first mobile application for implantable cardiac devices. The software, dubbed CareLink Mobile Application, allows clinicians to access cardiac device diagnostic and patient data directly from their mobile devices. The CareLink Network provides similar information as an office visit for pacemakers,



Worldwide medical IC market forecast in terms of revenue, Units, and ASPs (Source: Databeans)s)

implantable cardioverter-defibrillators (ICDs) and implantable cardiac monitors (ICMs).



Standards Comparison

Feature	Bluetooth LE	802.15.6 narrowband	Comment
Frequency	2.4-2.4835GHz	2.4-2.483GHz 2.36-2.4GHz (US) (400/868/915/950MHz)	Philips are asking ETSI to approve 2.36-2.4GHz in Europe
Symbol rate	1Msps	600ksps (250ksps & 187.5ksps)	
Data rate 2.4GHz	1Mbps	121.4kbps to 971.4kbps	Lower data rates provide a more robust link
Channels 2.4GHz	40 (37 data)	39 in MBAN, 79 in ISM	
FEC	None	BCH 51,63	
App Data thru put	260kbps	~750kbps	
Max payload	0-216 bits	0-2040bits	
Range: Specification	10m LOS	40m to 110m LOS	Based on specification TX=-10dBm
Range	75m LOS	100m to 260m LOS	Assuming the "reference receiver": NF=10dB, Implementation loss=6dB
Link Margin	+8.2dB	+10.2 to +18.7dB	-10dBm TX power @3m with 20dB fade margin
Modulation	GMSK	Rotated DBPSK/DQPSK	D-MPSK allows a range of data rates

Worldwide medical IC market forecast in terms of revenue, Units, and ASPs (Source: Databeans)s)

Then, in February of 2012, GE Healthcare said it would distribute AirStrip Technologies Inc.'s patient monitoring technology. The deal provides patient monitoring information to physicians via the iPhone and iPad. AirStrip's platform allows clinicians to monitor the heart, blood pressure, temperature, oxygen saturation, weight and pulse via a wireless network.

Also in February, Qualcomm Inc. invested in AirStrip. The two companies are working together to develop wireless chips. And in a related development, Qualcomm, Intel and others recently invested in Sotera Wireless, a startup that is developing "body-worn sensors" for remote monitoring applications.

Despite the momentum in the arena, there are still several challenges in remote monitoring, which impacts the growth of BANs. There is still a question just how doctors are paid — and how insurance providers are involved — in remote monitoring, said Intel's Hill.

Another challenge is sending critical data like patient information across a wireless network. "Security is an inherit problem," said Karthik Soundarapandian, systems application manager for health and fitness at Texas Instruments Inc.

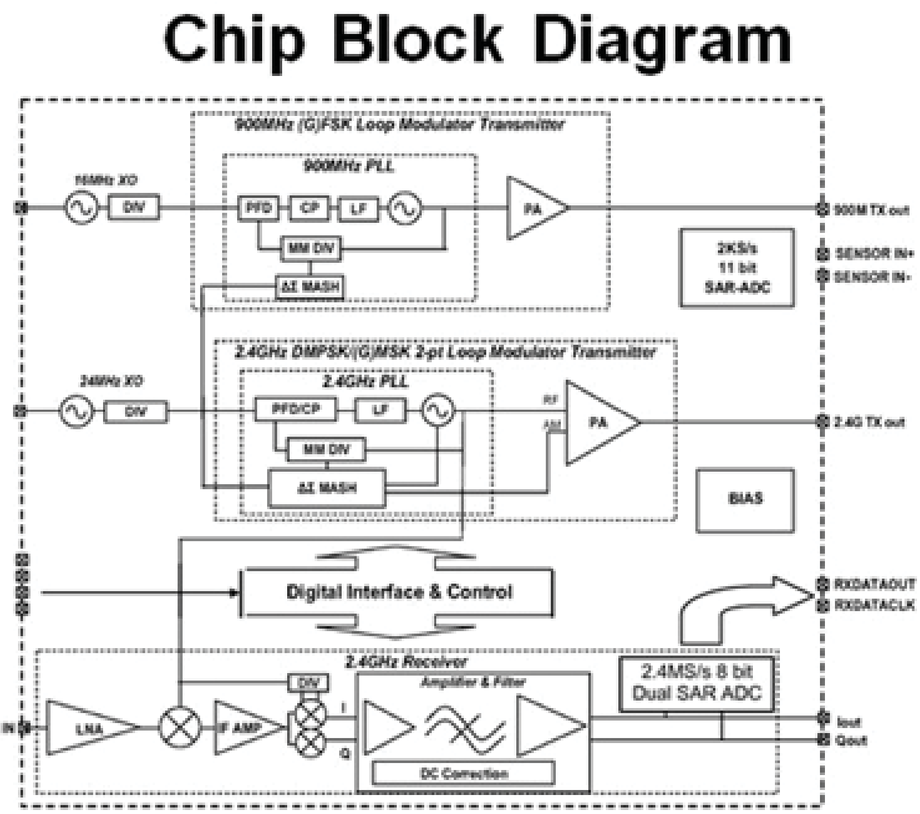
Standards also remain a problem. In recent times, the BAN community has worked together to develop a wireless standard — dubbed IEEE802.15.6 — which is geared for the quality-of-service (QoS) levels for personal medical data. The standard is expected to be completed this year. A variant of Bluetooth, Bluetooth Low Energy (LE), has also emerged as a competing standard. ZigBee and WiFi are also in the running.

Within the hospital environment, medical equipment may end up supporting multiple protocols, Soundarapandian said. But in terms of using the smartphone as a gateway for remote monitoring, "Bluetooth is the best option today," Soundarapandian said. "Bluetooth will prevail."

NEW BAN CHIPS

Another problem is power consumption. Many of BAN-like transceivers use from 20mW to 50mW of power, which is still too high for use in autonomous and semi-autonomous sensor nodes, according to IMEC. At the recent Integrated Solid-State Circuits Conference (ISSCC) in San Francisco, Alan Wong, head of IC design at U.K.-based Toumaz, presented a paper on an ideal solution: The company is apparently working on a 1-Volt, 5mA transceiver that supports 802.15.6, Low Energy Bluetooth and proprietary protocols.

Based on 0.13-micron technology, the chip operates in the 2.36-GHz BAN spectrum, specifically allocated for medical devices, and the worldwide 2.4-GHz ISM band. "The network needs to be secure and able to respond immediately," Wong said.



Toumaz tips body area networking chip (Source: Company)

In a separate presentation at ISSCC, IMEC and Holst Centre described a 2.3-/2.4-GHz transmitter for wireless sensor applications compliant with IEEE802.15.6/4/4g and Bluetooth Low Energy. The transmitter has been fabricated in a 90nm CMOS process, and consumes only 5.4mW from a 1.2-Volt supply at 0dBm output.

This is two to five times more power-efficient than the current Bluetooth-LE solutions, according to IMEC. IMEC's new transmitter saves at least 75 percent of power consumption by replacing several power-hungry analog blocks with digitally-assisted circuits.

In a somewhat related field, the University of Washington in Seattle and the University of Virginia at ISSCC presented a paper on a 19uW battery-less energy harvesting chip for body area sensors. Conventional wireless sensors are powered from a battery. In contrast, the two universities propose a chip "powered by energy harvested from human body heat using a thermoelectric generator (TEG)."

The digital section includes a custom digital power management processor, general purpose microprocessor and SRAM. It also has dedicated accelerators for ECG heart rate extraction, atrial fibrillation (AFib) detection, and EMG band energy calculation. A sub-mW 400/433-MHz MICS/ISM band transmitter performs BFSK transmission up to 200kbps.

Besides the wireless front, TI will shortly expand its analog front-end lines for heart monitors, sports, and fitness applications. The ADS1291/2/2R line of AFEs are a family of 24-bit, delta-sigma (ΔΣ) analog-to-digital converters (ADCs). Based on a proprietary analog process, the parts represent part of TI's "ECG signal chain." With the integrated AFEs, "we can take the complexity out of designs," TI's Soundarapandian said.

Going forward, Ritesh Tyagi, director of product marketing for Renesas Technology America Inc., said the medical field will remain a steady growth market for chip makers — and not the booming business many had hoped. He also warned that vendors must have patience: The IC design cycle can take as much as three years for a new system platform in the medical field.

Mark LaPedus has covered the semiconductor industry since 1986, including five years in Asia when he was based in Taiwan. He has held senior editorial positions at Electronic News, EBN and Silicon Strategies. In Asia, he was a contributing writer for Byte Magazine. Most recently, he worked as the semiconductor editor at EE Times.

By Akmarul Ariffin Bin Salleh

Fast and New Method for Cycle Slip Analysis in PLL: Part 1

I. INTRODUCTION

CYCLE slip observed in a PLL during transient, is due to the cyclic nature of the phase detector. Papers that describe the analysis of PLL cycle slips are few, and those that are available are relatively complex.

In a PLL with a saw tooth phase detector (e.g., a PFD), cycle slip happens when the phase error is greater than |2π| rad. When this is the case, for example |2π+0.1| rad, the actual phase error seen by the phase detector is only |0.1| rad and the loop will think that the phase error has switched direction, thus switching its tuning direction too. The tuning profile of forward tuning VCO is shown in Fig. 1. This paper will only deal with PLL with PFD, as it is widely used

Transient will happen when it is required to change the output frequency of a PLL. Fig 2 shows the PLL diagram that use charge pump PFD and fractional N divider. To change the PLL output, the divider is programmed to a different value.

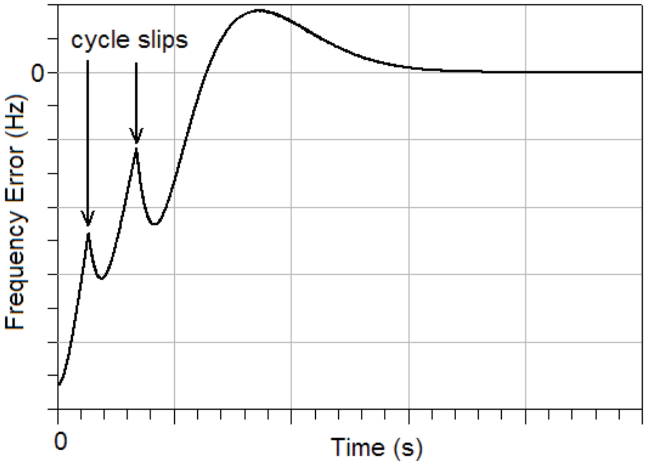


Fig. 1. Cycle slips during PLL transient. A similar profile can be seen on Vtune.

Charge pump PFD outputs current of Ipd for a given phase error of θerr. Kpd is the gain for the PFD. F(s) for the loop controller, Kv for the VCO, and 1/N.F for the divider. The output frequency Fvco is N.F*Fref. The 1/s factors at both PFD inputs are there as we are dealing with frequency at input Fref and at output Fvco.

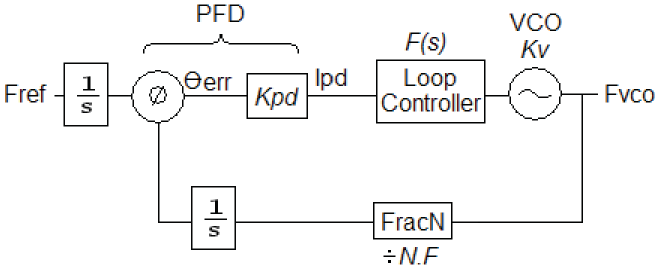


Fig. 2. PLL block diagram.

Fvco can also be changed by changing the Fref, but this is uncommon in practice. Nevertheless, it is more convenient from an analysis point of view as the change is directly at the input of the PLL. For a PLL in Fig.2, the equivalent change at Fref when the divider is changed is given by (1). Nold is the old divider value and Nnew is the new divider value after stepping. The change ΔFref is in step, as the change in the programmable divider value is instantaneous.

$$\Delta Fref = \left(\frac{N_{old}}{N_{new}} - 1\right) Fref \tag{1}$$

Before this new PLL cycle slip analysis is explained, small signal transient must first be analyzed. Small signal is valid when the PFD's phase error never exceeds |2π|, thus everything is linear and Laplace can be used. For a given input, the output is calculated by multiplying the input with the PLL's system transfer function H(s), defined as the ratio of Fvco(s)/Fref(s) and is calculated in (2). The output response at Fvco is given in (3). The transient response at Fvco can be calculated in (4) by taking the inverse Laplace transform of (3).

$$H(s)=\frac{1}{s}\cdot\frac{Kpd\cdot F(s)\cdot Kv}{1+Kpd\cdot F(s)\cdot Kv\cdot\frac{1}{N.F}\cdot\frac{1}{s}} \tag{2}$$

$$Fvco(s)=H(s)\cdot\frac{\Delta Fref}{s} \tag{3}$$

$$fvco(t)=L^{-1}\{Fvco(s)\} \tag{4}$$

As will be shown later on, the transient response at the output of the PFD must be analyzed to determine if cycle slip will occur. This can be done by multiplying the PLL's error transfer function E(s) in (5), with the input. E(s) is the ratio of Ipd(s)/Fref(s). The transient response at node Ipd is calculated using (6) and (7).

$$E(s)=\frac{1}{s}\cdot\frac{Kpd}{1+Kpd\cdot F(s)\cdot Kv\cdot\frac{1}{N.F}\cdot\frac{1}{s}} \tag{5}$$

$$Ipd(s)=E(s)\cdot\frac{\Delta Fref}{s} \tag{6}$$

$$ipd(t)=L^{-1}\{Ipd(s)\} \tag{7}$$

The cycle slip analysis presented in this paper is mainly in the s-domain where the Laplace and inverse Laplace transform will be used. The paper is structured in the following manner. Section II describes the cycle slip condition. Section III will describe 1 cycle slip analysis. Section IV will cover the analysis for generalized n cycle slips. Section V compares the results using this new technique against ADS and Section VI concludes the discussion.

II. CYCLE SLIP CONDITION

When the equivalent change at Fref causes phase error θerr to be >|2π|, then linear analysis as outlined in Section I can't be used. This paper will describe this can be done somewhat through linear analysis so that intuitive understanding on cycle slip could be achieved.

Instead of looking at the phase error to determine cycle slip, the current output Ipd of the PFD is used, as this is physically accessible for probing. Without loss of generality, the charge pump PFD will be used throughout this paper.

Charge pump PFD is actually a time discrete device instead of time continuous. The output toggles between 3 discrete values of Ipdpeak, 0 or – Ipdpeak amp. Even though it is discrete, the phase error information is analog as it contains the varying width of Ipdpeak or – Ipdpeak pulse. The wider the pulse is, the larger the phase error. Even though the phase error is analog, it is not time continuous, as the phase error information is only available at every 1/Fref period, thus disabling analysis in s-domain. To enable analysis in s-domain, the charge pump has to be modeled as a time continuous device. To achieve this, we can assume that the charge pump PFD outputs continuous current between – Ipdpeak to Ipdpeak, instead of discrete. As the phase error dynamic range of the PFD is -2π to 2π, the modulation gain of the PFD can then be defined as Kpd= Ipdpeak/(2π) whose unit is A/rad. At 0 phase error, the PFD output is 0 A and at the max phase error of 2π, the PFD outputs Ipdpeak A. So the max current at note Ipd as in Fig. 2 can only be Ipdpeak before the loop goes into cycle slip. This cycle slip condition, achieved by looking at node Ipd, will be used throughout.

III. ONE CYCLE SLIP ANALYSIS

A transient response with only one cycle slip will be first explained before generalization is done for n cycle slips. When cycle slip occurs, the current at Ipd will step from Ipdpeak down to 0 A for positively increasing phase error, or from – Ipdpeak to 0 A for negatively increasing phase error. Without loss of generality, positively increasing phase error will be assumed throughout the analysis. Equivalently, the phase error θerr will step down from 2π down to 0 rad. This phase step can also be viewed as a -2π step at the phase detector input, applied at the moment cycle slip occur. This different perspective of cycle slip is the key to this fast and new approach of cycle slip analysis.

When the N divider is stepped, the transient response at node Ipd can be first calculated using the linear response outlined in the Introduction section, regardless of whether cycle slip will or will not occur. This is shown in (8).

(8) $$ipd_0(t) = L^{-1}\{E(s)\cdot\frac{\Delta Fref}{s}\}$$

When the first cycle slip occurs at t = tslip1, this can be viewed as a phase step of -2π rad being applied at the input of the PFD at t = tslip1. To calculate the response at Ipd due to this -2π rad phase step, (6) can be leveraged with a slight modification as the input is now in rad rather than in Hz. The transient response can be calculated by first assuming that the -2π rad phase step is applied at t = 0, rather than at t = tslip1, and is shown in (9). The inverse Laplace is then applied on (9) and arrives at (10).

(9) $$Ipd_{1\_shifted}(s) = E(s)\cdot(-2\pi)$$

(10) $$ipd_{1\_shifted}(t) = L^{-1}\{Ipd_{1\_shifted}(s)\}$$

We then have to shift the transient response in (10) by +tslip1 on a time scale and force the response to be 0 for t < tslip1. This is shown in (11) where u(t) is a unit step function. The total transient response is the sum of the two transient responses as shown in (12).

(11) $$ipd_1(t) = ipd_{1\_shifted}(t - tslip_1)\cdot u(t - tslip_1)$$

(12) $$ipd_{total\_1}(t) = ipd_0(t) + ipd_1(t)$$

For the one cycle slip case, finding tslip1 is straightforward as shown in (13). Caution must be taken when solving (13) as there can be 2 solutions; tslip1 is the time whereby ipd0(t) crosses Ipdpeak the first time.

(13) $$tslip_1 = root(ipd_0(t) - Icp)$$

So far we have only discussed the solution at node Ipd. The solution at node Fvco will take similar steps. Once tslip1 is figured out, the cycle slip analysis at any node is relatively simple. What follows are the steps for solutions at Fvco. The first step is to calculate the transient due to the equivalent change at Fref as in (14)

(14) $$fvco_0(t) = L^{-1}\{H(s)\cdot\frac{\Delta Fref}{s}\}$$

Next, we need to calculate the transient response when the cycle slip occurs at t = tslip1 where this is equivalent to having a -2π rad phase step applied at the input of the PFD. To simplify the analysis, it is assumed first that the -2π is applied at t=0, instead of at t=tslip1. The steps to arrive at the shifted time-domain response are shown in (15) and (16). The transient solution in (16) needs to be time shifted by tslip1. The response prior to tslip1 is forced to 0, as defined in (17). The total transient solution at Fvco is given in (18).

(15) $$Fvco_{1\_shifted}(s) = H(s)\cdot(-2\pi)$$

(16) $$fvco_{1\_shifted}(t) = L^{-1}\{Fvco_{1\_shifted}(s)\}$$

(17) $$fvco_1(t) = fvco_{1\_shifted}(t - tslip_1)\cdot u(t - tslip_1)$$

(18) $$fvco_{total\_1}(t) = fvco_0(t) + fvco_1(t)$$

CONCLUSION FOR PART 1

The Part 2 of this paper will be covering the generalized solution for N cycle slip analysis and comparison with analysis from ADS.

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By John Blyler, Editor-in-Chief

MEMS and Packaging Hold Keys to Radio Connectivity

Building on Intel's Rattner introduction to the future of mobile computing, IMEC's Liebet Van der Perre recently spoke about the need for ultra-low-power, ultra-high-speed, versatile radios. Dr. Van der Perre is the director of the Green Radios Program at IMEC. What follows is a summary of her presentation.

The prerequisite technology to achieve context-aware mobile computing is improved connected devices—from smartphones and smart buildings to smart devices and displays. This technology is supported by growth numbers, which project that the number of wireless devices will reach beyond 10 billion units in the next few years.

The continued growth in wireless devices brings with it the predictable need for greater bandwidth, connectivity, and mobility. What is far less predictable is the associated user behavior, desired applications, and business models needed to support the market. No one is quite sure what connectivity applications will excite future users. Who could have predicted the rise of Facebook? This is why user-experience-based design has taken on new urgency.

The one certain trend is that all of the technical aspects that support future connectivity will take place in "the cloud"—connecting machines, users, content providers, governments, and everything imaginable. Dr. Van der Perre highlighted machine-to-machine (M2M) connectivity via the cloud with a picture of a Twittering plant. Using simple electronics and low-power wireless connectivity, the plant tells the farmer when it needs more or less water. The name of the platform tells it all: Botanicalls (www.botanicalls.com; see Figure 1). I recently covered an unusual Hollywood-style application of low-power, wireless cloud connectivity (see "Embedded World Illuminates TRON," http://www.entertainmentengineering.com/v8.issue05/18).

Figure 1: One example of machine-to-machine, low-power-radio connectivity via the cloud is provided by Botanicalls.

In addition to unpredictable user demands and applications, such future connectivity brings enormous technical complexity and uncertainty. The best way to address certain technical crossroads is still being defined in areas ranging from lithography, EUV, and patterning types to interconnect, air gap, 3D, and packaging issues.

Where is certainty to be found in all of this unpredictability? For wireless devices, the requirements are clear: Decrease power consumption with every increase in performance. But this tradeoff between power and performance is old news. The one new requirement for future connectivity is the versatility of the radios.

Versatile radios can operate in small heterogeneous cells. Furthermore, they can exploit all spectral resources—from today's crowded 6-GHz ranges to future huge-capacity, unused, and free 60-GHz bandwidths (see Figure 2). The challenge for smaller cells is that they must operate with increasing capacity while radiating less and consuming less energy. Conversely, larger cells will need to achieve greater mobility while increasing transmission coverage areas.

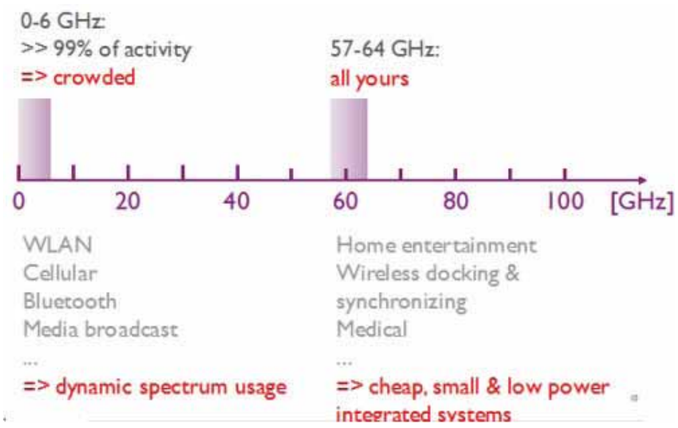


Figure 2: Future connectivity requires that all spectral resources be exploited—ranging from 0 to 6 GHz and huge bandwidths at around 60 GHz. (Courtesy of IMEC)

The versatility requirement translates to spectral agility for existing 0-to-6-GHz radios, which now must support 17+ bands for fourth-generation (4G) communications. IMEC has reconfigurable analog-front-end (Scaldio) and digital-baseband (Cobra) systems-on-a-chip (SoCs) that address these requirements.

It's one thing to have a sophisticated RF front end to handle 17+ bands. But you also must have an equally versatile antenna interface. Reconfigurable surface-acoustic-wave (SAW) filtering with radio-frequency (RF) microelectromechanical-systems (MEMS) technology provides the most promising answer to the antenna bottleneck issue. RF MEMS also could be tightly integrated within the front-end and baseband chip packages.

In fact, one idea is to integrate the RF MEMS and related passives (like low-loss inductors) into a portion of die-packaging interposer substrate. Using the interposer would provide several benefits, ranging from low-loss antenna filtering to integrated CMOS power amplifiers and low-phase-noise voltage-controlled amplifiers (VCOs).

RF MEMS also could be used to integrate a switched-capacitor MEMS array within a single software-defined-radio (SDR) package. The MEMS for the array might be located above the integrated circuit (IC) or directly on the interposer.

For the currently uncrowded, free 60-GHz spectrum, versatility will require improved radio platforms to meet the need for cheap, small, and low-power modules for the consumer markets. This means using leading-edge, 40-nm, low-power CMOS processes. Phased-array radio transmitters and receivers will be needed as well as new beamforming functionality. Power consumption must be low: 260 mW for the multiple receivers and 420 mW for the transmitters. Standards bodies have been formed to address this new technology—including a group within the IEEE and the Wireless Gigabit Alliance (WGA).

As always, the big question boils down to balancing performance (speed) and power. How can we design ultra-high-speed, versatile radios that consume ultra-low power? The good news is that we can. The bad news is that it takes a comprehensive, co-designed approach that requires system, architecture, and technology consideration.

At a system level, the challenge is to move from a performance and coverage mindset to one of capacity and energy. Meeting this challenge will mean connecting via the shortest and best direct link. Designs will need to enable the versatility to determine—on the fly—what type of link is the best for any given connectivity scenario.

Architecturally, connectivity platforms must be multi-mode and scalable. Improved designs will be needed for the next generation of power-efficient transmitters. Technology will help through further process scaling below 40 nm and with more heterogeneous integration of chip dies and related structures, such as MEMS and interposers.

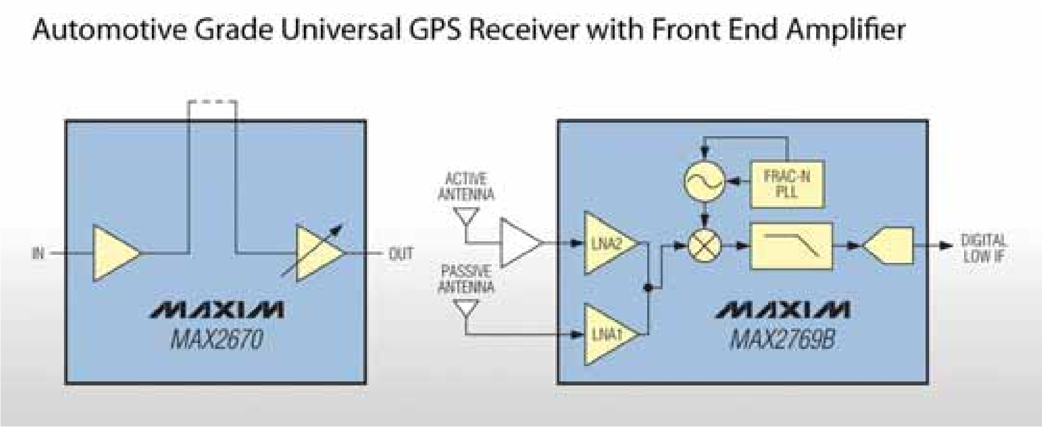
From a wireless perspective, all of these challenges and solutions will welcome a future of very versatile radio devices that can operate at ultra-low power over a variety of heterogeneous networks. These platforms will then provide the technology upon which a sensor-rich, context-aware, user-experience-driven world can exist. Whether it proves to be more beneficial or distracting for most of us remains to be experienced.

John Blyler is the Editorial Director of Extension Media, which publishes Chip Design and Embedded Intel® Solutions magazine, plus over 36 EECatalog Resource Catalogs in vertical market areas.

By Ashok Bindra

Front-End Power Amplifier and Receiver Combo For Global Navigation

Using low-power silicon germanium (SiGe) BiCMOS process, Maxim Integrated Products has released automotive grade flexible universal receiver solution for global navigation satellite system (GNSS) applications. The receiver MAX2769B is supported by a front-end power amplifier (PA) MAX2670. The universal receiver and PA combination is designed to handle navigation standards, such as GPS, GLONASS, Galileo, and Compass. The chips are complaint with automotive PPAP process and meet AEC-Q100 specs.



Combining a universal GNSS receiver with front-end amplifier delivers a highly flexible, high performance system solution for navigation applications.

While MAX2670 is a dual-stage low noise amplifier (LNA) designed for the antenna module, MAX2769B resides within the dashboard as the receiver. For improving receiver sensitivity, the MAX2769B offers very low noise figure (NF), which is rated at 1.4 dB.

MAX2670 is designed to operate across all GNSS frequency standards with a 34.8 dB typical cascaded gain and a 25 mA supply current. For maximum stability in system design, the two LNA stages allow the use of a wide range of GNSS filters. The final RF output pin, which drives the cable to the GNSS receiver, is also the power-supply connection that accepts a DC supply in the +3.0 V to +5.5 V range. Alternatively, the DC supply can be applied to pin 4.

By implementing on-chip monolithic filters, MAX2769B completely eliminates the need for external IF filters and requires very few external components to implement a low-cost GNSS RF receiver solution. In addition, its integrated analog-to-digital converter (ADC), which is programmable from 1 to 3 bits, makes it highly configurable and flexible receiver design.

Key receiver functions integrated on-chip include a dual-input LNA and mixer, followed by the image-rejected filter, PGA, VCO, fractional-N frequency synthesizer, crystal oscillator, and a multibit ADC. The total cascaded NF of this receiver is as low as 1.4dB. According to Maxim, the integrated delta-sigma fractional-N frequency synthesizer allows programming of the IF frequency within a ±30 Hz ($f_{XTAL} = 32$ MHz) accuracy while operating with any reference or crystal frequencies that are available in the host system. The ADC outputs CMOS logic levels with 1 or 2 quantized bits for both I and Q channels, or up to 3 quantized bits for the I channel. I and Q analog outputs are also available.

The MAX2769B is packaged in a 5-mm x 5-mm, 28-pin thin QFN package with an exposed paddle. And the front-end PA comes in a 10-pin TDFN surface-mount package (3-mm x 3-mm).

Ashok Bindra, formerly the EiC of Power Electronics Technology, has more than 20 years of editorial experience covering analog, power devices, and DSP technologies. He is a graduate of Clarkson College of Technology (Now Clarkson University).

By Pallab Chatterjee

The Wi Of CES

There has already been quite a bit written about the tablets, TVs and ultrabooks that consumed most of the floor space at this year's CES show in Las Vegas. There was an underlying technology that was brought out at the show to bind these together—wireless.

As the proliferation of content consumption device continues, creating a connected network to get this media and data from point to point is becoming more of a challenge. The data sets—now rich with high-resolution images and video—are getting very large, which is presenting a problem both from a power point of view and from the perspective of the size of the pipe for ingesting data.

With the majority of new data-consuming devices being connected wirelessly and driving both the need for broadband and for handshake and connectivity for the "Internet of Things," wired networks are moving to the high-performance, IT supportable, corporate applications only. This is making the main connectivity wireless. These wireless protocols fit into three bins: cellular network, small data networks, and full wireless networking and large-data-transfer connectivity.

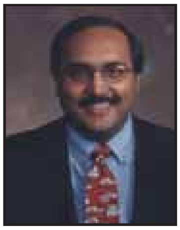
Cellular 2G, 2.5G, 2.75G, 3G, 4G and 4G LTE systems have been shown at CES for years. This year, the data-oriented 4G LTE was center stage. Handsets were available from every supplier for the interface, and there were a couple of high-profile infrastructure suppliers. Alcatel-Lucent along with Renesas Mobile were both showing high-speed transmission equipment. While the performance of the units was quite high—upward of 112Gbps with the Renesas unit—the effectiveness in the field is limited by range. LTE is targeted at a two-kilometer radius from the tower, and Renesas reported a data rate of 98Gbps still at one kilometer in tests in real cities. However, the data connectivity and rate dropped off almost exponentially beyond that due to a number of issues, including signal obstruction from existing buildings and structures, which minimized the usable distance for large area coverage.

With the exception of new Bluetooth accessories targeted at tablet and smart phone users, the small data wireless network providers were showing production-ready and form factor-ready units that were introduced as prototypes in 2011. The Internet of Things is being dominated by these protocols, as the typical data sent is less than a 10K stream. Target markets include medical, home automation and security, smart appliances, lighting and convenience. While there is a tight race for the protocol of choice, Zigbee appears to still have the lead over Zwave and Bluetooth based on power and autonomous connectivity.

The large data side is filled with new groups and ideas all fighting over a couple of radio bands—900MHz, 2.4GHz, 5GHz and 60GHz. The fundamental goal of these groups is to get still pictures, audio and video from point A to point B. This has turned out to be a very big technical challenge as digital still pictures moved from 160×160 pixels to the mainstream 8Mpixels and high-end 18M+ pixel images. Audio also has not stayed still. Early media players were providing 10-bit, 22KHz, 2-channel sound with high compression. Today, home theater and audiophile sound feature 24 bit, 192KHz, 8-channel (7.1 surround) sound with minimal compression at playback time.

Video data has been the biggest challenge. The new high end is UHD, also known as 4K/2K. This is a 3096×2048 pixel display, with 60Hz refresh and 24-bit color planes, or 9,130,475,520bps (about 9Gbps) for a streaming data rate. The lotto machine created organization names that are addressing these applications, including WiFI, WiDi, WiSA, DLNA, WiHDMI. WiUSB, WiGig. WiPower (Qi), iWPC, WiHD, XWHD, and the MHL/MSL. These groups have wireless extensions in progress. At this time, the interoperability and cooperation between groups appears cordial but not very productive.

Pallab Chatterjee is Coordinating Regional Editor of Chip Design. He has been and independent consultant in the EDA and Mixed Signal design space for over 20 years. Pallab holds a BSEE from UC Berkeley and an MSEE from San Jose State University.



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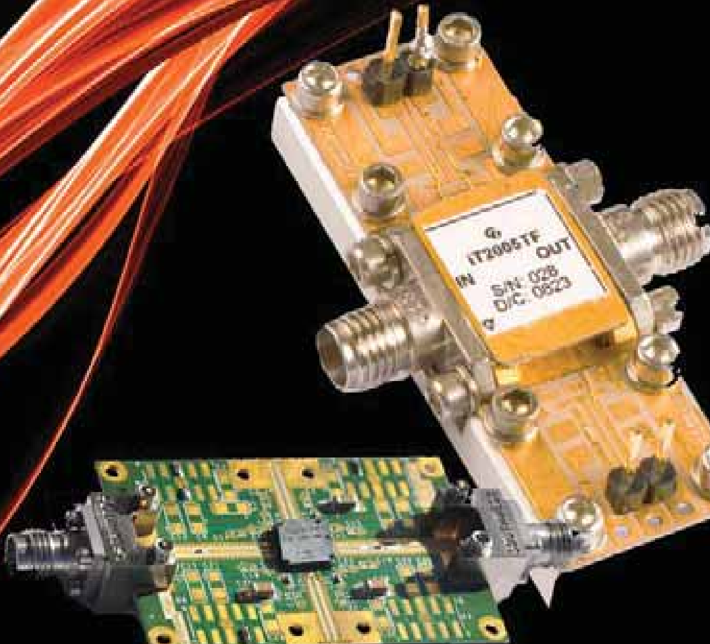

Die	Frequency (GHz)	Gain (dB) Typ.	P1dB (dBm) Typ.	Psat (dBm) Typ.	OIP3 (dBm) Typ.	Bias Current	Bias Voltage (V)	Package Style
EWH2001ZZ	DC to 20	18	27 @ 10GHz 23 @ 20GHz	28 @ 10GHz 24 @ 20GHz	35 @ 10GHz 32 @ 20GHz	290	8	Bare Die
iT2005	DC to 26.5	16	25 @ 10GHz 20 @ 26.5GHz	23.5 @ 20GHz 21 @ 26.5GHz	40 @10GHz 36 @ 20GHz	220	8	Bare Die
iT2008	DC to 26.5	10	29 @ 10 GHz 24.5 @ 26.5GHz	29.5 @ 10GHz 25 @ 26.5GHz	41 @ 10GHz 29 @ 26.5GHz	350	9	Bare Die
iT2009	2 to 26.5	20	29 @ 10 GHz 24.5 @ 26.5GHz	29.5 @ 10GHz 25 @ 26.5GHz	41 @ 10GHz 29 @ 26. 5GHz	600	9	Bare Die
iT2018	5 to 18	21	33.5 @ 10GHz 31 @ 18GHz	34.5 @ 10GHz 32 @ 18GHz	34.5 @ 10GHz 32 @ 18GHz	1100	8	Bare Die

Packaged	Frequency (GHz)	Gain (dB) Typ.	P1dB (dBm) Typ.	Psat (dBm) Typ.	Bias Current (mA)Typ.	Bias Voltage (V)	Package Style
EXH2008	DC to 26.5	9	27.5 @ 10GHz 23 @ 26.5GHz	23 @ 10GHz 23.5 @ 26.5GHz	350	8	7x7mm QFN
EXH2009	2 to 26.5	19	27.5 @ 10GHz 23 @ 26.5GHz	23 @ 10GHz 23.5 @ 26.5GHz	600	8	7x7mm QFN

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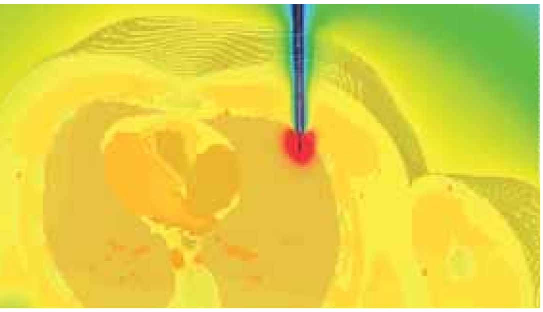

Simulation of cancer treatment by RF thermoablation