Vol. 53 • No. 7

July 2010

Microwave Journal

How Design Software Changed the World
Part II

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30 Day Delivery
On Select Models
Rapid Delivery Parts

Frequency Range (GHz)	Model Number	Insertion Loss (dB, Max.)	Isolation (dB, Min.)	VSWR (Max.)	Rise/Fall Time (ns, Typ.)	On/Off Time (ns, Typ.)	On/Off Time (ns, Max.)	DC Power Positive/Negative (mA, Max.)
SPST								
0.2 – 2	SW1-002020RN1NF	1.7	70	1.6:1	10/10	20	35	35/70
2 – 8	SW1-020080RN1NF	2	80	1.7:1	10/10	20	35	35/70
4 – 12	SW1-040120RN1NF	2.2	80	1.7:1	10/10	20	35	35/70
2 – 18	SW1-020180RN1NF	3	80	2:1	10/10	20	35	35/70
1 – 18	SW1-010180RN1NF	3	70	2:1	10/10	20	35	35/70
SP2T								
0.2 – 2	SW2-002020RN1NF	1.5	70	1.6:1	10/10	20	35	60/60
2 – 8	SW2-020080RN1NF	1.8	80	1.7:1	10/10	20	35	60/60
4 – 12	SW2-040120RN1NF	2.2	80	1.7:1	10/10	20	35	60/60
2 – 18	SW2-020180RN1NF	2.8	80	2:1	10/10	20	35	60/60
1 – 18	SW2-010180RN1NF	3	70	2:1	10/10	20	35	60/60
SP3T								
0.2 – 2	SW3-002020RN1NF	1.6	70	1.6:1	20/20	150	180	85/85
2 – 8	SW3-020080RN1NF	1.9	80	1.7:1	20/20	150	180	85/85
4 – 12	SW3-040120RN1NF	2.4	90	1.7:1	20/20	150	180	85/85
2 – 18	SW3-020180RN1NF	3	80	2:1	20/20	150	180	85/85
1 – 18	SW3-010180RN1NF	3.1	70	2:1	20/20	150	180	85/85

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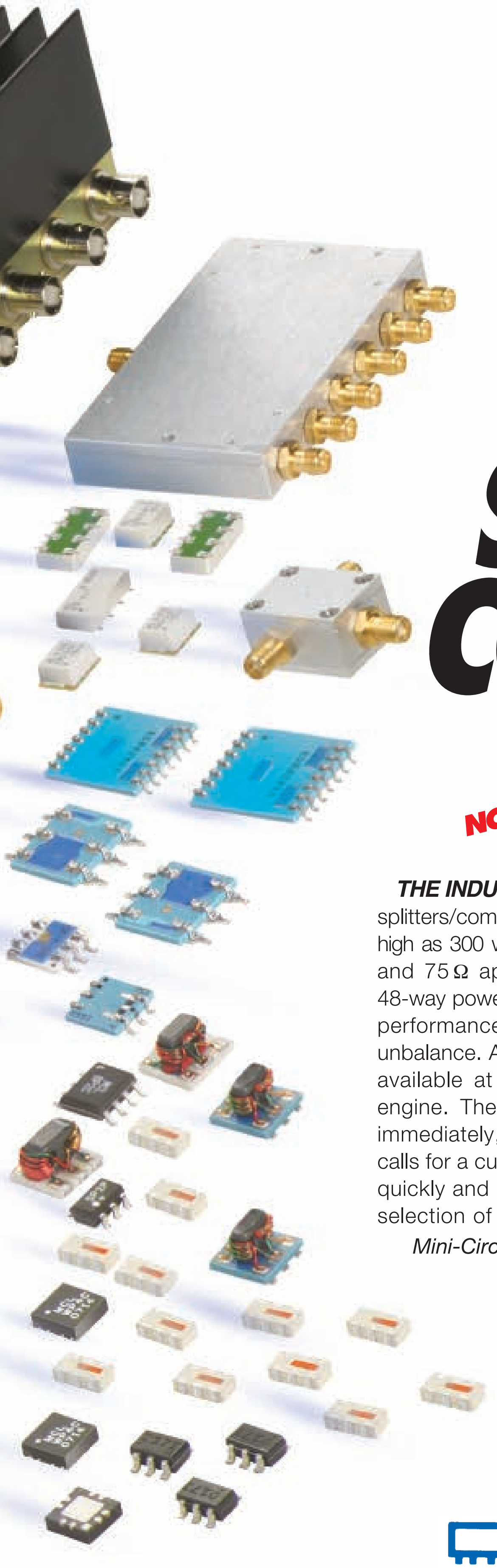
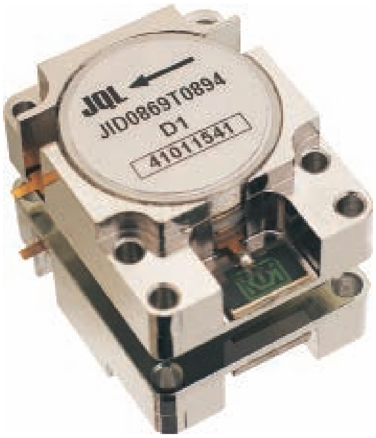


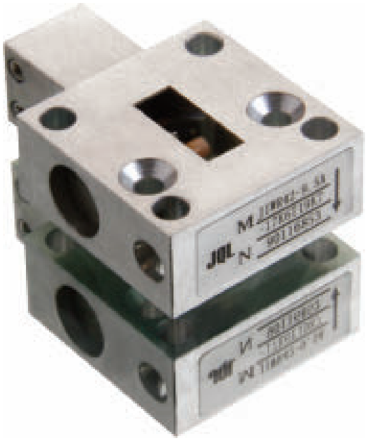
Technology On the Move ™



Drop-in Isolators

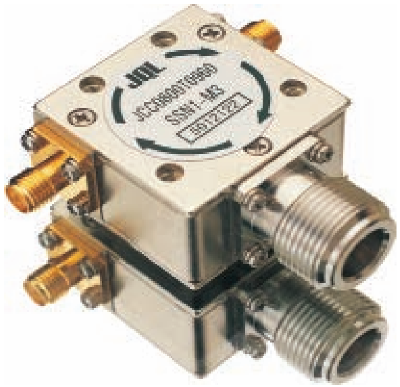
Cavity Filters

Surface Mount Circulators



Waveguide Isolators

Power Combiners



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FEATURES

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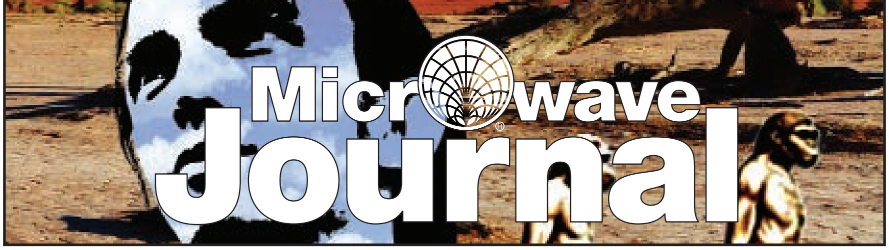

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CEO: William M. Bazzy
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Executive Editorial Office:
685 Canton Street, Norwood, MA 02062
Tel: (781) 769-9750
FAX: (781) 769-5037
e-mail: mwj@mwjournal.com

European Editorial Office:
16 Sussex Street, London SW1V 4RW, England
Tel: Editorial: +44 207 596 8730 Sales: +44 207 596 8740
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Free Webinars

MWJ/Besser Associates Webinar Series: Electrically Small Antennas

This month's webinar presents basic antenna property definitions such as impedance, bandwidth and quality factor for general wireless, cellular and RF/microwave systems. Design considerations and simulation are also discussed.

Sponsored by **CST**

Live webcast: 7/20/2010, 11:00 am (ET)

Online Technical Papers

Wireless Backhaul for Microcellular WiMAX and LTE Networks
Erik Boch, Dragonwave Inc.

The Emergence of Compact Base Stations in the New RAN Architecture Paradigm
White Paper, ABI Research

What is Packet Microwave?
Stuart Little, Aviat Networks

Automatic Test Procedure for RF Characterization of a C-band Rotary Field Phase Shifter
K.K. Jain, Kirti Bansal, Meenakshi Aggarwal, B.S. Matheru and U.C. Ray, Solid State Physics Laboratory, India

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Executive Interview

Ulrich Jakobus, Director of **EM Software & Systems** and **FEKO** Product Manager, outlines how his involvement with the company has taken him from Germany to South Africa, his approach to software development and strategies for achieving global expansion.

Expert Advice

Paul Colestock, RFIC Product Manager, **Agilent EEsof EDA**, writes about solving the RFIC Design for Yield and Verification Dilemma with GoldenGate, Agilent EEsof's integrated RF circuit design within the Cadence Virtuoso design flow.

MarketWatch

In this month's MarketWatch, **Erik Boch**, CTO & VP of Engineering from **Dragonwave Inc.**, looks at the changing hardware requirements for high capacity wireless backhaul especially among microcellular deployments for 4G. Visit www.mwjournal.com/marketwatch_july2010 for more information.

IMS 2010 Videos

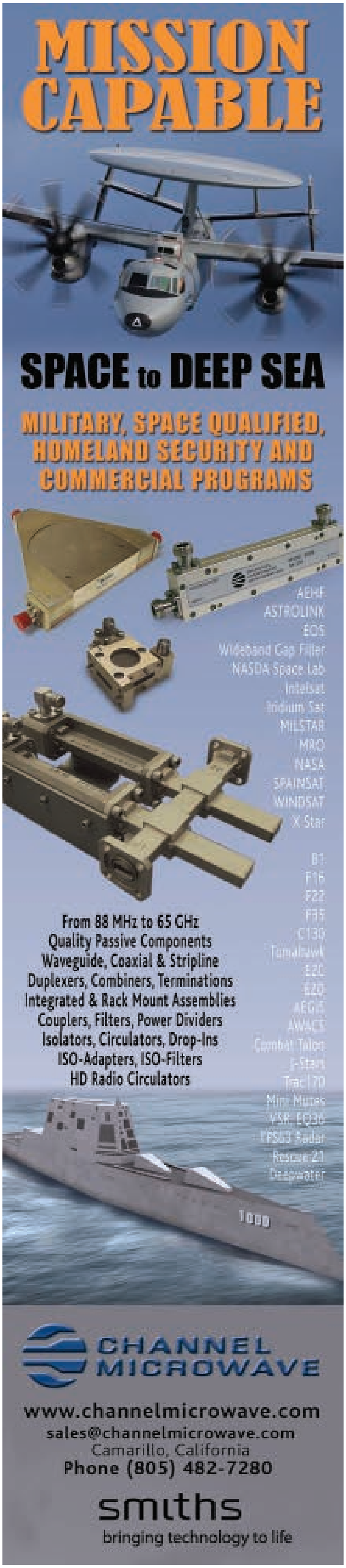
Enjoy video coverage of IMS 2010, including an interview with Chairman J.K. McKinney and the CEOs of both M/A-COM and Mimix in addition to product demos from many leading companies who exhibited at the show. Visit www.mwjournal.com/IMS2010videos.

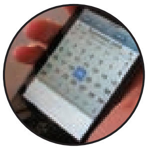
Mark Your Calendar

AUGUST 2010

SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
1	2	3 (Aug 3–4) **ASQED 2010 Asia Symposium on Quality Electronic Design** Penang, Malaysia (Aug 3–5) **NI Week 2010** Austin, TX	4	5 (Aug 5–6) ANSOFT **HFSS for Antenna** Boston, MA	6	7
8	9	10 (Aug 10–11) CST **MICROWAVE STUDIO® Training for EMC/ Signal Integrity** Darmstadt, Germany	11	12	13 **Call for Papers** MILCOM Deadline: **August 13, 2010**	14
15	16	17 **MWJ/Besser Webinar: MMIC Design** Sponsored by AWR® Anritsu	18	19	20	21 (Aug 21–22) **Sonnet Software Presentation "Examples of Microwave Filter Optimization Using Perfectly Calibrated Ports"** Reykjavik, Iceland
22	23	24	25 (Aug 25–27) **MMS 2010 10th Mediterranean Microwave Symposium** Guzelyurt, Turkey	26	27	28
29	30	31 **Call for Papers Microwave Update** Deadline: **August 31, 2010**	1	2	3	4

Go to: www.mwjournal.com/events





Coming Events

CALL FOR PAPERS

Radio Wireless Week 2011
Deadline: July 30, 2010

Mobile World Congress
Deadline: July 30, 2010

MILCOM 2010
Deadline: August 13, 2010

Microwave Update (MUD)
Deadline: September 1, 2010

ISSCC 2011
Deadline: September 13, 2010

MEMS 2011
Deadline: September 14, 2010

www.mwjournal.com/events

JULY

EMC 2010
IEEE International Symposium on Electromagnetic Compatibility
July 25–30, 2010 • Fort Lauderdale, FL
www.emc2010.org

AUGUST

ASQED 2010
Asia Symposium Quality Electronic Design
August 3–4, 2010 • Penang, Malaysia
www.asqed.com

NIWeek 2010
August 3–5, 2010 • Austin, TX
www.ni.com

10th Mediterranean Microwave Symposium (MMS)
August 25–27, 2010 • Guzelyurt, Turkey
www.mms.ncc.metu.edu.tr

SEPTEMBER

IEEE Great Lakes Technology Symposium
September 16–17, 2010 • Ann Arbor, MI
www.ieeegreatlakes.org

EuMW 2010
European Microwave Week
September 26–October 1, 2010 • Paris, France
www.eumweek.com

OCTOBER

AOC 2010
47th Annual AOC International Symposium and Convention
October 3–6, 2010 • Atlanta, GA
www.crows.org

Bipolar/BiCMOS Circuits and Technology Meeting
October 4–7, 2010 • Austin, TX
www.ieee-bctm.org

MWP 2010
International Topical Conference on Microwave Photonics
October 5–9, 2010 • Montreal, Canada
www.mwp2010.org

AMTA 2010
Antenna Measurement Techniques Association
October 10–15, 2010 • Atlanta, GA
www.amta2010.com

IEEE International Symposium on Phased Array Systems & Technology
October 12–15, 2010 • Waltham, MA
www.array2010.org

4G World
October 18–21, 2010 • Chicago, IL
http://4gworld.com

Microwave Update (MUD)
October 21–24, 2010 • Cerritos, CA
www.microwaveupdate.org

MILCOM 2010
October 31–November 3, 2010 • San Jose, CA
www.milcom.org

DECEMBER

APMC 2010
Asia Pacific Microwave Conference
December 7–10, 2010 • Yokohama, Japan
www.apmc2010.org

JANUARY

Radio Wireless Week 2011
January 16–20, 2011 • Phoenix, AZ
http://rawcon.org

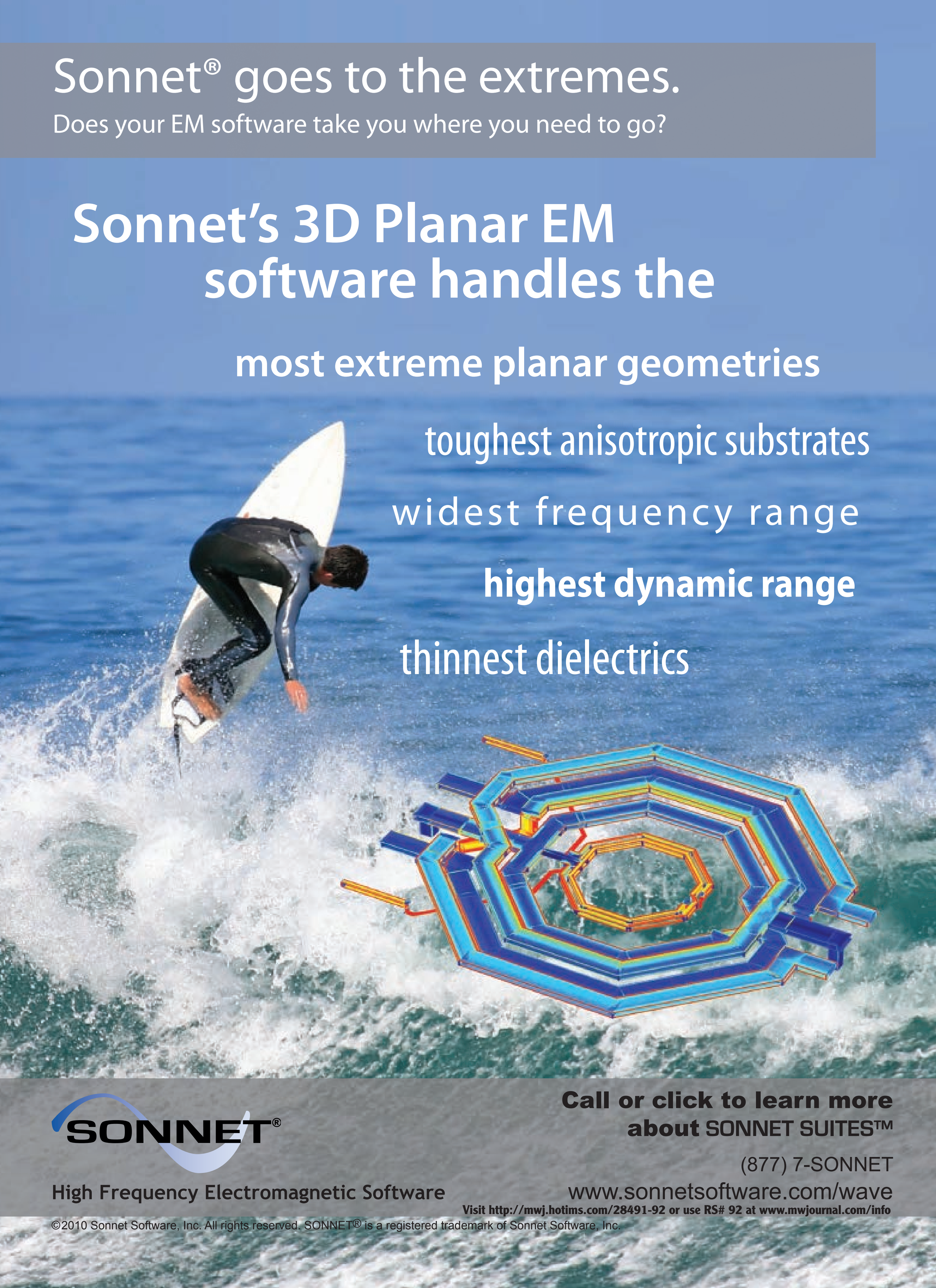
MEMS 2011
IEEE International Conference on Micro Electromechanical Systems
January 23–27, 2011 • Cancun, Mexico
www.ieee-mems2011.org

FEBRUARY

MWC 2011
Mobile World Congress
February 14–17, 2011 • Barcelona, Spain
www.mobileworldcongress.com

ISSCC 2011
IEEE International Solid-State Circuits Conference
February 20–24, 2011 • San Francisco, CA
http://isscc.org

NATE 2011
National Association of Tower Erectors
February 21–24, 2011 • Oklahoma City, OK
www.natehome.com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Cover Feature

How Design Software Changed the World, Part II

Before design software, microwave engineers spent their days with copper tape and soldering iron applying cut and try methods. Without software, the MMIC, the RFIC, the LTCC, the SoP and SiP would almost certainly not exist and we would not have today's smart phones or smart weapons.

"How Design Software Changed the World, Part I" (*Microwave Journal*, July 2009) looked at design software and microwave hardware from the early 1960s up through 1987. During this period, the US defense department needed to develop smarter systems to counter balance the superior size of the soviet military in Eastern Europe. The weapon systems envisioned required reliable, high performance RF/microwave electronics. This is when MIC and MMIC technologies came into favor and design began to rely on "home-grown" software programs.

The Department of Defense (DoD) helped fund software development that affected MMIC implementation, namely simulation, layout and work flows. The microwave and mm-wave monolithic integrated circuits (MIMIC) program promoted collaboration between defense contractors, software providers and branches of the armed services to further the adoption of software tools among engineers.

By 1988, the Reagan administration, which was responsible for the military build-up of the 1980s, was in its final year. Military spending, which peaked at 6.2 percent of GDP in 1986, was trimmed down to 5.8 percent and would continue to decline to the present day (roughly 3.0 percent). However, the MIMIC program was well-funded and entering its second year. Among the major commercial RF/microwave software vendors vying for contract money were EEsof, Compact and Hewlett Packard. Over the next decade, software would be influenced by the downsizing of defense spending, the emergence of the commercial mobile communications market, new technologies, start-ups, mergers, acquisitions and fierce competition among vendors.

System Simulation

Heading into the 1988 IEEE MTT-S Symposium in New York, EEsof unveiled a new system level simulator in the May issue of *Microwave Journal*. The product—OmniSys—allowed microwave system designers to predict the overall system performance (gain, noise, dynamic range, nonlinearities, spurious signals, distortion and more) from the performance data of the constituent components. The frequency-domain component data (scalar, S-parameter or pole-zero) could

David Vye
Editor, Microwave Journal

be synthesized from circuit simulations or test measurements. The initial release contained 50 internal component models and signal generators and was capable of simulating systems with up to 350 components, targeting radios, radars, EW systems, receivers/transmitters and feedback control loops.

The introduction was well-timed as many MMIC and MIC devices were becoming available for system integration. In the same May issue, an article by Bob Bierig of Raytheon and David McQuiddy of Texas Instruments entitled "Broadband MMICs for System Applications" described a series of MMIC-based building blocks for microwave systems targeting military applications. The authors' respective companies were partners in the MIMIC program. Noting that "one of the more notable features of MMIC technology is the relative ease with which components with broad operational bandwidths can be demonstrated," the article heralded a variety of successful MMIC designs including driver and power amps, mixers, phase shifters and switches; all front-end components for the defense department's next generation of military systems and undoubtedly made possible through simulation.

EARLY DESIGN ENVIRONMENTS

System simulation added to the number of discrete, dedicated software tools available, which now included linear and nonlinear simulators, measurement data acquisition, yield analysis, schematic capture and physical design layout. Around this time, software vendors began to market bundled solutions, followed shortly by the introduction of new design environments, which unified the user interface and integrated functionality. Pressure to develop powerful user interfaces was driven by the growing complexity of MMIC design, the introduction of schematic capture (over text-based netlist entry) by HP MDS and the need to support a variety of platforms from the IBM compatible PC to Sun, Apollo, HP and Digital Equipment Corp. UNIX workstations.

By early 1988, EEsof promoted the interoperability of its products: Libra, Touchstone, mw SPICE, MiCAD, ANACAT, E-Syn and Libraries across multiple computer platforms. While the company had initially gained market share through the PC, they now shifted focus to the same platforms as other CAD tools such as Mentor Graphics and Cadence, namely 32-bit workstations and mainframes. By April, EEsof introduced the MMIC Design Workstation and the EEsof Microwave/RF Design Workstation for board designs. These short-lived products were a stop-gap measure to counter the market gains made by the Design Capture System of HP's MDS and Compact's strong position among workstation users.

In November, six months after introducing the MMIC Design Workstation, EEsof introduced its new Microwave Design Environment – Academy, a front-end schematic and layout capture user interface for both Touchstone and Libra. Academy emphasized an integrated workflow, allowing engineers to create designs from either schematic or layout, moving seamlessly between editors.

Compact Software was also busy building up its product portfolio and bundling tools into solutions for MIC and MMIC design. Under Ulrich Rohde's leadership, Compact focused its attention on improving the capabilities (speed, accuracy and robustness) of its harmonic balance engine, Microwave Harmonica, as well towards the company's noise analysis and model accuracy.

Along with its analysis tools—Super Compact (linear), Microwave Harmonica (nonlinear), Microwave SPICE and LINMIC (EM)—the company expanded its offering of synthesis tools that included Filter, PLL, and RF & Communications Design Kits along with the new Complex Match II, a unique impedance matching tool for designing feedback amplifiers, matching antenna impedances, transforming lumped designs into distributed ones and synthesizing commensurate distributed matching networks.

For design entry and layout, Compact partnered with third parties, releasing the clumsily named "Gas Station" (along with AutoArt) in March of 1988. This "mouse-driven, menu-oriented graphics system" generated layouts and geometrically related schematic displays from "hierarchically flat" Super Compact files. Unfortunately, this cobbled together user interface and layout tool was a lackluster competitor to the front-ends offered by HP and EEsof, and was a poor show of the solid engineering going into Compact's analysis capabilities. By December, Compact stopped actively promoting Gas Station and released the Microwave Design Workstation (MDW).

As described in a July 1989 MWJ product feature called "New Design Workstation Simplifies the Design Process," MDW combined Compact's nonlinear simulator, Microwave Harmonica with Design Framework—a schematic and layout tool from Cadence Design Systems—into a single CAD workstation. The combination of Compact's analysis and modeling capabilities with Cadence's powerful design automation made a formidable challenge to HP and EEsof's products.

The Compact/Cadence collaboration provided users with a number of powerful design features including forward and back annotation, open architecture (ability to create custom pull-down menus, define macros, etc.), design rule checking, hierarchical schematic, GDS II output for mask generation and a "zoom" feature. Compact focused on the analysis capabilities of Microwave Harmonica with new temperature-dependent models, improved noise performance predictions of active devices (MWJ cover story, December 1988) and a new harmonic balance algorithm resulting in a 300 time speed up in convergence.

In case any engineers were drawn into believing that these advances in simulation and design automation were going to free them from actual design work, future MWJ editor, Harlan Howe, brought optimization-happy designers back down to earth with his November 1988 special report, "Computers Don't Innovate… People Innovate!" Howe reminded readers that the human element was still very much needed in microwave circuit design and that "a Calma tape full of cell designs is basically no more than the rack of plastic drawers with resistors, capacitors and inductors sitting against the back wall in every laboratory." Howe warned that ignoring MMIC process variations or the impact of temperature variations was a guaranteed recipe for failure.

By July of 1990, Compact was introducing its own system analysis tool, Microwave Success, supporting top-level block design capabilities, budget


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• Vibration
• Coupled EM-Mechanical analysis

calculations, an unlimited number of cascade-able n-ports and unlimited number of sources including multiple carriers and modulations. A MWJ special report, also in the July issue, discussed the features of CAD/CAE tools on display at that year's IMS in Dallas, TX, noting that as Compact was introducing enhancements to new and upgraded elements, file syntax, time-domain steady-state analysis and graphics, EEsof was releasing Academy version 3.0 with a number of user interface and analysis enhancements.

While the development of an integrated design environment with schematic capture and layout took several twists and turns (MDW, Gas Station, EASI) from 1987 to 1990, Compact introduced a new design workstation called Serenade in August. Based on X-Windows, Motif and GKS, the product supported the use of remote terminals with networking capabilities that allowed the simulator engine, graphics and user-interface to run on different computers. The new "look and feel" of the user interface to Super Compact, Microwave Harmonica and the new Microwave Success was a big improvement to Compact Software's user interface. Though Compact now offered a more competitive PC-based CAD product, the complexity of MMIC design had shifted much of the engineering work back toward workstations.

EM SIMULATION

In his March 1989 MWJ article, Carl Denig of M/A-COM presented a technique for designing microstrip interdigital filters, "applying an approximate method for modeling these structures in CAD programs such as Super Compact and Touchstone." Earlier approaches to modeling multiple-coupled sections using parallel sections of singly coupled lines ignored coupling between nonadjacent lines and resulted in errors that became more pronounced at lower substrate dielectric constants.

Denig provided an eight-step procedure to analyzing a multiple-coupled line filter that included determining an equation relating even- and odd-mode impedances using linear regression, calculating even- and odd-mode phase velocities and estimating parasitics to include in the CAD netlist. While the author achieved reasonable results, the approach was not for the weak of heart and clearly illustrated the need for a more accessible and generalized solution.

Ray Pengally (formerly with Compact Software) further represented this need in his 1990 MWJ article "CAD for MMIC Implementation." describing how GaAs foundries would fabricate and characterize (from measurement) a large array of passive structures such as a multi-turn spiral inductor, each with different physical dimensions. Working with CAD vendors, equivalent circuit models were fitted to measured S-parameters over a specified frequency range. It was often possible to fit simple polynomial expressions as a function of geometry to these equivalent circuits, relying on less-than-reliable interpolation for unmeasured components.

A more rigorous solution using electromagnetic simulation for passive structure characterization was of great interest to engineers and university researchers alike. Pengally described several programs including Linmic+, EMSym, Sonnet Software and Stingray (a quasi-static analysis based on finite element for calculating local capacitance matrices for multi-coupled lines, Apogee Software, Oakland, NJ), which could simulate structures in two dimensions "since considerable reductions in computing time can be achieved if planar metalized patterns are assumed where two-dimensional current distributions exist."

The evolution of EM simulation technology occurred over multiple decades, producing a variety of techniques. The basic FDTD space grid and time-stepping algorithm can be traced back to a seminal 1966 paper by Kane Yee in *IEEE Transactions on Antennas and Propagation*, while the "Finite-difference time-domain" (FDTD) descriptor supposedly originated with Allen Taflove in a 1980 paper in *IEEE Transactions on Electromagnetic Compatibility*. Today, approximately 30 commercial and university-developed FDTD software suites are available. Word of early commercial offerings began appearing more regularly in publications during the late 80s and early 90s.

In 1977, Weiland introduced Finite Integration Theory (FIT), also known

as FI. In this technique, the integral form of Maxwell's equations is approximated by summations around small loops. This technique is different than FDTD in which the differential form of Maxwell's equations is represented as finite difference approximations. In 1983, at the Deutsches Elektronen Synchrotron (DESY) in Hamburg, Weiland set up an international collaboration in order to develop the software package MAFIA (Maxwell's equations Finite Integration Algorithm) for 3D EM and charged particle simulation. By 1992, Weiland founded Computer Simulation Technology (CST) to commercialize MAFIA and focus on the telecoms industry along with three managing directors: Dipl.-Ing. Michael Bartsch, Dr. Peter Thoma and Dr. Bernhard Wagner.

In 1996, CST decided to implement the perfect boundary approximation (PBA) into its simulation software. Unfortunately, MAFIA could not be easily adapted into a conformal code so Weiland reformulated FIT in terms of global quantities assigned to space objects, allowing matrix formulations that were valid for irregular and non-orthogonal grid systems. In addition, CST decided to build a new environment from scratch, taking advantage of the improved usability offered by Microsoft's new Windows OS. The result was CST's current flagship product CST MICROWAVE STUDIO (CST MWS), which was first released in 1998. By that time telecoms were dominating CST's business and CST MWS was aimed squarely at people designing antennas and connectors for mobile phones and base stations.

In 1988, Sullivan, et al. published the first 3-D FDTD model of sinusoidal steady-state electromagnetic wave absorption by a complete human body, while Zhang, et al.—the founder of Zeland Software (and IE3D)—introduced FDTD modeling of microstrips. In February of 1990, *Microwave Journal* featured HP's high frequency structure simulator (HFSS) on its cover, "Software Computes Maxwell's Equations." Promising to replace empirical design procedures, the software, which was jointly developed by Ansoft Corp., was able to accurately simulate the RF performance of a coaxial-to-waveguide adaptor on an HP 9000 model 835 workstation, taking less than one hour for a single frequency point.

Using a mathematical technique known as finite elements, the simulator provided key information, including multi-port S-parameters and color displays of electromagnetic field plots. Based largely on the work of Ansoft founder Zoltan Cendes and some of his graduate students from Carnegie Mellon University, the technique had been used in civil and mechanical engineering before Cendes and his team figured out a way to address the spurious signal modes that were problematic at high frequencies.

Ansoft also developed an adaptive mesh refinement algorithm, capable of generating and refining the mesh automatically. With adaptive meshing, engineers just had to accurately define the structure, its materials, boundary conditions and port excitations in order to obtain correct results, at least in theory. HP contributed by defining the scope of functionality, managing the product de-


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velopment, QA, testing and marketing.

While HFSS allowed microwave engineers to address 3D problems such as waveguide filters and antennas, planar geometries could be solved more rapidly with a 2D or 2.5D approach. The July 1990 MWJ report on CAD/CAE at IMS reported on planar EM technology from Sonnet software as did a May 1991 product feature, "EMSim 3.0" by EEsof. The Sonnet product "em" operated on a UNIX platform with a mouse-driven user interface. The designer provided the multi-point polygons of the layout; input the dielectric constants, port definitions, simulation frequencies and the grid size.

EEsof's EMSim applied a similar method-of-moments technique using a closed-form solution to Green's function to characterize planar microwave passive circuits. In the article, EM simulation of an edge-coupled filter was compared to results based on a Touchstone microstrip model and measurements of the fabricated filter. The agreement between the EM results and the measured filter were significantly better than the Touchstone response, which neglected inter-element coupling.

Within the year, Compact began offering its planar EM solution, Explorer v1.0. In 1992, HP introduced Momentum, originally developed by Belgian company, Alphabit, a spinoff from IMEC, Europe's largest independent research center in nano-electronics and nano-technology. Today, planar and 3D EM simulation provides such an improvement to circuit simulation accuracy that all major RF/microwave circuit simulation environments have some form of integrated EM technology.

ACTIVE DEVICE MODELING

Active device modeling plays a critical role in accurate RF circuit simulation and thus HP introduced a new approach to transistor modeling based on its expertise in test and measurement. In September 1991, David Root of HP wrote the MWJ cover feature, "A Measurement-based FET Model Improves CAE Accuracy," describing a technique for improving large-signal simulations by explicitly constructing device nonlinearities from measured data. An automated procedure of collecting DC and S-parameter data was proposed as a replacement for conventional parameter extraction and physical or empirical model generation.

Nonlinear model functions were stored in tabular form as functions of two independent controlling terminal voltages. The lookup-table model "avoided the ad hoc procedure of optimizing equation coefficients of process specific models to fit measured data." They were also process technology independent, meant to alleviate the need for specialized active device modeling personnel. The HP IC-CAP model extraction software program provided the graphical interface and instrument drivers to generate the compiled table-based "Root" model for use with HP MDS. Root continued working with HP (and later Agilent) researchers on measurement-based models and nonlinear vector network analyzer measurements, resulting in today's X-parameters and NVNA technology. For more details, see the MWJ March 2010

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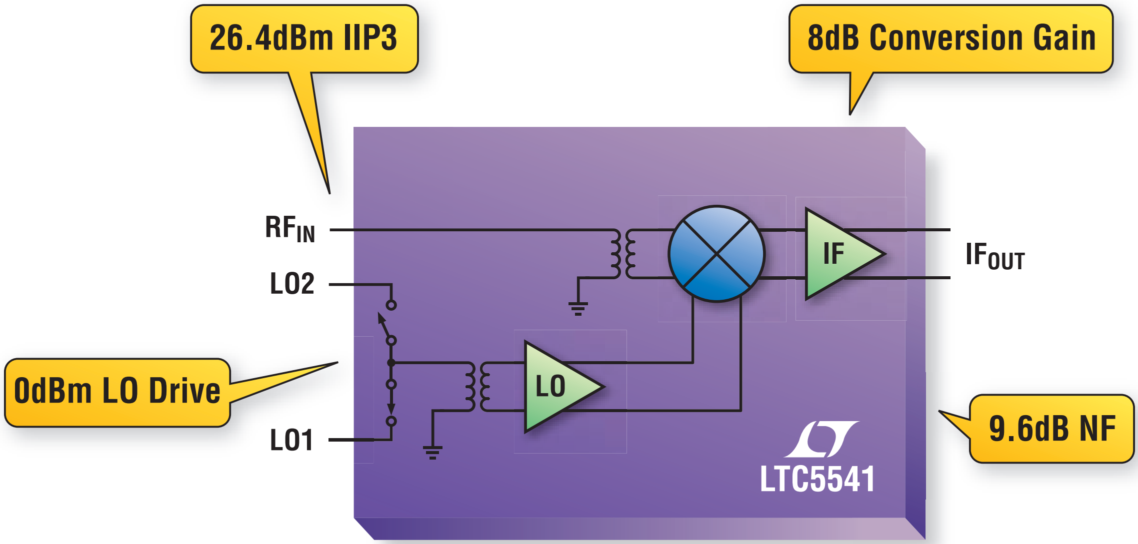

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Input IP3	26dBm	26.4dBm	26.4dBm	24.5dBm
Conversion Gain	8dB	8dB	8dB	8dB
Noise Figure (NF)	9.9dB	9.6dB	9.9dB	10.2dB
NF @ 5dBm Blocking	16.2dB	16.0dB	17.3dB	17.5dB
Power Consumption	0.66W	0.63W	0.65W	0.66W

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Compact Software's Scout™ was a PC and workstation-based active device extraction and large-signal modeling program with interactive modeling features. Users could modify parameter values and observe the effects on both DC and S-parameters. MMIC-focused modeling software from other companies included Optotek's Small and Large Signal Analysis (SALSA™), dedicated to MESFET and HEMT modeling, compatible with the company's simulation software MMICAD™. Optimization Systems Associates' (OSA) offered a nonlinear device-modeling program called HarPE™, which included popular FET models, a Gummel-Poon model for BJTs and HBTs, models for HEMTs, as well as user-defined models. In 1997, OSA was acquired by HP for its EM optimization technology to complement its Momentum and HFSS products.

INDUSTRY CONSOLIDATION

Mergers and acquisitions are common in the software world where markets can only support one or two major vendors and smaller companies are eagerly acquired for their game-changing innovations. In 1992, the RF EDA market was fiercely competitive with three major players. That fall, EEsof launched a stealth marketing campaign for a new high-frequency analog design suite that the company claimed would "redefine the industry standard." Two months later, the company revealed EEsof Series IV, a new design environment that offered unprecedented ease-of-use, eight simulation engines, time, frequency electromagnetic simulation, statistical design, yield optimization, models, libraries and synthesis tools. Series IV was well-received by engineers and went on to have great success in the market despite a short-lived ad campaign that ended in December, when the independently-owned EEsof disappeared from the pages of *Microwave Journal* forever.

Something momentous was about to occur.

By 1993, EEsof CEO Chuck Abronson had been contemplating a bold strategic move. HP and EEsof were wrestling for the top position in the RF software market, each company realizing approximately $20 M in annual revenue. The new Series IV design environment took three years to develop and was designed to go up against Cadence, Mentor Graphics and Avanti in the emerging wireless chip set market. To compete, EEsof needed to dominate its current market so that its resources could re-focus on design tools for the RFICs being built for the next generation of handsets.

While the EEsof sales force was bullish on competing against HP, Bill Childs, EEsof's head of development, was less optimistic about the company's prospects of forcing HP out of the RF software business. Abronson had two options. He first contacted HP's executive leadership to gage its desire to sell the EDA group to EEsof. As a strategic part of its design through test solution, HP was not interested in leaving the software business. Therefore, Abronson proposed that HP acquire EEsof, a transaction that was publicly announced the following September. HP GM Jake Egbert led

the new HP EEsof from 1993 until 1999; Bill Childs stayed another year through the transition while Chuck Abronson retired from EDA to focus on the California real-estate market.

In the 1990s, the 'second generation' (2G) of mobile phone systems emerged, primarily using the GSM standard. These 2G phone systems differed from the previous generation in their use of digital transmission instead of analog and also by the introduction of advanced and fast phone-to-network signaling. The rise in mobile phone usage as a result of 2G was explosive and would greatly impact the opportunities for design software as well as the required functionality.

In 1993, as HP-EEsof shifted its focus toward this new market, the new organization found itself serving roughly 80 percent of the traditional RF market with two similar products. Setting a course for new product development, HP executives identified two requirements they considered essential to making the next leap forward in simulation software. The first was the advancement of system simulation and support for the digital modulation that was driving future mobile phone technology. HP initially intended to address this first requirement with its acquisition of EEsof's Omnisys.

Coinciding with the introduction of 2G systems was the trend away from the larger "brick" phones toward tiny 100 to 200g hand-held devices. This drove the other requirement for RF circuit simulation, namely enhancing EM simulation to address the component miniaturization for smaller handheld devices. For this second requirement, HP had its planar EM tool, Momentum and an exclusive marketing agreement to sell HFSS under the HP name. Any new design environment would look to further integrate these simulators into the engineering workflow.

As HP was developing its new platform, the relationship with Ansoft was beginning to strain. In 1992, Ansoft introduced a new software product, Maxwell Spicelink, which targeted signal integrity applications. Spicelink essentially combined Ansoft's EM technology with SPICE for high-speed electronic circuit design. While HP had the exclusive rights to sell HFSS, a technical clause in the contract allowed Ansoft to sell Maxwell Spicelink and HFSS in a bundled a package called Eminence, which essentially allowed Ansoft to compete in the RF/microwave market as well. Meanwhile, HP was developing its own version of HFSS.

During the early 1990s, Ansoft grew steadily, as management prepared to take the company public. Revenues grew from $3.47 M in 1993 to $6.15 M in 1995. In 1996 Ansoft made an initial offering of stock to the public, netting some $12 M and allowing the company to acquire technologies that would further expand its product portfolio and market reach. It was also during this period that Ansoft and HP became competitors, as both companies vied for supremacy in the 3D electromagnetic modeling market.

Revenue from the HP agreement accounted for 12 and 13 percent of Ansoft revenue in fiscal 1997 and 1996, respectively. When the HP agreement expired in January 1997, it was not renewed, although HP


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maintained the non-exclusive rights to sell HFSS through January 1998. While Ansoft was directly marketing and selling HFSS version 5, HP introduced the HFSS product it had been developing internally, resulting in two products of the same name and plenty of confusion among engineers.

THE NEW KIDS ON THE BLOCK

HP's acquisition of EEsof resulted in considerable overlap in simulation technologies and model sets. Rather than support two similar products or select one environment over the other, the HP management team directed the joint group of developers to start work on a totally new platform. The plan for this multi-year project was to combine the best technologies from both products while adding the new functions required for the emerging wireless technology. The product known internally as DE 1.0 (Design Environment 1.0) was re-named to Advanced Design System (ADS) prior to its introduction in June 1997.

ADS was promoted as the industry's first integrated, end-to-end signal path design solution for communications products, providing design technologies—from circuit and electromagnetic simulation to digital signal processing (DSP) synthesis and physical design—all in a single environment.

> *"The HP system provides new DSP design and synthesis software in addition to significant new design capabilities for microwave and radio-frequency integrated circuit (RFIC) design. The integration and co-simulation of RF and DSP analysis is unique in the EDA industry, as is the software's availability on both UNIX and PC platforms."*
> initial press release, June 2, 1997

ADS included two new DSP tools—DSP Designer and DSP Synthesis. The DSP Synthesis software targeted communications products with features for optimizing and implementing high-level DSP designs into application-specific integrated circuits (ASIC) and field programmable gate arrays (FPGA), including both behavioral and register transfer level (RTL) VHDL/verilog code generation, simulation and synthesis capability, outputting the hardware description language (HDL) in industry-standard formats for logic-synthesis tools.

DSP Designer merged software from HP research and technology from the University of California at Berkeley Ptolemy project. This simulation engine facilitated co-simulation of time, frequency and data flow technologies for mixed RF/analog/DSP communications projects. The system simulation had also been enhanced with harmonic balance co-simulation to allow full-budget simulations on any RF topology using patented new technologies, which included new high-frequency SPICE, harmonic balance (speed enhancements up to 100 times faster than comparable solutions with a reduction in memory usage by up to 15 times) and new Circuit Envelope simulation technologies.

HP was ambitious in both the scope and schedule set for ADS. According to Larry Lerner, Agilent EEsof R&D Manager, "The decision to build ADS

was a risky one. It was by far the most complex and most expensive project ever attempted by the HP Test & Measurement Group. It was also a heavily constrained project with many must-have requirements." Many engineers expected the new product to provide the same functionality and feature sets found in both Series IV and MDS. Designers accustomed to a particular user-interface found the new environment non-intuitive and complex, especially with the new system, circuit and physical design capabilities rolled into one. In addition, migrating legacy designs into the new environment was problematic. Needless to say, ADS got off to a rocky start, with many customers delaying their upgrade from MDS or Series IV. Ultimately, the functionality goals initially set for ADS would prove to be well-aligned with the needs of RF/mixed-signal IC and multi-chip module design. ADS (as well as Ansoft, CST and AWR products) would also find a customer base among the emerging high-speed (giga-bit) design market.

While the ADS product was stabilizing and designers became familiar with its operation, HP competitors sensed a market opportunity and pounced. Since the introduction of SpiceLink, Ansoft viewed EM-simulation as a critical component to high speed/frequency circuit design. In April 1997, the company made its move to complement HFSS with a dedicated RF/microwave circuit-design tool, acquiring HP EEsof's largest competitor in the RF space—Compact Software. In August, the company also acquired its own planar EM solution with the purchase of Boulder Microwave Technologies Inc. for $1.5 M.

After competing for several years, HP EEsof left the 3D EM market with the sale of its HFSS product to Ansoft in 2001 (Agilent returned in 2008 with EMPro), allowing Ansoft to focus on its next generation architecture/environment while continuing to develop the Serenade product suite—Serenade (circuit), Symphony (system) and Ensemble (planar EM). The dual development efforts were a strain on Ansoft's limited resources and delayed the product release until 2003. The resulting platform, Ansoft Designer, raised the bar on EM/circuit integration, yet the window of opportunity for replacing ADS had passed.

By 2003, HP was no longer an Ansoft competitor. In November 1999, the T&M division—including the EDA group—had been spun off into an entirely new corporation called Agilent Technologies, executing the largest IPO in Silicon Valley history. In addition to Agilent, Ansoft also faced new competitors utilizing Microsoft's core set of application programming interfaces (API) and Windows operating system. With advances in programming, software companies were able to create RF design tools with the feel of standard Microsoft Office programs.

Joe Pekarek joined Hughes Aircraft in 1988 as an engineer. By the early 1990s, he was leading the development of a low-cost radar receiver chipset in Hughes's solid-state microwave division. As a hardware designer, he was an experienced software user, yet he was dissatisfied with the functionality from a user's perspective. In particular, he wanted tools

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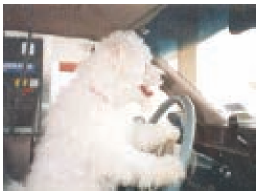

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that would help him to design high-frequency electronics at the system and circuit levels while laying out the physical components in order to reduce errors.

While at Hughes, Pekarek entered the doctoral program at UCLA to focus on harmonic balance circuit simulators, but switched subjects to numerical electromagnetics after his dissertation advisor left the university a few years into his studies. Undaunted, his prior EDA experience inspired him to change his dissertation topic toward developing a new environment explicitly for simulating high-frequency chip design. In 1994, with a year left to go on his doctoral studies, Pekarek left Hughes to start Applied Wave Research (AWR) and develop the company's first product, Microwave Office (MWO).

Pekarek and two other engineers worked on a shoestring budget to prepare MWO for market in 1998; credit-card debt being among their few sources of financing. MWO debuted at MTT-S IMS 1998 in Baltimore, with a limited set of features compared to the products from Ansoft and HP EEsof. Nonetheless, the graphic oriented user interface, friendly design methodology and real-time tuning (using fast, nonlinear Volterra Series analysis rather than harmonic balance) caught the eye of many attendees and put Microwave Office on the map.

The MWO interface was conceived for the "typical" RF engineer's workflow, placing emphasis on productivity and utilizing an underlying architecture that leveraged Win 32 APIs and object-oriented programming. Modeled after established design frameworks from EDA companies such as Cadence, the environment was constructed as a socket for supporting technologies, allowing AWR to partner with third-party technologists in order to supplement product functionality and offer designers a choice in solvers. This approach provided AWR with the time needed to enhance product functionality toward support of complex end-to-end communication systems being targeted by Agilent and Ansoft.

While MWO capability was being developed for the wireless chip set market, the product's ease of use and lower price tag made it a hit with the traditional RF board market. AWR uncovered or at least demonstrated the existence of a market for tools that were less complex, used primarily by individuals or small groups working for cost-sensitive companies. This non-RFIC market now included a sizable number of MMIC and MIC design houses.

This market was also fertile ground for Eagleware (known as Circuit Busters until 1991), which had quietly been selling its linear simulator (=SuperStar=) and EEpal tools since the company was founded by Randy Rhea in 1985. A product feature for EEpal appeared in the May 1991 issue of MWJ. This program was a combination of scientific calculator and microwave product/vendor selector guide. Users could solve polynomial equations, the Fourier coefficients of a square wave or look up the fax and phone numbers of microwave filter vendors.

In 1995, Todd Cutler joined Eagleware as CEO. Cutler had spent 20 years at HP, where he worked as a development engineer, led applications development in the European Microwave and Communications Group, and was a founding member of the HP microwave design software business, serving as Marketing Manager of HP-EEsof after the merger. At Eagleware, Cutler steered the development and marketing of the Genesys RF and microwave circuit and system design software platform in a direction similar to Agilent, Ansoft and AWR. The company began promoting its various synthesis tools (PLL, Filter, oscillator, Tline and matching), schematic and layout editors and linear simulator under the Genesys name. Over time, Genesys added a harmonic balance nonlinear simulator (Harbec) and a planar EM tool (EMPower).

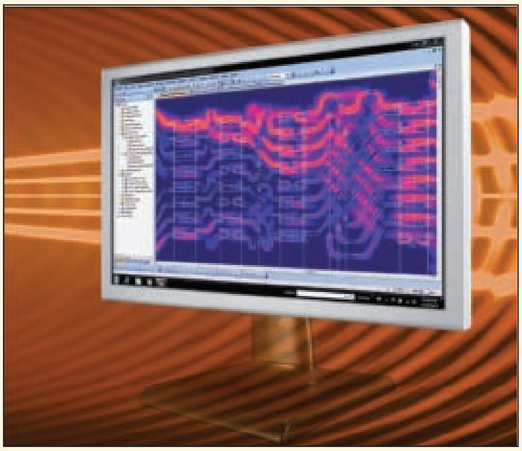
In 2004, the company acquired Elanix Inc., an electronic-system level tool provider, thereby adding SystemVue signal processing design software for behavioral modeling of communication and DSP systems to their portfolio of high-frequency simulation, analysis and synthesis software. By the middle of the decade, software vendors offering an RF design solution with circuit, system, planar EM simulation, integrated into a single user environment included Agilent, Ansoft, AWR and Eagleware-Elanix.

In 2005, Cutler's career went full-circle as he helped broker the deal for Agilent EEsof's acquisition of Eagleware-Elanix, complementing their portfolio of RFIC products (ADS, Golden Gate, RFDE) with products intended for smaller enterprises, individual professionals and personal (contractor) use. Meanwhile, AWR has made several significant acquisitions including ICUCOM (system-level simulator in 2000), APLAC (harmonic balance simulation in 2005) and Simulation and Applied Research or STAAR (3D FEM in 2009). In 2008, Ansoft was acquired by Ansys. Continuing to sell its HFSS, Ansoft Designer/Nexxim, SIWave and Spicelink tools, the company recently announced further integration of its HFSS product within Ansoft Designer and HSPICE co-simulation.

EPILOGUE

The introduction of new simulation technology and integration with powerful design entry tools reflect the major advances in software development over the past two decades. The wireless revolution gave birth to several software start-ups and mergers. Through it all, the needs of the microwave circuit designer have been met with innovative software products supporting the ever-increasing complexity required for the next generation of wireless devices and defense systems.

This article looked at the larger RF circuit/system-level design software vendors as well as two innovators in EM technology (i.e. CST and Sonnet). A complete guide to all the software companies, researchers and products that have been developed for the wide range of microwave frequency design challenges could fill a book. ■



PLANAR ANTENNA SIMULATION IN AXIEM

AXIEM™, a 3D planar electromagnetic (EM) simulator from AWR Corp., was first announced in 2007 with innovative technology to solve large, complicated problems with unprecedented speed and accuracy. Released as an integral part of AWR's design environment, AXIEM provided designers with the ability to simulate large problems (more than 100,000 unknowns), send the layout of a circuit to AXIEM, simulate and seamlessly bring the results back into the circuit simulator.

The new 2010 release of AXIEM takes the speed, capacity and accuracy assets of the technology a step further by opening up the design space (literally). AXIEM 2010 has added post-processing capabilities for antenna analysis, including various field patterns, antenna currents, and, of course, feed impedances. It is now possible for designers to see the standard antenna parameters of interest, including gain and directivity, polarization, and power patterns. Planar antenna arrays are traditionally a formidable problem for planar EM simulators because of the large number of unknowns resulting from the meshing of the elements. AXIEM has the capability of solving problems with over 100,000 unknowns in minutes using compressed, iterative, matrix solution techniques. This feature is critical for large arrays, because it is simply not possible to solve these large problems with traditional direct matrix methods.

AXIEM's integration into AWR's design environment gives users a great deal of flexibility in how the tool is to be used. For example, portions of a circuit's layout can be automatically sent to AXIEM for EM analysis, and the resulting S-parameters can be automatically included in the circuit for further analysis. The method, called EM extraction, can be controlled in sophisticated ways. As such, AXIEM is ideal for planar antenna problems, as the designer can draw the antenna in the same layout as the rest of the circuit, have it automatically sent to AXIEM for analysis, and then have the results returned for further analysis.

SIMULATION OF LARGE PROBLEMS

The bulk of the simulation time spent in a

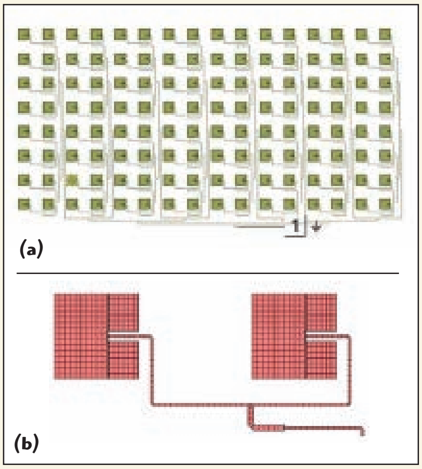
AWR CORP.
El Segundo, CA

planar EM simulation is in solving the matrix. The matrix is formed by looking at the interactions between the mesh currents on the conductors of the circuit. Roughly speaking, if there are N meshes, the matrix created is a dense N × N matrix. Traditionally, it takes order N^2 amount of time to create the matrix and order N^3 amount of time to solve the matrix. The mathematical term "order of" means the following: If the number of cells is doubled, the fill time is four times longer (order N^2), and the solve time is eight times longer (order N^3). This is why the matrix solve dominates for large enough problems, roughly about 10,000 unknowns.

The problem for antenna designers is that a large array, for example 16 × 16 elements, can have well over 100,000 unknowns, and the N^3 scaling of the solve time quickly renders the problem completely impractical to solve. Say it takes 10 seconds to solve 1000 unknowns at one frequency. The number of unknowns in the array is 100 times bigger (100,000 unknowns), and takes 10^6 times longer to solve. Therefore, the solve time is 10^7 seconds, which is about four months.

Fortunately, new iterative solution methods have been developed, where the matrix is compressed and solved by making repeated guesses or iterations to the solution. When properly applied, the methods can lead to matrix fill and solve times as fast as order Nln(N). The array problem mentioned in the previous paragraph can be solved in about 80 minutes per frequency point, which is a realistic simulation time for a practical design. The matrices that result from planar array problems typically have many blocks of elements that have about the same value. These blocks of elements correspond to groups of cells that are far away from one another. This is why the compressed, iterative methods work well.

The compression methods only work well if the matrix is properly conditioned. The mathematical term "conditioning of a matrix" refers to how easy it is to solve the matrix condition on a computer with finite precision arithmetic. The matrices generated in EM simulators are traditionally not well conditioned. It is therefore necessary to pre-condition the matrix. There are several ways to do this. A large part of AWR's 20 man-years of development investment in AXIEM has been devoted



▲ *Fig. 1 An 8 × 16 patch array antenna with a corporate feed mesh (a) and close up for two elements in the array (b).*

to perfecting the iterative solvers and pre-conditioners (for more information, read http://web.awrcorp.com/default.asp?docId=16033).

Figure 1 shows an 8 × 16 patch array, which had a mesh of 96,000 elements. The total number of unknowns was 164,000. This array simulated in about 30 minutes per frequency point on an 8-core machine with 8 GB of RAM (AXIEM takes advantage of multi-core machines).

EM EXTRACTION

Planar antennas are normally coupled together with the associated feed network and drive circuitry. EM extraction is a technique where the antenna is coupled with the circuit in the schematic and its layout. The advantages are that the designer can see the antenna as part of the entire layout, the feed network of the antenna can be easily drawn and simulated, and the resulting S-parameter files from AXIEM are automatically incorporated back into the entire circuit simulation. ***Figure 2*** shows the schematic of an eight-element patch array and its associate Butler feed matrix. Note the element labeled "Extraction Block." This element can be configured to automatically send all, or part of, the layout of the schematic to AXIEM for simulation. The resulting S-parameters are used by the circuit for the final simulation. ***Figure 3*** shows the layout, and a 3D version of the layout.

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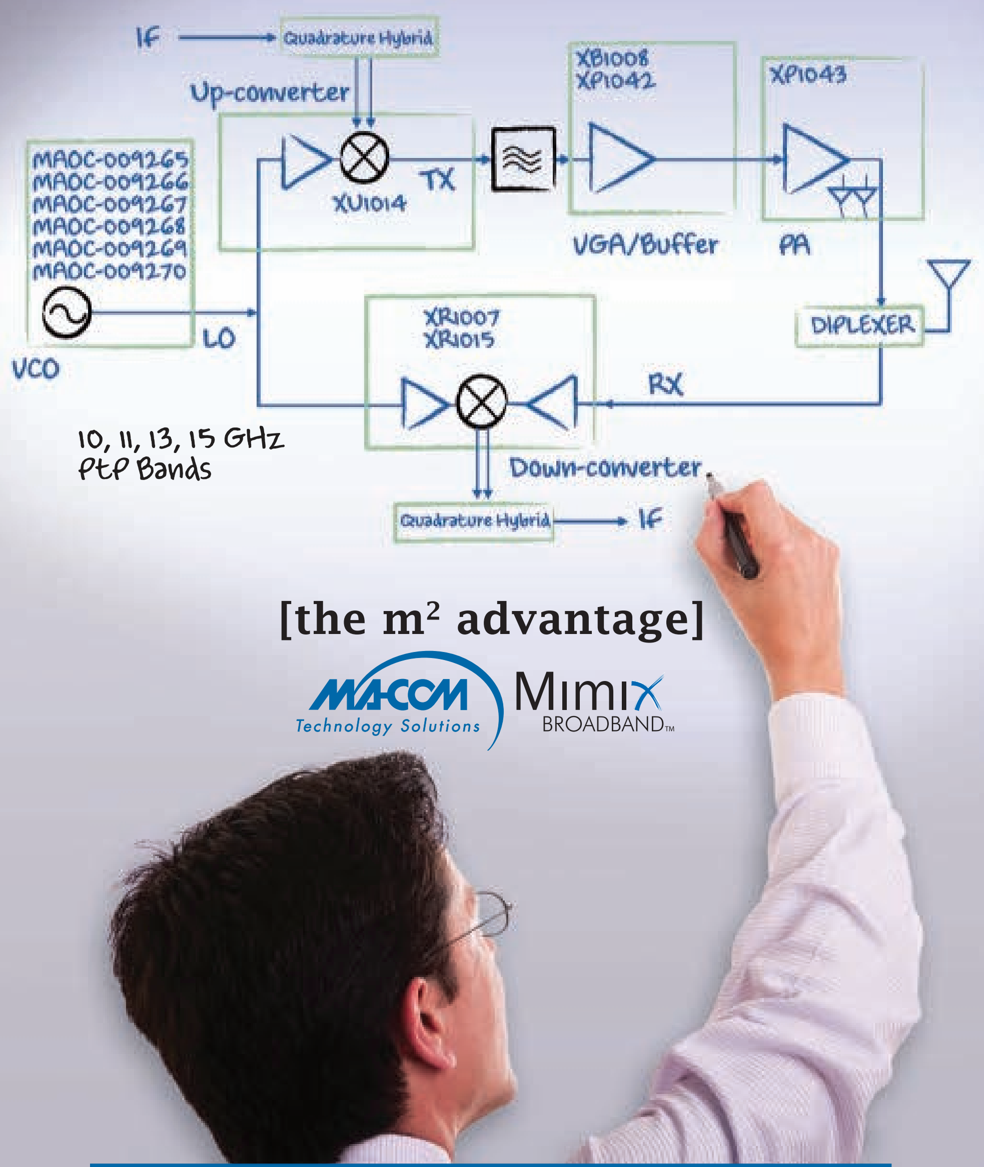

Part Number	Frequency (GHz)	Gain (dB)	P1dB (dBm)	OIP3 (dBm)	Pout (dBm)	PN at 100 kHz (dBc/Hz)	Current (mA)	Package (mm)
XP1043-QH	12.0-16.0	21.5	30.0	41.0			700	4x4
XP1042-QT	12.0-16.0	21.0	25.0	38.0			500	3x3
XB1008-QT	10.0-21.0	17.0	19.0	32.0			100	3x3
XU1014-QH	8.0-18.0	-10.0	2.0	12.0			80	4x4
XR1007-QD	10.0-18.0	13.5		4.0 (I/P)			150	7x7
XR1015-QH	10.0-16.0	12.0		2.0 (I/P)			170	4x4
MAOC-009265	9.0-10.3				6.0	-110	175	5x5
MAOC-009266	10.2-11.3				9.0	-114	185	5x5
MAOC-009267	11.2-12.6				3.5	-110	165	5x5
MAOC-009268	12.7-14.2				7.0	-105	175	5x5
MAOC-009269	11.4-12.8				3.0	-110	165	5x5
MAOC-009270	12.2-13.8				6.5	-105	155	5x5

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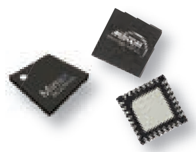

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antenna measurements, including the standard antenna pattern measurements for electric field as a function of sweep angles theta and phi. Both circular and polar antenna pattern measurements can be made. ***Figure 4*** shows the left hand and right hand polarization patterns in the principal planes for the 8 × 1 array fed by the Butler matrix. Two different scan angles are shown. Additionally, the designer can look at currents on the antennas, as well as the electric fields in various cross-sections of the circuit. This can be useful when trying to diagnose an impedance mismatch or phasing problem.

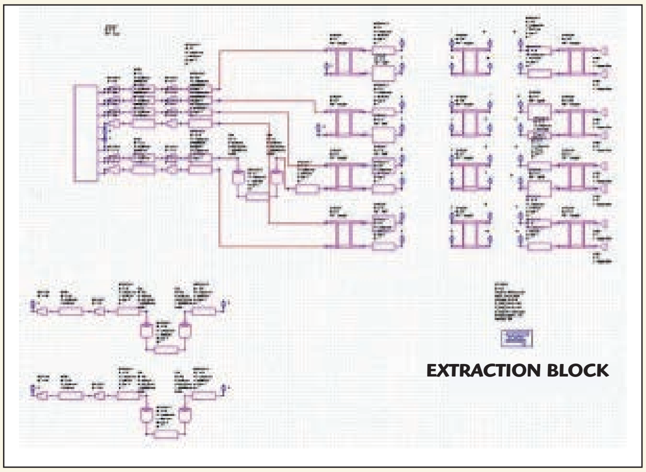

Fig. 2 Schematic of the antenna array and feed network.

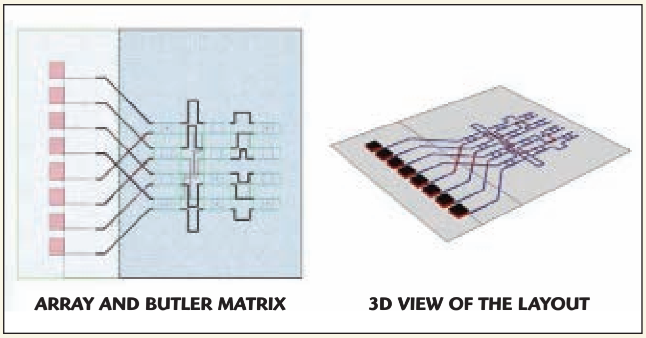

Fig. 3 An eight-element array and Butler matrix feed.

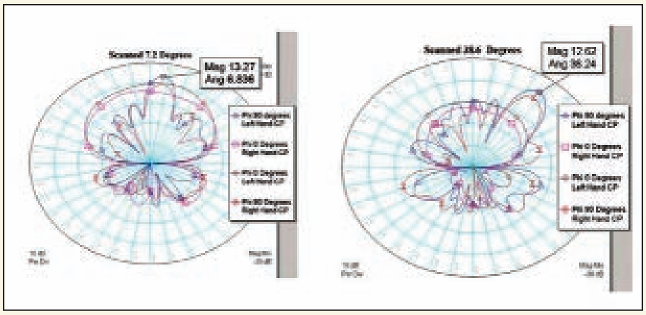

Fig. 4 8 × 1 array antenna patterns for two different scan angles.

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  - Current visualization

CONCLUSION

Developed specifically to provide designers with a way to implement EM simulation as a practical part of the design flow rather than simply a back-end verification tool, AXIEM continues to fulfill its promise as a software product that offers cutting-edge technologies engineers need as they face the design challenges posed by today's complex wireless products. Highlighted in the new 2010 release of AXIEM are innovative antenna capabilities that are quickly becoming an indispensable tool for antenna designers.

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Boeing and Northrop Grumman Partner for Missile Defense Competitive Contract

The Boeing Co. and Northrop Grumman Corp. announced a strategic partnership in pursuing the competitive development and sustainment contract for future work on the Ground-based Midcourse Defense (GMD) system for the US Missile Defense Agency.

"Boeing takes great pride in supporting the Missile Defense Agency on GMD, providing 24/7/365 protection of the United States against attack by ballistic missiles, and we are pleased to join with Northrop Grumman in this competition for future development and support of this critical element of the defense of our homeland," said Greg Hyslop, Vice President and General Manager of Boeing Strategic Missile & Defense Systems. "This partnership offers MDA the most experienced and responsive team, ready to adapt GMD to future needs and requirements. At the same time, this proven team will continue to offer the warfighter an unmatched level of mission readiness, availability and support—affordably and with the lowest risk."

"This partnership offers MDA the most experienced and responsive team, ready to adapt GMD to future needs and requirements."

The two companies also announced leaders for the combined team. As part of the strategic partnership, Norm Tew, Boeing Vice President and GMD Program Director, will serve as Program Manager of the Boeing-Northrop Grumman GMD team. Steve Owens, Northrop Grumman GMD Program Director, will be the team's Deputy Program Manager.

In leading the Boeing-Northrop Grumman GMD Team, Boeing will build on its experience of supporting the Missile Defense Agency as prime contractor for the GMD program since 2001, leading the industry team in the development, deployment, integration and testing of the GMD weapon system. The Boeing-led team also operates and sustains the deployed weapon system while actively developing and testing innovative technologies to provide greater reliability and meet its customer's evolving needs and requirements.

Northrop Grumman is responsible for designing and deploying the command-and-control systems that form the backbone of the ground system, known as GMD Fire Control/Communications (GFCC) products. GFCC products connect and orchestrate GMD components that launch and guide interceptors in-flight. In addition, Northrop Grumman has developed and sustained ground-based missile systems for more than 50 years and has been prime contractor for the US Intercontinental Ballistic Missile (ICBM) weapon system since 1997. Northrop Grumman has been part of the Boeing Ground-based Midcourse Defense Team for more than 10 years. "As Boeing's strategic partner, we bring the low risk of our domain expertise on GMD fire control and communications, and the robust systems management model of our leadership role on ICBMs," said Karen Williams, Vice President, Air and Missile Defense Systems, for Northrop Grumman's Information Systems sector. "Those are very powerful capabilities we can use to help our team bring GMD into a new era of efficiency, affordability and long-term partnership with MDA."

ThalesRaytheonSystems Awarded $21.8 M to Modernize US Army AN/MPQ-64 Radars

ThalesRaytheonSystems has been awarded a $21.8 M contract by the US Army to upgrade multiple AN/MPQ-64 Sentinel air defense radar systems. This award is an option to the existing upgrade contract originally awarded in June 2007. The contract will upgrade the US Army Sentinel radar transmitters, receivers and exciters, and increase functional capabilities such as faster data processing and greater detection range for smaller targets. Additional capabilities will also help minimize instances of fratricide and accidental counter-missile firing and facilitate a transition to defense-force mobility.

"The latest system enhancements will benefit the warfighter by providing earlier threat detection," said Kim Kerry, Chief Executive Officer, ThalesRaytheonSystems, US Operations. "It will also prepare the Sentinel for future missions such as special events protection, air traffic control and general homeland defense." Upgrade work will be performed in El Paso, TX, and Fullerton, CA.

"The latest system enhancements will benefit the warfighter by providing earlier threat detection."

The Sentinel radar is the premier air surveillance and target acquisition and tracking sensor for the US Army's Cruise Missile Defense Systems program. The radar's primary mission is to protect maneuver forces and critical assets from cruise missile, unmanned aerial vehicles, and rotary- and fixed-wing threats. The Sentinel accurately acquires targets far enough forward of friendly troops to provide sufficient reaction time for air defense weapons to engage at optimum ranges. More than 200 Sentinel radars are currently deployed by military forces worldwide.

Lockheed Martin Delivers First US Air Force Advanced EHF Satellite

Lockheed Martin has delivered the first satellite in the Advanced Extremely High Frequency (AEHF) program to Cape Canaveral Air Force Station, FL, where

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it will be prepared for a July 30 liftoff aboard an Atlas V launch vehicle. The AEHF system will provide the US military and national leaders with global, protected, high capacity and secure communications.

"Shipment of the first AEHF satellite is testimony to a strong government and industry partnership focused on achieving total mission success on this vitally important program," said Col. Michael Sarchet, Commander of the Protected Satellite Communications Group at the US Air Force's Space and Missile Systems Center. "AEHF will play an integral role in our national security space architecture, and we look forward to providing this new capability to the warfighter."

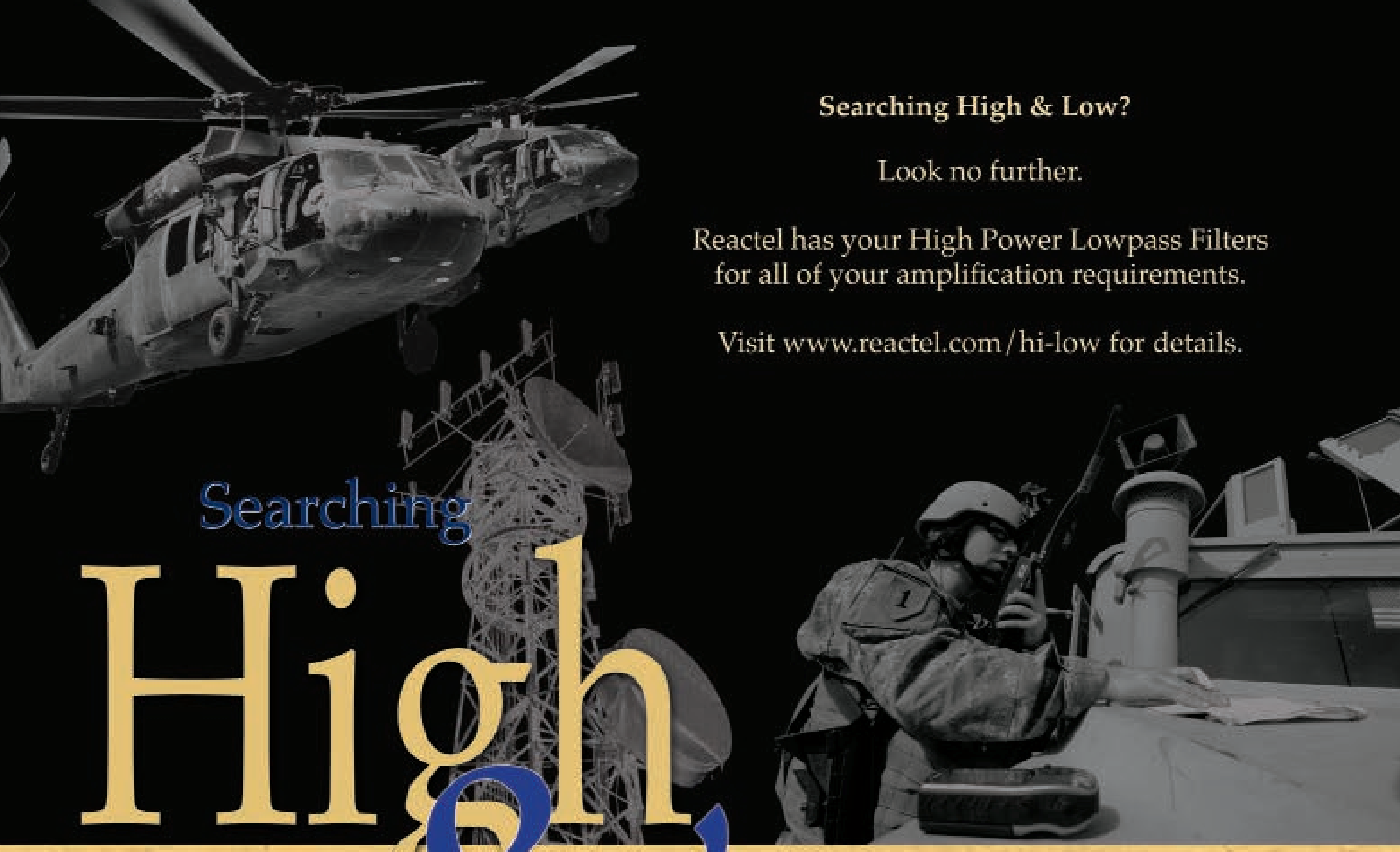
The AEHF system is the successor to the five-satellite Milstar constellation and will provide significantly improved global, highly secure, protected, survivable communications for all warfighters serving US national security. The governments of Canada, The Netherlands and the United Kingdom participate in the AEHF program as international partners and will have access to the communications capability of AEHF. A single AEHF satellite will provide greater total capacity than the entire Milstar constellation currently on-orbit. Individual user data rates can be up to five times higher than Milstar's highest speed. The faster data rates will permit transmission of tactical military communications, such as high-quality real-time video and quick access to battlefield maps and targeting data.

"Lockheed Martin is extremely proud of this significant program milestone," said Mike Davis, Lockheed Martin's AEHF Vice President. "This satellite will provide substantially improved protected communications capabilities for the warfighter, and we look forward to achieving mission success for our customer."

"AEHF will play an integral role in our national security space architecture..."

The second AEHF spacecraft (SV-2) has completed Final Integrated System Test, which verified all spacecraft interfaces, demonstrated full functionality and evaluated satellite performance, and is now preparing for Intersegment testing to ensure the spacecraft is ready for flight. The third AEHF satellite, SV-3, has completed acoustic testing, one of several critical environmental tests that validate the overall satellite design, quality of workmanship and survivability during space vehicle launching and on-orbit operations. SV-2 and SV-3 are on track for launch readiness in 2011.

The AEHF team is led by the US Air Force Military Satellite Communications Systems Wing at the Space and Missile Systems Center, Los Angeles Air Force Base, CA. Lockheed Martin Space Systems Co., Sunnyvale, CA, is the AEHF prime contractor and system manager, with Northrop Grumman Aerospace Systems, Redondo Beach, CA, as the payload provider.



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20 - 75 MHz, minimum	≥ 40 dB @ 90 MHz & ≥ 50 dB @ 135 - 600 MHz
20 - 115 MHz, minimum	≥ 40 dB @ 150 MHz & ≥ 50 dB @ 250 - 600 MHz
20 - 150 MHz, minimum	≥ 40 dB @ 200 MHz & ≥ 50 dB @ 300 - 600 MHz
20 - 220 MHz, minimum	≥ 40 dB @ 300 MHz & ≥ 50 dB @ 450 - 900 MHz
20 - 335 MHz, minimum	≥ 40 dB @ 440 MHz & ≥ 50 dB @ 660 - 1400 MHz
20 - 500 MHz, minimum	≥ 35 dB @ 670 MHz & ≥ 50 dB @ 1005 - 2000 MHz
20 - 700 MHz, minimum	≥ 40 dB @ 980 MHz & ≥ 50 dB @ 1470 - 2000 MHz
20 - 1010 MHz, minimum	≥ 35 dB @ 1400 MHz & ≥ 50 dB @ 2100 - 3000 MHz
20 - 1400 MHz, minimum	≥ 40 dB @ 2000 MHz & ≥ 50 dB @ 3000 - 4200 MHz
20 - 2000 MHz, minimum	≥ 40 dB @ 2800 MHz & ≥ 50 dB @ 4200 - 5000 MHz
20 - 3000 MHz, minimum	≥ 40 dB @ 3940 MHz & ≥ 50 dB @ 5910 - 6000 MHz

Common Specifications

- IL: ≤ 0.3 dB @ PB
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EARTH Aims to Halve 4G Network Energy Use

A group of 15 leading telecommunications service providers, component and infrastructure vendors, and academic institutions have launched Energy Aware Radio and Network Technologies (EARTH), a consortium whose goal is to achieve a 50 percent reduction in the energy consumption of 4G mobile wireless communication networks within the next two-and-a-half years.

The consortium comprises: Alcatel-Lucent, Ericsson, NXP Semiconductors France, DOCOMO Communications Laboratories Europe GmbH, Telecom Italia S.p.A., CEA, University of Surrey, Technische Universität Dresden, imec, IST - Technical University of Lisbon, University of Oulu, Budapest University of Technology and Economics, TTI and ETSI.

> *"What makes EARTH so compelling is that it has the potential to deliver tangible benefits to society on a number of levels..."*

EARTH will adopt an approach that considers the energy efficiency of mobile networks at a comprehensive system level rather than focusing on discrete network elements. The consortium members will research approaches to allow for unprecedented energy savings in the area of wireless networks, their components and its radio interfaces. Based on this, EARTH will develop a new generation of energy-efficient network equipment and components, craft energy-oriented deployment strategies, and conceive energy-aware network management solutions.

The EARTH initiative supports the European Union's Work Programme for Information and Communication Technologies under the objective "Network of the Future". The project is funded within the European Union's Seventh Framework Program (FP7).

Rainer Fechner, head of Bell Labs in Germany and member of the management board, Alcatel-Lucent in Germany, said, "What makes EARTH so compelling is that it has the potential to deliver tangible benefits to society on a number of levels: reducing energy consumption of networks and their impact on the environment while making broadband wireless service available to a greater number of people in Europe. The value of our contribution derives from deep experience and innovations in both green technology and advanced wireless systems."

ETSI Launches Open Radio Equipment Interface ISG

ETSI and NGMN have announced the creation of the ETSI Industry Specification Group on Open Radio equipment Interface (ISG ORI) that will specify an open interoperable interface for radio equipment in distributed mobile cellular base stations—GSM, UMTS and LTE. ISG ORI is a direct result of requirement work undertaken by the NGMN Alliance, in its Open BBU RRH Interface (OBRI) project, and leading mobile network operators and telecom equipment vendors have agreed to become founding members.

> *"The NGMN Alliance... will actively participate in the ISG to enable the early implementation of this essential specification..."*

The use of distributed radio equipment can lead to significant cost savings for a mobile operator, as well as offering a greater level of flexibility in network design and deployment. The interface that will be defined by the ISG ORI is an important step towards realising these benefits through widespread deployment of distributed radio equipment.

Peter Meissner, Operating Officer of the NGMN Alliance, commented, "The Board of the NGMN Alliance highly appreciates the broad vendor commitment and support for the activities to drive open interface specifications. The NGMN Alliance will follow the future specification work closely and will actively participate in the ISG to enable the early implementation of this essential specification in future mobile radio access networks."

Universities Join UK Industrial Design Coalition

Thirteen leading UK universities have joined with British Design Innovation (BDI)—the trade organisation for leading industrial design, service design and innovation consultancies—to form a national University Design Industry Partnership Scheme (UDIPS), in a bid to create world-changing innovations, products and processes. The scheme underscores the value private sector industrial design companies can bring to discovery-led university research results by acting as a bridge between the technology and consumer-focused market applications, and between originators and industry.

> *"...Industrial designers with multi-sector experience are uniquely positioned to identify 'right technology, wrong market'..."*

The 13 pioneering UDIPS universities—each one hand-picked to reflect a representative mix of disciplines, students, staff, geographical spread and a commitment to collaborative innovation—are the Universities of Anglia Ruskin, Brunel,

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Cambridge, Cranfield, Hertfordshire, Loughborough, Middlesex, Nottingham Trent, Queen's Belfast, Staffordshire and Sussex, the Open University and UCA.

"We all need to recognise that the discovery-led nature of university research will only ever be properly commercially exploited if it engages with strategic designers' unique ways of thinking, commercial knowledge and global client portfolios," said Maxine Horn, BDI's CEO.

She added, "Industrial designers with multi-sector experience are also uniquely positioned to identify 'right technology, wrong market' for those who are either not specialists in certain industry sectors, or are specialists in only one industry sector. Our proven knowledge transfer processes are accredited by the Institute of Knowledge Transfer, and our designers' abilities to validate the Visual Business Case not only assists universities, spinouts, start-ups and SMEs to communicate their potential to investors, venture capitalists and other stakeholders, but also prevents market application mistakes from occurring."

ITU Conference Adopts Hyderabad Action Plan

The Hyderabad Action Plan, adopted by the ITU World Telecommunication Development Conference (WTDC-10), outlined a road map to foster the global development of information and communication technology (ICT) networks and services over the next four-year cycle. The roll out of next-generation networks (NGN) and increased access to broadband services, wireless technologies and the Internet were recognized as catalysts to achieve the broader development goals.

"Broad access to telecommunications and ICTs is essential for the world's collective economic, social and cultural development…"

The Hyderabad Declaration states: "Broad access to telecommunications and ICTs is essential for the world's collective economic, social and cultural development, and the building of a global Information Society. This access brings new opportunities for interaction amongst people, for sharing of the world's knowledge resources and expertise, for transforming people's lives, and for contributing to the global development agenda."

P.J. Thomas, Secretary, Department of Telecommunications of the Government of India, said, "The increasing role of ICT in the life of the common man cannot be overemphasized. Keeping in view the latest technological developments in ICT, the Hyderabad Declaration adopted by WTDC-10 will play a decisive role in the development of the ICT sector across the world, especially in developing countries."

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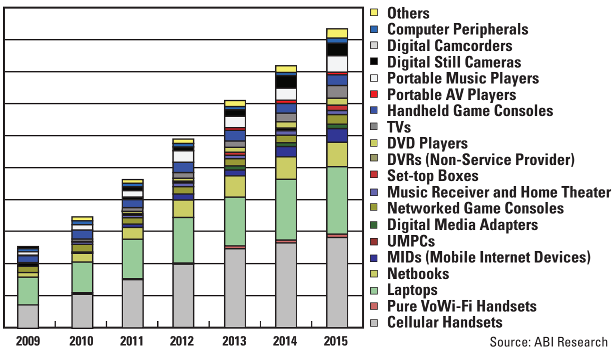
Dan Massé, Associate Technical Editor

MarketWatch

The escalated Radio Access Network (RAN) data rates for 4G networks are placing new demands on infrastructure and supporting hardware, requiring significant bandwidth upgrades (anywhere from 50 to 200 Mbps) to base stations and the backhaul layer. Aside from capacity, another less apparent impact relates to the shift to higher operating frequencies, which due to increased losses associated with diffraction, refraction and absorption negatively impacts cell coverage.

Currently, "micro-cellular" networking structures are being developed to combat the reduction in cell area at higher frequencies. For instance, in downtown urban-canyon environment, the base stations have to be moved off roof-tops and brought down toward street level, creating new design challenges. In this month's MarketWatch, Erik Boch, CTO & VP of Engineering, Dragonwave, looks at changing hardware requirements for high capacity wireless backhaul for microcellular deployments. Visit www.mwjournal.com/marketwatch_july2010.

Wi-Fi Shipments to Surpass 770 Million Units in 2010



Wi-Fi shipment forecast by product type.

Global shipments of Wi-Fi ICs have experienced an extraordinary growth in recent years, due to the increasing demands for wireless-enabled devices and enterprise level applications. Wi-Fi IC shipments are forecast to surpass 770 million units in 2010, up almost 33 percent compared to 2009. Shipment of 802.11n ICs will surge ahead of 802.11g and dominate the market this year, accounting for approximately 60 percent of total Wi-Fi IC shipments.

"The 802.11n standard which was ratified last year is a powerful growth engine to drive the Wi-Fi IC market increases," says ABI Research Wireless and Semiconductor Industry Analyst Celia Bo.

The accompanying chart shows the Wi-Fi IC shipment forecast by product type. The cellular handset segment is seen to be maintaining the highest unit shipment of Wi-Fi-enabled products in the next five years, achieving an estimated CAGR of 25 percent between 2009 and 2015; the penetration rate will reach approximately 40 percent of total handsets shipped in 2015. Laptops, netbooks and MIDs are other segments that will see higher shipments across all Wi-Fi-enabled products, and the trend will carry on throughout the following years.

"The penetration rate of Wi-Fi ICs in consumer electronic products will continue to grow robustly," Bo continues. "Total shipments of consumer electronic products with Wi-Fi functionality are expected to exceed 530 million in 2015, with a 26 percent CAGR between 2009 and 2015. Shipments of Wi-Fi-enabled digital still cameras, TVs and DVD players will increase more than tenfold in 2015 as compared to 2009. The demand for Wi-Fi-enabled home entertainment products such as networked game consoles and handheld game consoles is increasing as well: between 2009 and 2015, the CAGR will reach 8 percent and 6 percent, respectively."

ZigBee Alliance and IPSO Alliance Collaborate

The ZigBee® Alliance and the IPSO (IP for Smart Objects) Alliance announced an agreement to collaborate on wireless home area networks (HAN) using the ZigBee IP specification and the ZigBee Smart Energy™ version 2.0 standard. The two alliances will collaborate on expanding HANs by using IP technology. The ZigBee Alliance is a global ecosystem of companies creating wireless solutions for use in energy management, commercial and consumer applications; the IPSO Alliance promotes the use of Internet Protocol (IP) in smart objects.

ZigBee Smart Energy is the market leading wireless HAN standard with more than 40 million smart meters being installed around the world. Common HAN devices include utility meters, thermostats, pool pumps, water heaters, appliances and plug-in electric vehicles. It was developed by industry leading utilities, suppliers and technology companies to connect those everyday household devices to the Smart Grid. Last year, it was selected by the US Department of Energy and the National Institute of Standards and Technology (NIST) as an initial interoperable standard for HAN devices.

"Working with the IPSO Alliance will speed our development work on ZigBee Smart Energy," said Bob Heile, Chairman of the ZigBee Alliance. "By using IP technology, ZigBee Smart Energy will give utilities more flexibility in future Smart Grid deployments." IPSO is the latest organization to collaborate on ZigBee Smart Energy. Four other organizations are working to expand this standard for HANs, including DLMS, EPRI, ESMIG and HomePlug Powerline Alliance.

"The IPSO Alliance is pleased to be working with the energy experts at the ZigBee Alliance on their industry leading standard for HANs," said Geoff Mulligan, Chairman of

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the IPSO Alliance. "We have been playing an active role in this space and our contributions to ZigBee Smart Energy and the ZigBee IP specification will help speed adoption of the Smart Grid."

ZigBee Smart Energy enables wireless communication between utility companies and common household devices such as smart thermostats and appliances. It improves energy efficiency by allowing consumers to choose interoperable products from different manufacturers giving them the means to manage their energy consumption more precisely using automation and near real-time information. It also helps utilities and energy providers implement new advanced metering and demand response programs to drive greater energy management and efficiency, while responding to changing government requirements. For more information and a list of ZigBee Certified products, visit: www.ZigBee.org/SmartEnergy.

ABI Research's Google Earth 4G deployment tracker.

2012 Will Be a "Bellwether" Year for 4G

ABI Research has been tracking cities and population coverage for 4G for the past year. At the end of 2009 there were more than 170 802.16e carriers across 65 countries, covering 480 million people. That number is projected to cross the 1 billion mark by 4Q-2012. USB dongles have been an excellent vehicle to prime the market along with CPE and laptops, but mobile handsets will be essential to the success of WiMAX. Yota, Sprint and Clearwire have already started beefing up their lineups with models from HTC and Samsung. Meanwhile, mobile operators are seeking out LTE licenses. Twenty carriers will launch by 4Q-2010. Population coverage lags WiMAX, but will catch up, reaching 600 million people by 4Q-2012. LTE coverage will start in urban hotspots, but carriers indicate they will push coverage rapidly in order to handle the increasing mobile data wave.

The 4G market could well have 150 million subscriptions by 4Q-2014. The split between WiMAX and LTE will depend on WiMAX carrier commitments to upgrade to 802.16m. WiMAX vendors such as Motorola and Huawei are gearing up to offer "802.16e+", which will bring features of 802.16m to the current market. Many companies in the ecosystem are already working on interoperability testing for 802.16m.

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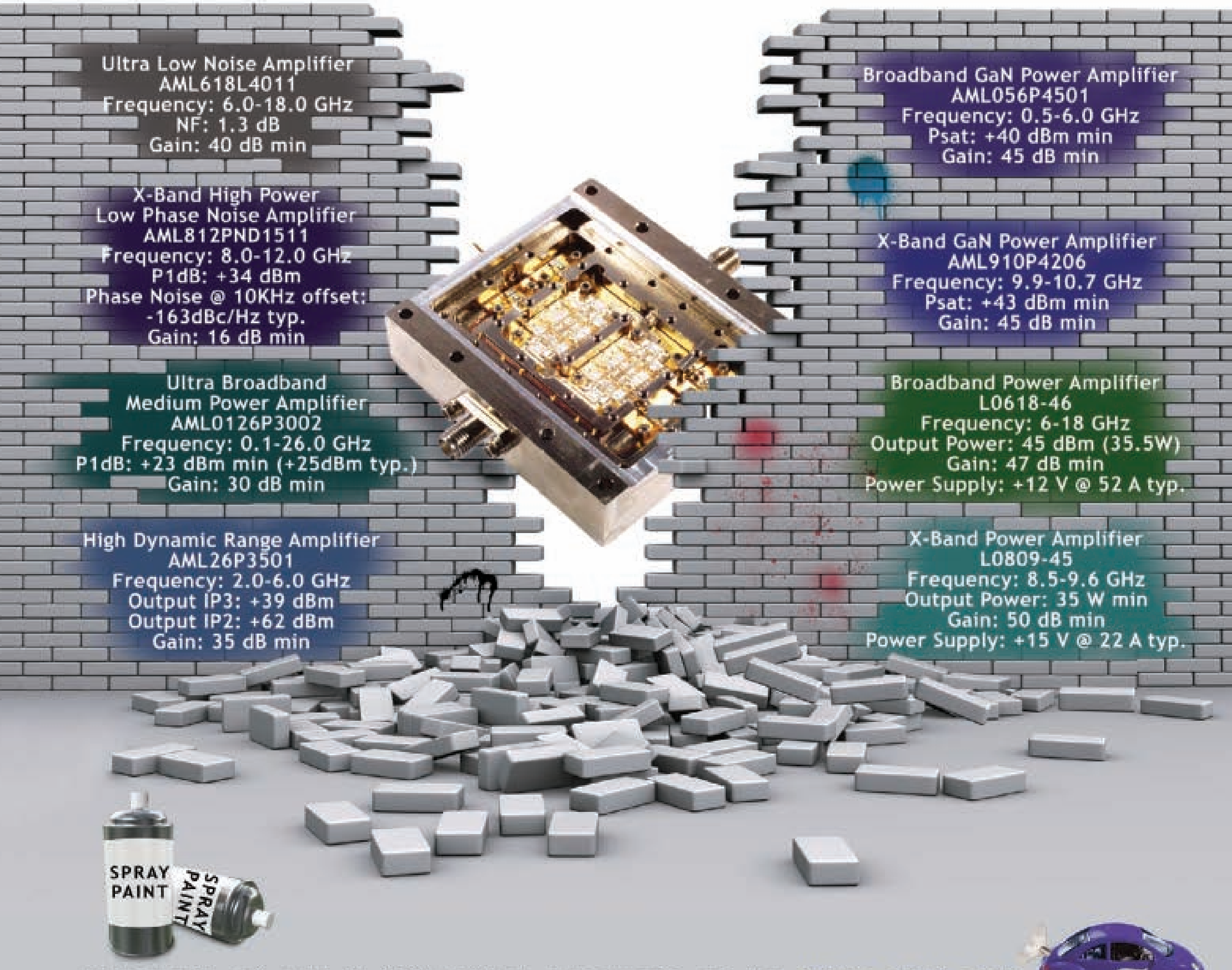

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Around the Circuit

Jennifer DiMarco, Staff Editor

INDUSTRY NEWS

M/A-COM Technology Solutions Inc., a supplier of semiconductors, components and subassemblies for use in RF, microwave and millimeter-wave applications, and **Mimix Broadband Inc.** jointly announced that their respective corporate parents have signed a definitive merger agreement that will add Mimix and its subsidiaries to the M/A-COM Tech family of companies. Mimix is a fabless supplier of high performance gallium arsenide (GaAs) semiconductors from DC to 50 GHz for RF, microwave and millimeter-wave applications. Pursuant to the merger agreement, Mimix Holdings Inc. and its subsidiaries will join M/A-COM Tech as subsidiaries of M/A-COM Technology Solutions Holdings Inc. Financial terms were not disclosed.

Rosenberger Hochfrequenztechnik GmbH & Co. KG, Tittmoning, Germany, has acquired **CDS DataComm** of Plano, TX. The newly acquired company will be called **Rosenberger CDS LLC** and will continue to operate with its current management and staff in its Plano, TX facility. Details of the transaction were not disclosed.

CPI International Inc. announced the signing of a definitive merger agreement with **Comtech Telecommunications Corp.** (CMTL) under which Comtech will purchase CPI in a cash and stock transaction with an enterprise value of approximately $472.3 M. Comtech will fund the acquisition by redeploying approximately $372.0 M of its existing cash plus the issuance of approximately 4.4 million shares of Comtech common stock. All existing CPI debt is anticipated to be repaid upon the closing of the transaction.

Linx Technologies Inc., a provider of easily applied, cost-effective wireless solutions, announced its acquisition of **Apex Wireless Inc.** in a transaction with undisclosed terms. Based in Boulder, CO, Apex Wireless has provided RF product development, contract design and wireless consulting services since 1985. Apex specializes in high performance, cost-optimized wireless products employing RF transmitters, receivers and transceivers, including frequency hopping and direct sequence radios.

Wireless Telecom Group Inc. announced the completion of its previously disclosed agreement to sell substantially all of the operating assets of its wholly owned subsidiary **Willtek Communications GmbH** and affiliates to **Aeroflex Inc.**, a Delaware corporation, in exchange for $2,750,000 in cash and the assumption of certain liabilities. The cash purchase price is subject to a post-closing adjustment if the adjusted net assets sold at the date of closing are less than the adjusted net assets target set forth in the purchase agreement. As part of the sale, all current employees of Willtek Communications GmbH and its affiliates will be offered employment with affiliates of Aeroflex.

Murata Manufacturing Co. Ltd. announced the restructuring of its wireless module business in North America, establishing **Murata Wireless Solutions**. This action aligns the resources of SyChip Inc. with those of Murata Electronics North America Inc.'s existing Wireless Business Development Group, thus significantly extending the company's customer support and design services. John F. Denslinger will head the new organization and serve as Senior Vice President, Murata Wireless Solutions and President of SyChip Inc.

Valpey Fisher Corp., a leader in low noise timing solutions, announced the creation of its Microwaves Products Group. The group will focus on the design, manufacture and marketing of high performance RF/microwave components and integrated modules for a broad range of end markets, including microwave point to point, wireless infrastructure and military communications.

RF Micro Devices Inc. (RFMD) announced the company has added high power Integrated Passive Component (IPC) technology to RFMD's foundry services portfolio and began providing IPC technology to customers of its Foundry Services business unit in June of this year. RFMD's IPC technology is complementary to its GaN technology, and other power semiconductor technologies, for the design of multi-chip modules (MCM). With RFMD's IPC technology, foundry services customers can design integrated matching networks and other passive functions on RFMD's gallium arsenide (GaAs) process technology. This allows RFMD's foundry services customers to reduce costs and achieve higher levels of integration by leveraging RFMD's industry-leading scale and cost structure in GaAs and GaN manufacturing.

The Wi-Fi Alliance and the **Wireless Gigabit Alliance** (WiGig Alliance) announced a cooperation agreement for multi-gigabit wireless networking. The Wi-Fi Alliance and the WiGig Alliance will share technology specifications for the development of a next-generation Wi-Fi Alliance certification program supporting Wi-Fi® operation in the 60 GHz frequency band. This agreement further encourages the development of products supporting 60 GHz technology to expand existing Wi-Fi capabilities.

Agilent Technologies Inc. and **Tabor Electronics Ltd.** announced an OEM agreement establishing Tabor as a provider of Agilent test solutions for the high-speed arbitrary waveform generator (AWG) market. An integral aspect of this OEM agreement is the all-new Agilent 81180A, a 4.2 GSa/s arbitrary waveform generator that delivers exceptionally high dynamic range.

Carlisle Interconnect Technologies, Jerrik Division, announced its US Patent 7,672,140, CIRCUIT BOARD CONFIGURATION, issued March 2, 2010. Using an

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innovative new design, CarlisleIT Jerrik has developed a printed circuit board (PCB) for transient voltage suppression (TVS) filter connectors that incorporate the TVS diodes directly into the PCB. Previously the TVS diodes were clustered around the PCB in a 'cordwood' type arrangement. This new development in PCB design creates a TVS filter that is more compact, lighter in weight, costs less and is quicker to manufacture. Now military and aerospace avionics suppliers can design electromagnetic pulse and lightning protection into their modern equipment while using less space and weight than a conventional filter connector. This patented design for diode packaging can be used in several applications including military aircraft, commercial aircraft and helicopter environments.

EM Research Inc., a designer and manufacturer of miniature frequency synthesizers, phase-locked oscillators and signal sources for commercial, military and government systems, announced that it has achieved ISO 9001:2008 certification. EM Research has been awarded this designation by Orion Registrar Inc., for meeting the guidelines set out by the International Organization for Standardization.

Superior Technical Ceramics Corp. announced it has been awarded certification to AS9100, the International Aviation, Space & Defense Organizations Quality Standard by AQA. As such, Superior Technical Ceramics Corp. has simultaneously been certified by AQA to ISO9001. STC is an American owned manufacturer of custom technical ceramics for over 100 years.

CONTRACTS

TriQuint Semiconductor announced that it has been awarded a contract by the US Air Force Research Laboratories (AFRL) to develop new Gallium Nitride (GaN) modules for unmanned aerial vehicles (UAV). TriQuint's new GaN devices will extend the range and capabilities of UAVs that are used for reconnaissance missions over Afghanistan, Iraq and other regions.

Skyworks Solutions Inc., an innovator of high reliability analog and mixed signal semiconductors enabling a broad range of end markets, announced that it has captured design wins at **MediaTek** in support of several of its next-generation platforms targeting low-cost handsets in emerging markets.

Auriga Microwave announced it received its fifth Phase II Small Business Innovative Research (SBIR) award. Auriga will begin a two-year contract with the Navy's Naval Sea Systems Command (NAVSEA) to build a high-efficiency, solid-state radar power amplifier under SBIR N08-172. This award brings Auriga to a total of five Phase II SBIR awards granted to the company since early 2009.

In addition to the successful development in the Laser Direct Structuring (LDS) business, **LPKF** is about to achieve another breakthrough within the cutting and structuring laser segment. The company has received a major order

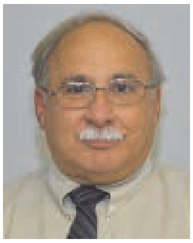
for laser systems used for the depaneling of assembled PCBs. The order volume is just under €6 M ($7.3 M) and is anticipated to be completed within the current financial year. The newly developed LPKF MicroLine laser systems will finally make the depaneling with lasers within mass production competitive and deliver, at the same time, unmatched accuracy.

NEW MARKET ENTRIES

TotalTemp Technologies Inc. is a manufacturer of temperature cycling and conditioning equipment. TotalTemp's primary expertise is based on creating thermally conductive environments to transfer heat to and from the Device Under Test (DUT). The most widely known product for this purpose is a thermal platform, often referred to as a "hot/cold plate". Thermal Platforms have a flat anodized aluminum surface that use thermal conduction to transfer heat to and from the DUT. Any product that requires temperature testing and has a reasonably low profile and a flat thermally conductive surface can be conditioned on a thermal platform. Two engineers with almost 40 years combined experience in this field formed TotalTemp Technologies to provide customers with a new and more affordable alternative to the standard thermal platform systems currently on the market. The real benefit of this improved simplified solution is that the TotalTemp's Next Generation product line is safer, extremely reliable and much more cost effective. For more information, visit www.totaltemptech.com.

Freescale Semiconductor entered the gallium arsenide (GaAs) Monolithic Microwave Integrated Circuit (MMIC) marketplace with the introduction of four new devices designed and optimized specifically for high performance in macro base stations, repeaters and femtocells employed in wireless networks. The devices address low-noise amplifiers and transmit power amplifiers, two elements of wireless infrastructure equipment for which extremely high RF performance is critical. The devices are also designed for low power consumption, resulting in optimized energy efficiency and long-term reliability.

PERSONNEL


▲ *Joseph Seminoro*

BC Systems announced the appointment of **Joseph Seminoro** as Manager of Business Development. In his new position, Seminoro will be responsible for expanding the company's sales within the aerospace and defense industry throughout North America. Seminoro has more than 22 years of experience in the RF and microwave industry. He comes to BC Systems from Microphase Corp. where he was Manager of Business Development. He was previously a Regional Sales Manager at RLC Electronics, National Sales Manager at Polyflon Co., and earlier held management and engineering positions in the electronic industry.

2 W & 5 W
DC to 18 GHz ATTENUATORS

from $29.95 ea. (1-49)

Rugged Stainless Steel Construction, High Repeatability, Miniature Size, Low Cost, and Off-The-Shelf Availability are some of the features that make Mini-Circuits "BW" family of precision fixed attenuators stand above the crowd! This extremely broad band DC to 18 GHz series is available in 5 watt Type-N and 2 & 5 watt SMA coaxial designs, each containing 15 models with nominal attenuation values from 1 to 40 dB. Built tough to handle 125 watts maximum peak power, these high performance attenuators exhibit excellent temperature stability, 1.15:1 VSWR typical, and cover a wealth of applications. So contact Mini-Circuits today, and capture this next generation of performance and value! *Mini-Circuits...Your partners for success since 1969*

MODELS (Add Prefix BW-)

2 W SMA $29.95	5 W SMA $44.95	5 W Type-N $54.95	Attenuation (dB) Nominal	Attenuation (dB) Accuracy*
S1W2	S1W5	N1W5	1	±0.40
S2W2	S2W5	N2W5	2	±0.40
S3W2	S3W5	N3W5	3	±0.40
S4W2	S4W5	N4W5	4	±0.40
S5W2	S5W5	N5W5	5	±0.40
S6W2	S6W5	N6W5	6	±0.40
S7W2	S7W5	N7W5	7	-0.4, +0.9
S8W2	S8W5	N8W5	8	±0.60
S9W2	S9W5	N9W5	9	-0.4, +0.8
S10W2	S10W5	N10W5	10	±0.60
S12W2	S12W5	N12W5	12	±0.60
S15W2	S15W5	N15W5	15	±0.60

Now Available! **Adapters** (Prices: qty. 1-49)

Type-N to SMA
DC-18 GHz $22.95 ea.

SMA to SMA
DC-18 GHz from $4.95 ea.

QUICK CONNECT SMA

SMA to BNC
DC-2 GHz $3.95 ea.

Type-N to Type-N
DC-6 GHz $9.95 ea.

To order Attenuators as RoHS, add + to base model No. *Example: BW-S1W2+*
Adapters available as RoHS, see web site.

Mini-Circuits®
ISO 9001 ISO 14001 AS 9100 CERTIFIED
P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661

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U.S. patent 7739260

IF/RF MICROWAVE COMPONENTS

331 rev P

Visit http://mwj.hotims.com/28491-53 or use RS# 53 at www.mwjournal.com/info

▲ *Timothy Lacey*

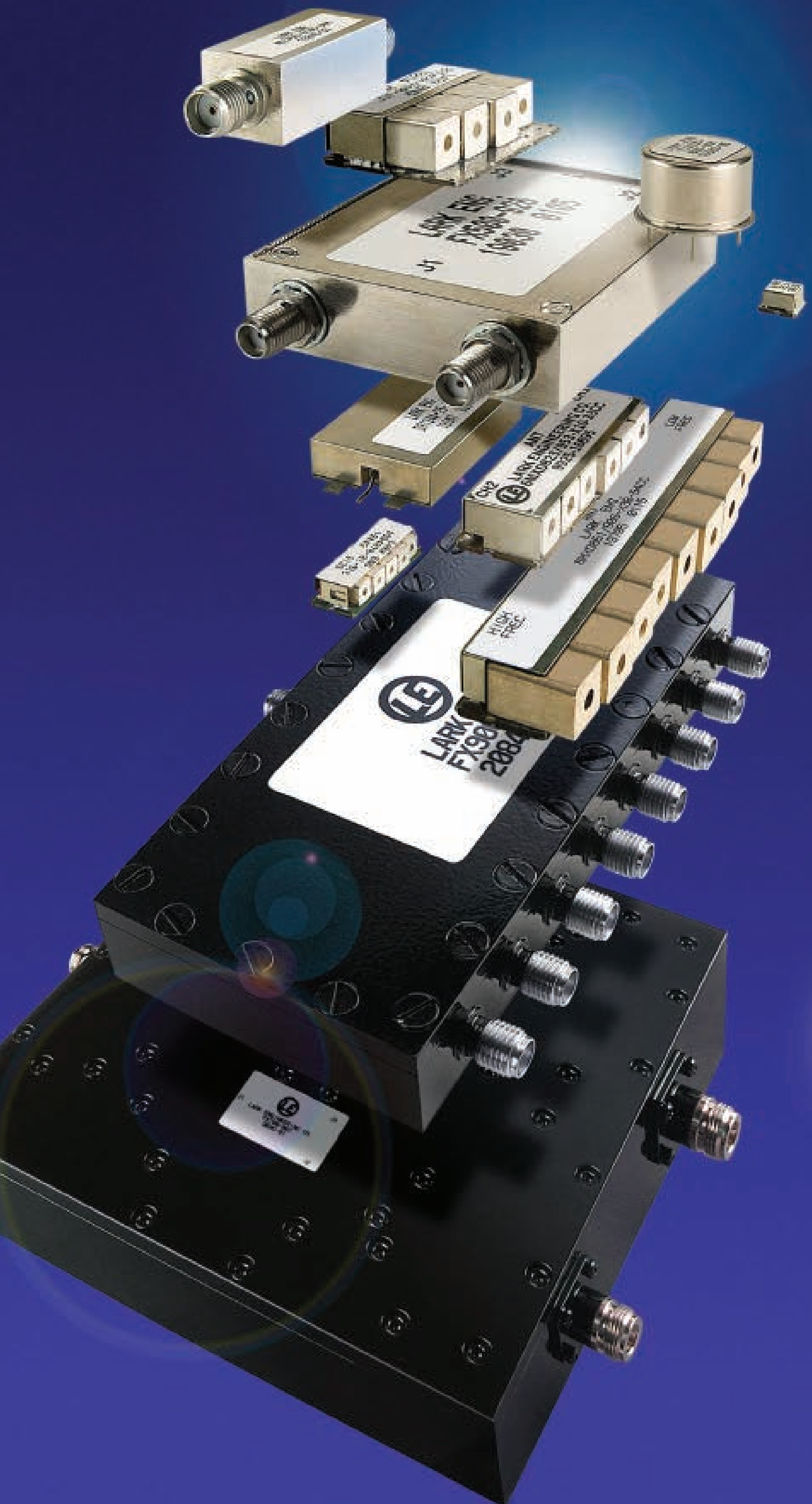
Thunderline-Z, a supplier of feedthrus and hi-rel packages to the RF/microwave community, has recently announced the appointment of **Timothy Lacey** to the position of National Sales Manager, effective immediately. Lacey most recently worked in the Emerson Climate Technologies Division in Sidney, OH, as a Strategic Commodity Manager, and has moved to Thunderline-Z where he will manage sales territories across the country. He obtained his Bachelor of Science Degree in Electrical Engineering from Ohio University and continued his education at the University of Pittsburgh where he obtained his Masters of Business Administration from the Katz Graduate School of Business.

REP APPOINTMENTS

International representation for **Endwave** in India will be covered by **Hicotronics Devices**, specifically by its military and space department. Hicotronics Devices will increase Endwave's international presence in India, and can be contacted by phone or e-mail (91-80-22420690/41203768, hicotronics.india@sril.net). **Alignment Co.** will do likewise for Endwave in China, as they are experienced professionals in the China IC market and understand the product technology, customer demands, channel management, and local business systems and methods. Located in Shenzhen, China, Alignment will cover all of China and can be reached by phone or e-mail (+86-755-82537066, dan.zhao@alignment-china.com, www.alignment-china.com). Tel Aviv-based **NextWave Technologies** will represent Endwave in Israel in its commitment to high-level engineering, sales and marketing to support both customers and manufacturers business models. NextWave can be contacted by phone or e-mail as well (972-3-9619000, michal@nextwave.co.il).

WEB SITE

RFCONNEXT Inc.'s new web page provides extensive information about the new high speed interconnect technologies PMTL™, VMTL™ and SMTL™, which together provide increased bandwidth for any high speed interconnects, thus help advancing the High Speed Interconnect Ecosystem. In addition to information, the web page provides a large number of white papers and information that will be of great interest to RF/microwave engineers as well as the high speed digital community. Additionally, the web page provides various examples of bandwidth enhancements in cables and connectors, high speed backplane, high speed and mmw packaging, test and measurement, and RF/microwave circuits and systems. For more information, visit www.rfconnext.com.



LARK ENGINEERING COMPANY

The Filter Source

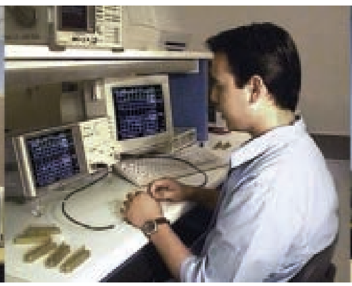
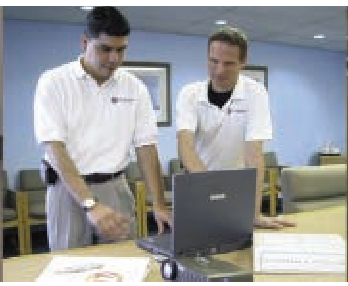
PRODUCT SELECTION GUIDE

LARK ENGINEERING COMPANY

A Division of Baier and Baier, Inc.

Lark Engineering Company is a leading supplier of RF and Microwave filters with ISO 9001 and ISO 14001 certifications. The company was established in 1987 with the goal to design and manufacture quality products to meet or exceed the customer's individual needs and requirements. Currently, Lark Engineering's products are being utilized in major digital and analog wireless devices ranging in use from communications systems to test equipment and military systems. Lark Engineering also produces filters for GPS, Cellular, ISM, PCN, PCS and many other wireless applications. For each customer, Lark Engineering is committed to providing the very best quality of filters and is dedicated to meeting our customers Microwave and Radio Frequency filter needs. Our commitment to quality and customer service has been a cornerstone of the company since its inception.

Today, with an ever-changing industry, Lark Engineering continues to be the leader in RF and Microwave filters by focusing on design, quality and customer service. We offer an extensive product mix with filters and Multiplexers that satisfy requirements from 100 KHz to 20 GHz. Our web based filter design tool allows you to design Band Reject, Surface Mount Combline, High Power Ceramics and many other filters. Many of our filters can be sampled in as little as 10 days.


Lark Engineering Standard Filter Capabilities include the following:

BANDPASS	CENTER FREQUENCY RANGE	3dB BW (% OF Fc)	CONFIGURATION
MC	1 – 5000 MHz	2 – 50	Miniature PCB Mount / SMA
SMC	5000 – 15000 MHz	3 – 20	SMT Combline
MS	1 – 5000 MHz	2 – 50	SMT Leadless
SD	250 – 5000 MHz	1 – 10	SMT Leadless Ceramic
SDP	800 – 2000 MHz	3 – 7	High Power Ceramic
3B	1000 – 18000 MHz	1 – 50	Combline Coaxial Connecters
4B	1000 – 18000 MHz	1 – 50	Combline Coaxial Connecters
2C	50 – 400 MHz	1 – 2.5	Cavity
3C	400 – 2000 MHz	0.2 – 3.5	Cavity
4C	800 – 2500 MHz	0.2 – 3.5	Cavity
5C	1000 – 3000 MHz	0.2 – 3.5	Cavity
6C	2000 – 7500 MHz	0.2 – 3.5	Cavity

BAND REJECT	CENTER FREQUENCY RANGE	3dB BW (% OF Fc)	CONFIGURATION
SDN	800 – 2500 MHz	1 – 5	SMT Leadless Ceramic

HIGHPASS	CUT OFF FREQUENCY RANGE	CONFIGURATION
HMS	10 – 1500 MHz	SMT Leadless
HMC	10 – 2000 MHz	Miniature PCB / SMA

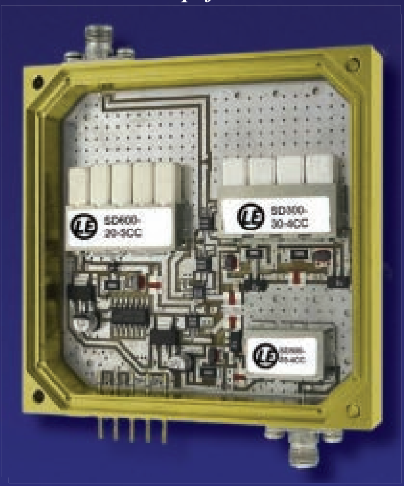
LOWPASS	CUT OFF FREQUENCY RANGE	CONFIGURATION
LMS	1 – 2500 MHz	SMT Leadless
LMC	1 – 3500 MHz	Miniature PCB / SMA

Please call Lark Engineering if your requiements fall outside of our standard range.

Switch Filter Systems

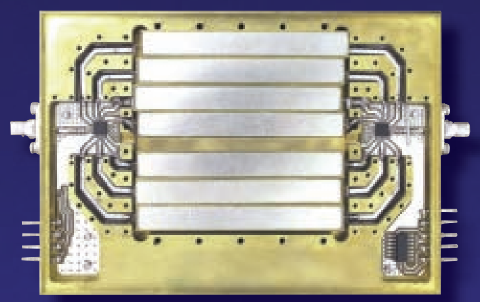
Lark's new Switch Filter Systems are designed with a wide array of Switch Filter Banks and low noise amplifiers. They are available in Ceramic and Lumped Element configurations, low profile connectorized packages and a wide frequency range. Switch Filters are ideally suited for receiver applications and assisting in overall system performance.

Switch Filter Amplifier- SFA series



SPECIFICATION	STANDARD
Frequency	100 to 3000 MHz
3dB Bandwidth	1 to 40%
Nominal Impedance	50 Ω
Gain	10 to 40 dB
Return Loss	18 dB Typical 14 dB Min.
Noise Figure	1.5-5.0 dB Typical
Number of chanels	2, 3, 4, 5, and 6
Switching Speed	300 ns Max.
Bias	+ 10 V DC, + 5 V DC
Shock	5 G's
Gross Leak	Mil STD 202 Method 112 Condition D
Fine Leak 10^ -7	Mil STD 202 Method 112 Test Condition C
Vibration	5 G's
Humidity	95%
Altitude	+/- 50,000 ft
Package	SMA, feed thru pins, or SMT

Switch Filter Bank- SFB series

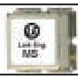
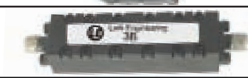
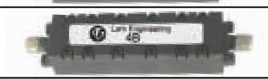
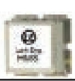


SPECIFICATION	STANDARD
Frequency	100 to 3000 MHz
3dB Bandwidth	1 to 40%
Nominal Impedance	50 Ω
Max Insertion Loss	3 - 7 dB
Return Loss	14 dB Min.
Number of chanels	2, 3, 4, 5, 6, 7, and 8
Switching Speed	300 ns Max.
Bias	-5 V DC / + 5 V DC
Shock	5 G's
Gross Leak	Mil STD 202 Method 112 Condition D
Fine Leak 10^ -7	Mil STD 202 Method 112 Test Condition C
Vibration	5 G's
Humidity	95%
Altitude	+/- 50,000 ft
Package	SMA, feed thru pins, or SMT

Contact Lark Engineering with your specific needs

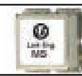
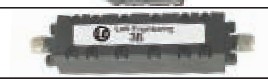
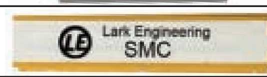
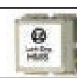
ELECTRICAL SPECIFICATIONS

1 MHz to 20 GHz

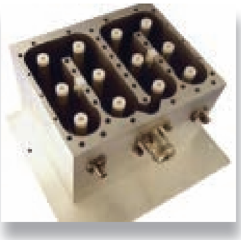
Series		*Configuration*	*Center Frequency (Fc)*	*Number of sections*	*Nominal Impedance*	*Max. VSWR*	*Max. Input Power (avg.)*	*Max. Input Power (peak)*
BANDPASS FILTERS								
MS		Surface Mount	1 to 5000 MHz	3 to 6	50 Ω	1.5/1	2 W	20 W
			1 to 6500 MHz	2 to 10	50 to 300 Ω	1.3/1	10 W	50 W
MC		Miniature	1 to 5000 MHz	3 to 6	50Ω	1.5/1	2 W	20 W
			0.1 to 6500MHz	2 to 10	50 to 300 Ω	1.3/1	20 W	100 W
SD		Ceramic	250 to 5000 MHz	2 to 6	50Ω	2/1	1 W	2 W
			200 to 6000 MHz	2 to 10	50 to 75 Ω	1.5/1	10 W	50 W
SDP		High Power	800 to 2000 MHz	2 to 4	50Ω	1.5/1	50 W	250 W
		Surface Mount	650 to 2250 MHz	2 to 5	50 to 75 Ω	1.3/1	50 W	250 W
SDN		Band Reject	800 to 2500 MHz	3 to 6	50 Ω	2/1	1 W	2 W
		Surface Mount	400 to 3500 MHz	2 to 8	50 to 75 Ω	1.5/1	2 W	10 W
3B		Combline	1000 to 18000 MHz	3 to 10	50 Ω	1.5/1	Up to 20 W	Up to 200 W
			1000 to 20000 MHz	2 to 14	50 Ω	1.3/1	Call Lark	Call Lark
4B		Miniature	1000 to 18000 MHz	3 to 8	50 Ω	1.5/1	Up to 10 W	Up to 100 W
		Combline	1000 to 20000 MHz	2 to 14	50 Ω	1.3/1	Call Lark	Call Lark
SMC		Surface Mount	5000 to 15000 MHz	2 to 6	50 Ω	1.5/1	Call Lark	Call Lark
		Combline						
2C		Hi-Q	50 to 400 MHz	3 to 6	50 Ω	1.5/1	Up to 8 W	Up to 37.5 W
		Cavity	50 to 500 MHz	2 to 7	50 to 100 Ω	1.3/1	Call Lark	Call Lark
3C		Hi-Q	400 to 2000 MHz	3 to 6	50 Ω	1.5/1	Up to 30 W	Up to 30 W
		Cavity	400 to 2500 MHz	2 to 7	50 Ω	1.3/1	Call Lark	Call Lark
4C		Hi-Q	800 to 2500 MHz	3 to 6	50 Ω	1.5/1	Up to 50 W	Up to 200 W
		Cavity	750 to 2500 MHz	2 to 7	50 Ω	1.3/1	Call Lark	Call Lark
5C		Hi-Q	1000 to 3000 MHz	3 to 6	50 Ω	1.5/1	Up to 7.5 W	Up to 30 W
		Cavity	800 to 4000 MHz	2 to 7	50 Ω	1.3/1	Call Lark	Call Lark
6C		Hi-Q	2000 to 7500 MHz	3 to 6	50 Ω	1.5/1	Up to 7.5 W	Up to 30 W
		Cavity	2000 to 9000 MHz	2 to 7	50 Ω	1.3/1	Call Lark	Call Lark
LOWPASS FILTERS			CUT OFF FREQUENCY					
LMS		Surface Mount	1 to 2500 MHz	3 to 6	50 Ω	1.5/1	2 W	20 W
			0.5 to 3000 MHz	2 to 10	50 to 300 Ω	1.3/1	10 W	50 W
LMC		Miniature	1 to 3500 MHz	3 to 6	50 Ω	1.5/1	2 W	20 W
			0.5 to 5500 MHz	2 to 10	50 to 300 Ω	1.3/1	20 W	100 W
HIGHPASS FILTERS			CUT OFF FREQUENCY					
HMS		Surface Mount	10 to 1500 MHz	3 to 6	50 Ω	1.5/1	2 W	20 W
			1 to 2500 MHz	2 to 10	50 to 300 Ω	1.3/1	10 W	50 W
HMC		Miniature	10 to 2000 MHz	3 to 6	50 Ω	1.5/1	2 W	20 W
			1 to 3000 MHz	2 to 10	50 to 100 Ω	1.3/1	20 W	100W

ENVIRONMENTAL SPECIFICATIONS

ISO 9001 and ISO 14001 Certified

Shock	*Vibration*	*Humidity (% Relative)*	*Temp. Range (Operating)*	*Temp. Range (Non- Operating)*			*Series*
							BANDPASS FILTERS
20 G's	10 G's	95%	-40˚C to + 85˚C	-65˚C to + 125˚C	Standard		**MS**
75 G's	30 G's	95%	-55˚C to + 125˚C	-65˚C to + 150˚C	Special		
20 G's	10 G's	95%	-40˚C to + 85˚C	-65˚C to + 125˚C	Standard		**MC**
75 G's	30 G's	100%	-55˚C to + 125˚C	-65˚C to + 150˚C	Special		
20 G's	10 G's	95%	-40˚C to + 85˚C	-65˚C to + 125˚C	Standard		**SD**
75 G's	30 G's	100%	-55˚C to + 125˚C	-65˚C to + 150˚C	Special		
15 G's	5 G's	90%	-30˚C to + 85˚C	-54˚C to + 100˚C	Standard		**SDP**
75 G's	30 G's	100%	-54˚C to + 100˚C	-62˚C to + 150˚C	Special		
15 G's	5 G's	90%	-30˚C to + 85˚C	-54˚C to + 100˚C	Standard		**SDN**
75 G's	30 G's	100%	-54˚C to + 100˚C	-62˚C to + 150˚C	Special		
25 G's	10 G's	95%	-40˚C to + 85˚C	-65˚C to + 125˚C	Standard		**3B**
50 G's	20 G's	100%	-55˚C to + 125˚C	-65˚C to + 150˚C	Special		
25 G's	10 G's	95%	-40˚C to + 85˚C	-65˚C to + 125˚C	Standard		**4B**
50 G's	20 G's	100%	-55˚C to + 125˚C	-65˚C to + 150˚C	Special		
Call Lark	Call Lark	95%	-40˚C to + 85˚C	-54˚C to + 100˚C	Standard		**SMC**
20 G's	10 G's	95%	-25˚C to + 85˚C	-54˚C to + 125˚C	Standard		**2C**
20 G's	15 G's	100%	-54˚C to + 85˚C	-54˚C to + 125˚C	Special		
20 G's	10 G's	95%	-25˚C to + 85˚C	-54˚C to + 125˚C	Standard		**3C**
20 G's	15 G's	100%	-54˚C to + 85˚C	-62˚C to + 125˚C	Special		
20 G's	10 G's	95%	-25˚C to + 85˚C	-54˚C to + 125˚C	Standard		**4C**
25 G's	20 G's	100%	-54˚C to + 85˚C	-54˚C to + 125˚C	Special		
20 G's	10 G's	95%	-25˚C to + 85˚C	-54˚C to + 125˚C	Standard		**5C**
25 G's	20 G's	100%	-54˚C to + 85˚C	-54˚C to + 125˚C	Special		
20 G's	10 G's	95%	-25˚C to + 85˚C	-54˚C to + 125˚C	Standard		**6C**
25 G's	20 G's	100%	-25˚C to + 85˚C	-54˚C to + 125˚C	Special		
							LOWPASS FILTERS
20 G's	10 G's	95%	-55˚C to + 85˚C	-65˚C to + 125˚C	Standard		**LMS**
50 G's	15 G's	100%	-55˚C to + 100˚C	-65˚C to + 125˚C	Special		
20 G's	10 G's	95%	-55˚C to + 85˚C	-65˚C to + 125˚C	Standard		**LMC**
50 G's	15 G's	100%	-55˚C to + 100˚C	-65˚C to + 125˚C	Special		
							HIGHPASS FILTERS
20 G's	10 G's	95%	-55˚C to + 85˚C	-65˚C to + 125˚C	Standard		**HMS**
50 G's	15 G's	100%	-55˚C to + 100˚C	-65˚C to + 125˚C	Special		
20 G's	10 G's	95%	-55˚C to + 85˚C	-65˚C to + 125˚C	Standard		**HMC**
50 G's	15 G's	100%	-55˚C to + 100˚C	-65˚C to + 125˚C	Special		

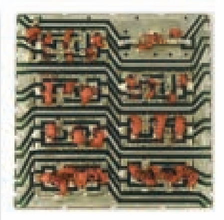
LARK ENGINEERING CAPABILITES



Satcom Diplexer

In response to the current market demand for a lighter filter with a reduced form factor while maintaining competitive electrical performance, Lark offers its Compact Satcom Diplexers. Our new design saves both space and weight for all systems working in the Satcom bands.

- Standard Diplexer Dimensions: 21.00” L x 6.50” W x 5.00” H
- Compact Diplexer Dimensions: 6.25” L x 3.00” W x 2.00” H

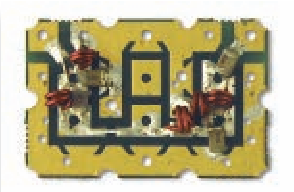


Ceramic Diplexers

Lark Engineering’s family of ceramic diplexers is based on our stand-alone ceramic filter series. The ceramic diplexer series uses a PCB / PWB board carrier with outputs in the corners and an axial port along the opposite side to provide the best channel-to-channel isolation. Through the addition of input match- ing circuitry, the ceramic diplexer is able to provide the best common junction match. Our design algo- rithms are capable of matching any two non-contiguous passbands using various filter configurations.

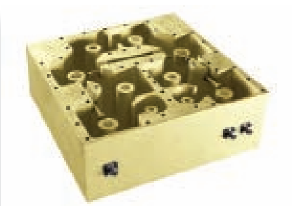
Triplexers and Multiplexers

Along with the Diplexer series of filters, Lark also offers Triplexers and Multiplexers. By creating a basic network of three or more bandpass series filters, a Triplexer or Multiplexer is able to separate the pass- band frequencies and apply the signal to isolated terminals. The passband of the individual network may be contiguous or separated by overlapping stopbands.



Ultra Compact Ceramic Filters

When board space is a premium and getting the best performance in a very small footprint is a must, Lark can offer ultra compact ceramic filters with resonator sizes as small as 1.5mm. The filter performance you need from a standard ceramic filter but in a size equal to or smaller than 8x8mm depending on the number of resonators.

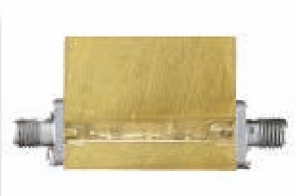


Elliptic Function Filters

Elliptic designs are available for very sharp rejection responses. This type of response can be used on Lump Element, Ceramic and Cavity filter designs.

Cross Coupled Cavities

To improve rejection in your filter without increasing the filters size, Lark offers a cross coupled cavity filter design. Using a Semi-Elliptical arrangement; resonators are cross-coupled to approach zeros in transmis- sion. The zeros in transmission can be placed in the upper or lower side of the Rejection skirt depending on your needs.



True Tune™ Test Fixtures

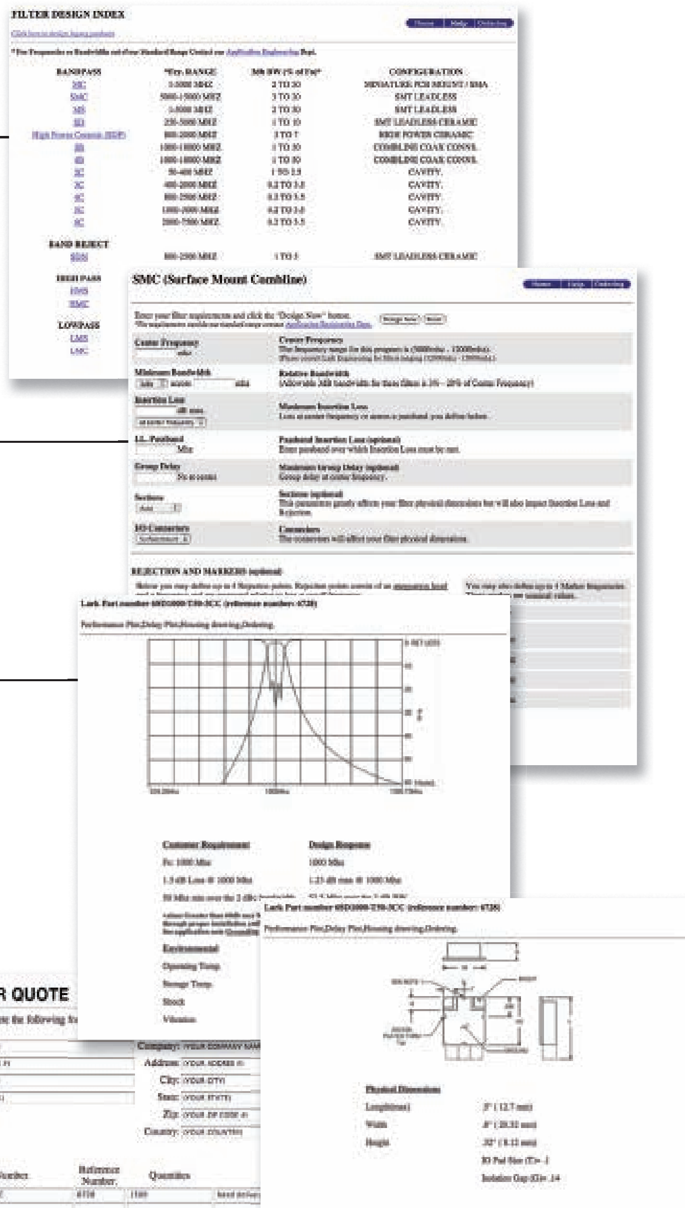
With designs becoming more and more complex, it is essential that the performance of the filters be similar on a test fixture as on your board. Lark Engineering will take your PCB / PWB and create a test fixture to fine tune the filters. This will significantly reduce the need for final tuning in production by matching the impedance and capacitance associated with your board. Lark offers this service to its customers to facilitate their time to market and success.

Legacy Filters

In addition to our surface mount and ceramic bandpass filters, Lark Engineering continues to offer the 2B, TO-8 and Tubular filter series. The 2B series is an interdigital configuration ranging in center frequency from 1,000 to 12,000MHz. The TO-8 series is offered in Lowpass, Highpass and Bandpass, and range in center frequency from 10 to 5000 MHz. The Tubular series offers Bandpass, Lowpass and Highpass filters ranging in center frequency of 60 to 8000 MHz.

LARK ENGINEERING FILTER DESIGN TOOL

Visit our web site FILTER DESIGN TOOL at www.larkengineering.com. CLICK ON THE FILTER DESIGN TOOL ICON. Just follow the simple steps to determine the optimal filter Lark Engineering can offer for your requirements. At any time you can click on the HELP button and use the FILTER DESIGN DEMO for directions and examples.

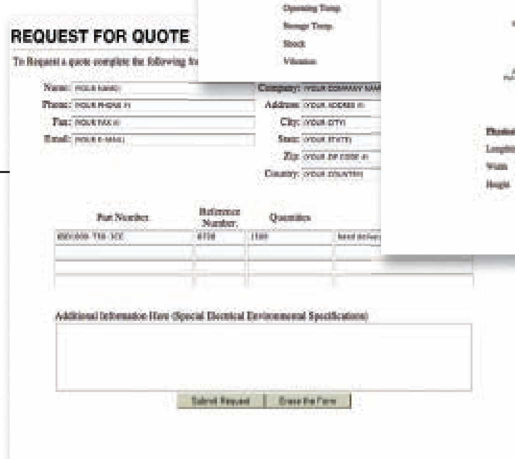


1 ***Select a FILTER SERIES in the left hand column. If you are not sure which series to use, check out our Filter Index page.***

2 ***Enter your filter requirements... your desired frequency, bandwidth, Insertion Loss, etc.***

3 ***Click the "Design Now" button.***

If your filter design is outside of Lark's standard range, forward your captured requirements to Lark via e-mail: Sales@larkengineering.com, or fax to: 949-240-7910.



For your convenience, a request for quote form is available on our website.

LARK ENGINEERING COMPANY

A Division of Baier and Baier, Inc.

27282 Calle Arroyo
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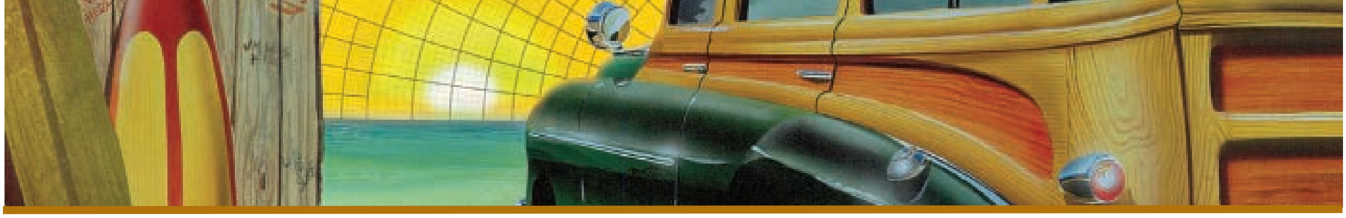
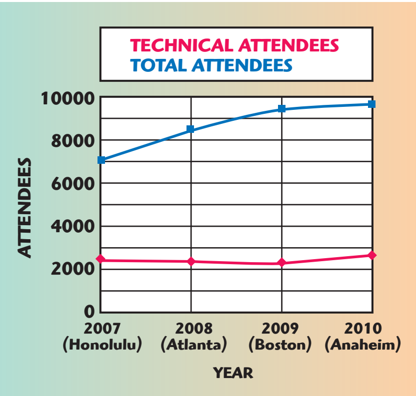


Making Waves in California: 2010 MTT-S IMS Wrap Up

This year's MTT-S IMS seemed to be a turning point for the industry as the business atmosphere seemed very positive and the show floor busier than the past few years. Going back to Hawaii in 2007, where the total attendance declined significantly, the number of people attending has increased each year; the preliminary numbers this year showed a seven percent increase in total attendance (see ***Figure 1***). The IEEE reported preliminary numbers of 9500 attendees, with technical registration numbers totaling 2,793 participants with 858 papers submitted and over 250 presented orally. The interactive forum saw 122 papers presented and new tracks were added for emerging technologies. This year's IMS Chairman, JK McKinney, and his team did a great job running the event and the technical program was strong.

Madhu Gupta, Chairman of the IMS Technical Program Committee, had 32 sub-committees reviewing papers and this year added a new category called New Emerging Technologies. The committee then found appropriate experts in each area to evaluate them. New sessions were added for RFID, high power microwaves for industrial/material processing and power scavenging technologies.

Other happenings included the student paper and design contests, panel sessions, workshops, short courses, MicroApps seminars on the show floor and the historical exhibit, which means there was no shortage of technical content for the week. The plenary presentation was Tuesday with the Honorable Zachary J. Lemnios, CTO for the Department of Defense (DoD), discussing an overview of a number of defense related technology opportunities and challenges.



▲ *Fig. 1 MTT-S IMS attendee totals (preliminary numbers for 2010).*

The RFIC Symposium took place on Sunday through Tuesday with workshops, sessions and a plenary session Sunday evening on "RF Power Amplification: Can CMOS Deliver?" by David J. Allstot of the University of Washington and "RF Application Trends of the Next Decade" by Gregory L. Waters, Executive VP and General Manager of Skyworks.

The ARFTG Microwave Measurement Conference took place on Friday and included technical presentations, an interactive forum and exhibition. The conference theme was "Measurement of Modulated Signals for Communications."

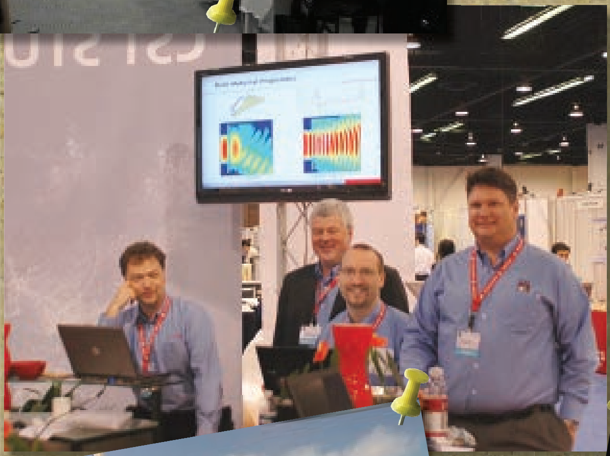
The commercial side of the event (aka - the exhibition) saw good traffic and increased activity from what most exhibitors reported to us. The exhibit floor showcased a total of 556 companies and 892 booths representing 40 countries to support the event. The exhibit-only registration numbers indicated 2,687 participants according to a preliminary count. The MicroApps presentations on the show floor attracted a wide audience and array of technologies; it seems to be coming into its own as an attraction for more applications oriented topics.

Some of the trends that we found were increased PIM testing (probably becoming a standard test soon for base stations), nonlinear behavioral modeling increasing its adoption, increased sensitivity/speed in test equipment to find signals that previously would not be detected, an increased presence of CMOS and GaN devices, high efficiency amplifiers (Doherty, feed forward, envelope tracking, etc., with one paper on 90 percent efficient devices), new low noise amplifiers with less than 0.5 dB noise figure for cellular applications, new compact filters for co-existence of signals in mobile applications, very low phase noise sources and new passive integration platforms.

Microwave Journal editors were extremely busy visiting exhibitors and covering the event. See our final coverage of the show from our link on the Events page at www.mwjournal.com/IMS2010Wrap for a complete summary of the new products and demos on the exhibition floor, video interviews and product demonstrations, photos, show news and more.

Pat Hindle
Editor, *Microwave Journal*

IMS 2010 Anaheim, California



Photos courtesy of Shmuel Auster and David Strand.

A THIN, LOW-PROFILE ANTENNA USING A NOVEL HIGH IMPEDANCE GROUND PLANE

The size of the antenna for a given application does not depend purely on the technology, but on the laws of physics where the antenna size with respect to the wavelength has the predominant influence on the radiation characteristics. With modern day communication devices becoming smaller and lighter, demand for low-profile antenna designs is greater than ever.[1]

One way of realizing a low-profile antenna design is to use a high impedance ground plane in place of the conventional metallic ground plane.[2-7] Metallic plates are used as ground planes to redirect the back radiation and provide shielding to the antennas. By nature, the conventional ground planes that are perfect electric conductors (PEC) exhibit the property of phase reversal of the incident currents that result in destructive interference of both the original antenna currents and the image currents. To overcome this effect, antennas are to be placed at a quarter wavelength above the metallic ground plane, making the size of the antenna bulky at low frequencies. To reduce the size of the antenna, a ground plane that is a dual of the conventional PECs is needed; in other words, a perfect magnetic conductor (PMC) is required. But how can a PMC that is not available in nature be realized? The answer to this problem is provided in the form of high impedance surfaces (HIS), which can essentially be considered as artificial magnetic conductors.[8,9]

HISs are popular for their widespread applications in reflect array antennas, low-profile antennas, electromagnetic absorbers and polarizers.[10-13] These surfaces exhibit unique properties like the in-phase reflection of incident waves and the suppression of surface waves. Different antenna parameters such as gain, impedance and size can be enhanced by incorporating the HISs into the antenna structures. The design of the HISs can be optimized to tailor their electromagnetic properties depending on the operational requirements. Computer-aided design tools have enabled the solution of complex problems by means of numerical optimization algorithms.[14,15] A large number of optimization methods are presently available for solving electromagnetic problems. Deciding the most appropriate method for a given problem, however, is a non-trivial task and depends on factors like the number and range of the varying parameters, the goal of the

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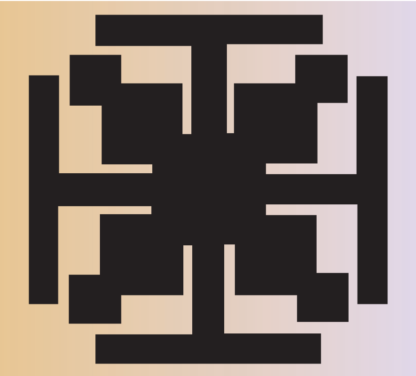
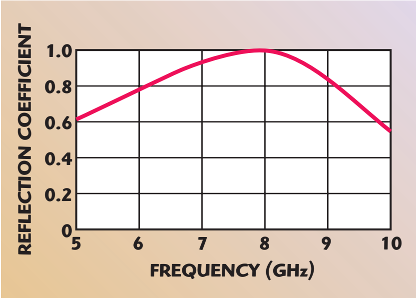
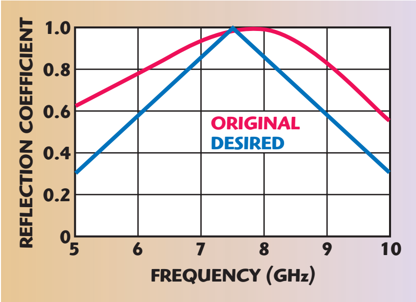


▲ *Fig. 1 The FSS unit cell.*



▲ *Fig. 2 Reflection coefficient of a periodic array of unit cells.*



▲ *Fig. 3 FSS reflectivity behavior, original and desired goal.*

optimization, the model size and the resources available.

Two-dimensional (2D) arrays of periodic resonant elements (printed or complementary slot) interact with electromagnetic waves within certain frequency band(s) and can be characterized as frequency selective surfaces (FSS). Different FSS elements have been described in the literature, where each design has its own advantage over the other. The multiband dipole structures are polarization dependent, the symmetric designs are dual-polarized and the fractal structures are compact designs. The HIS is realized by printing the periodic array of FSSs over a metal-backed dielectric substrate. It is important to optimize the performance of HIS over the frequencies of interest. It is observed that the characteristics of the FSS and HIS follow each other. This correlation can be exploited to speed up the optimization process by carrying out the design in two steps:

- Optimize the free-standing FSS
- Realize the HIS by printing the optimized FSS on a metal-backed dielectric substrate

Even though there is growing demand for wideband antennas, a narrowband design has its advantages in cordless and wireless phone applications that operate at 49 MHz, 900 MHz, 2.4 GHz and 5.8 GHz. Interference from adjacent frequency bands can be avoided by using narrowband antennas that operate only around the frequency of interest. This article describes a novel FSS structure that is optimized for steep behavior of the reflection coefficient. The FSS unit cell is the combination of a Jerusalem cross and a three-step fractal patch, as shown in ***Figure 1***. The reflection characteristics of the FSS structure are explored in designing a HIS that can be used as a potential substrate for antennas in cordless phone applications to reduce cross talk. The performance of the HIS substrate is demonstrated with a 5.8 GHz low-profile monopole (quarter wavelength) antenna with a 0.07 λ dielectric thickness. The monopole is first analyzed as a wire structure; this design is then translated to a printed format.

FSS DESIGN AND OPTIMIZATION

The operation of the FSS structure depends on the resonance of the unit cell. A periodic array of the unit cell interacts with the electromagnetic wave and resonates at certain frequencies, where it acts as a band stop filter with total reflection of the incident plane wave, as shown in ***Figure 2***.

The initial design of the FSS structure with broadband characteristics is optimized for sharp narrow band characteristics. The commercial software FEKO[22] is used for the analysis of the FSS structure using two different optimization methods: Simplex Nelder-Mead and Particle Swarm Optimization (PSO).[20]

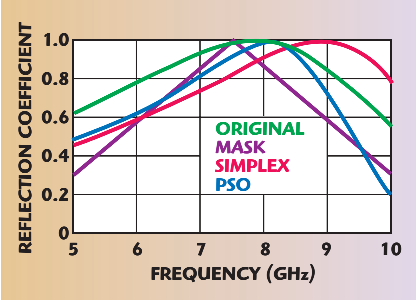
Simplex (Nelder-Mead Method)

The Simplex Nelder-Mead algorithm is a local or hill climbing algorithm in which the final optimum relies strongly on the starting point. The term simplex refers to the geometric figure formed by a set of N+1 points in an N-dimensional space. The basic idea of the simplex method is the comparison of values of the combined optimization goals at the N+1 points of the general simplex (where each point represents a single set of parameter values) to facilitate the movement of the simplex towards the optimum point during an iterative process. The movement of the simplex is achieved using three operations: reflection, expansion and contraction.

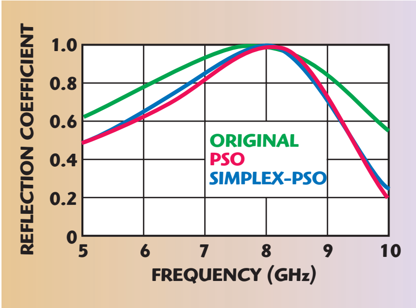
Particle Swarm Optimization (PSO)

Particle Swarm Optimization is a global search algorithm, which is a population-based stochastic evolutionary computation technique based on the movement and intelligence of swarms found in nature. The mechanism of PSO can be best described using the analogy of a swarm of bees in a field, whose goal is to find the highest concentration of flowers where each bee represents a set of parameter values. Every bee has information about the position of flower abundance based on its own experience (local best) and the position of maximum flower abundance based on the experience of all the other bees (global best). Based on the weights given to individuality or peer pressure, a bee flies in a direction between the positions of the local and the global bests. Once the flying is done, the bee conveys the new found information to all the other bees, which then adjust their positions and velocities. With this constant exploring and exchange of information, all the bees are eventually drawn towards the position of the highest concentration of flowers. The possible optimization parameters/variables in the proposed FSS unit cell are the dimensions of the Jerusalem cross arms and the fractal patch. An optimization mask was used to specify the optimization goal, as shown in ***Figure 3***.

Being a local optimizer, the convergence of the Simplex algorithm is much faster compared to the global optimizer PSO. However, unlike the global optimizer PSO, the success of the Simplex depends on the starting point, which carries the disadvantage



▲ *Fig. 4 Comparison of Simplex and PSO algorithms.*



▲ *Fig. 5 Comparison between PSO and Simplex-PSO hybrid optimization.*

of converging to a local minimum. From ***Figure 4***, it is clear that the global optimizer PSO was able to approximate the mask more closely compared to the Simplex, but at the cost of a huge run time.

To improve the chances of reaching the global minimum without compromising on the speed of convergence, PSO is hybridized with Simplex, where the global optimizer will be used to find the starting point for the local optimizer. The hybridized method has improved the speed of the optimizer without compromising on the ability to reach the global goal. In this process, the local optimizer was started after 100 iterations of the global optimizer. The local optimizer Simplex converged to the global minimum in 154 iterations, as shown in ***Figure 5***, reducing the runtime by 95 percent. ***Table 1*** describes the number of iterations and the time taken for each optimization algorithm to converge on a 2 GHz, EM64T Linux machine that has 2 physical CPUs with 4 cores per CPU.

HIS DESIGN AND VALIDATION

The optimization completes the first step in the realization of the artificial magnetic conductor, taking the design process to the next stage, where the optimized FSS structure is printed on a metal-backed dielectric substrate. The

TABLE I

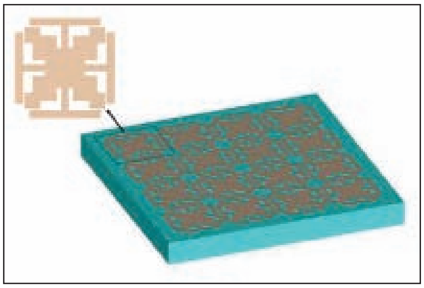
OPTIMIZATION RUN TIMES

Optimization Algorithm	No. of Iterations	Time Taken (hrs.)
PSO	5000	900
Simplex	179	32.2
PSO+Simplex	100+154	45.7

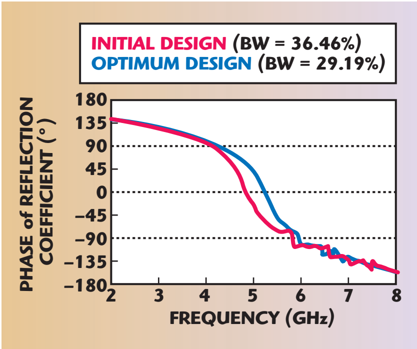
TABLE II

HIS DESIGN PARAMETERS

Periodicity of the unit cell	7.6 mm
Dielectric constant of the substrate	ε_r=2.2
Height of the substrate	3 mm = 0.07 λ_d



▲ *Fig. 6 HIS realized with optimized FSS.*



▲ *Fig. 7 Reflectivity characteristics of HIS realized with un-optimized and optimized FSS.*

design parameters of the HIS shown in ***Figure 6*** are given in ***Table 2***, where λ_d denotes the wavelength inside the dielectric at 5.8 GHz.

The reflectivity characteristics of the HIS ground planes realized using the un-optimized and the optimized FSS structures reveals the correlation between the FSS and the HIS. The HIS realized with optimized FSS reduced the bandwidth of the un-optimized design by 7 percent, as shown ***Figure 7***, where the bandwidth is defined for the phase of the reflection coefficient varying between +90° and -90°.

Unlike the conventional PEC ground planes, antennas can be placed very close to the surface of the

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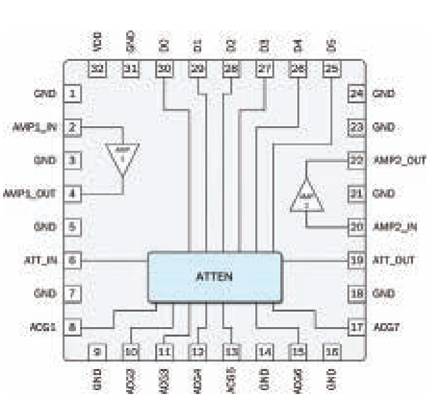
Freq Range (Min) (MHz)	*Freq Range (Max) (MHz)*	*Number of Bits*	*Gain (dB)*	*Step Size (dB)*	*P1dB (dBm)*	*OIP3 (dBm)*	*Interface*	*V_{cc} (V)*	*Package (mm)*	*Part Number*
50	850	6	18.5	0.5	20.0	42.0	serial	5.0	5 x 5 MCM	RFDA0025
50	850	6	18.5	0.5	20.0	42.0	parallel	5.0	5 x 5 MCM	RFDA0015
50	4000	6	18.5	0.5	21.0	39.0	serial	5.0	5 x 5 MCM	RDA1005L
50	850	6	38.5	0.5	20.0	42.0	serial	5.0	6 x 6 MCM	RFDA0016
50	1000	6	38.5	0.5	20.0	42.0	parallel	5.0	5 x 5 MCM	RDA2032Z
400	2500	6	11.5	0.5	25.0	42.0	serial	5.0	5 x 5 MCM	RFDA2025
400	2500	6	11.5	0.5	25.0	42.0	parallel	5.0	5 x 5 MCM	RFDA2015
850	1035	6	32.0	0.5	24.0	41.0	serial	5.0	6 x 6 MCM	RFDA0026
1800	2400	6	32.0	0.5	25.0	43.0	serial	5.0	6 x 6 MCM	RFDA2026

RDA2032Z



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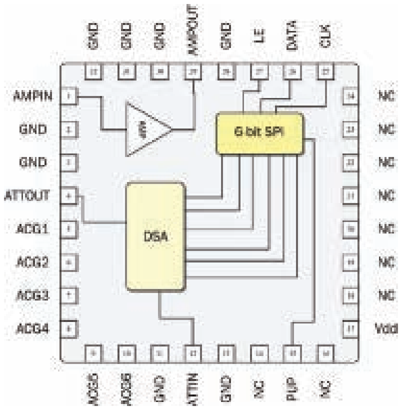

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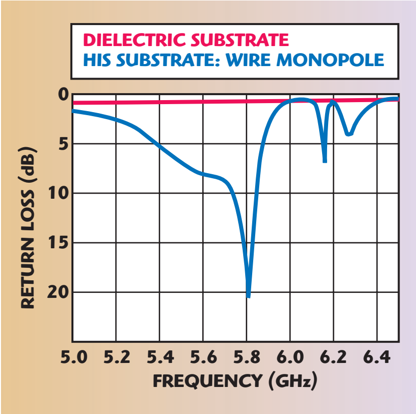
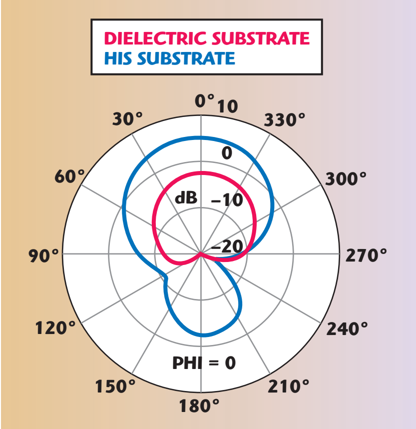


▲ *Fig. 8 Return loss of monopole on HIS and dielectric substrate.*

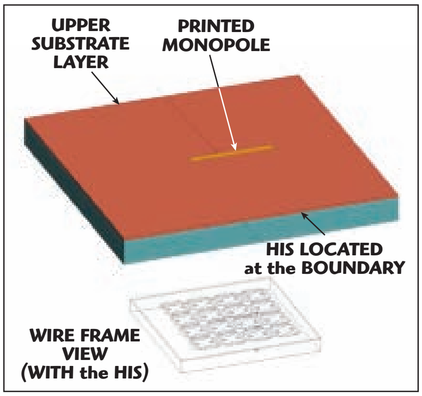


▲ *Fig. 9 Monopole antenna gain on HIS and dielectric substrate at 5.8 GHz.*

HIS ground plane resulting in a low-profile design.[21] The performance of the low-profile design is tested with a quarter wave (at cordless frequency of 5.8 GHz) monopole antenna with the HIS ground plane and a metal-backed dielectric substrate of same thickness. ***Figures 8*** and ***9*** validate the performance of the HIS ground plane with low return loss and an improvement of 7.5 dB in the gain over the metal-backed dielectric substrate.

PLANAR ANTENNA

Antennas are generally preferred in a printed format, so that they can be made flush with the surrounding environment. Printed planar antennas also have the advantage of being cheap and more convenient to manufacture and lend themselves more easily to mass production than non-printed antennas. For these reasons the design is transferred from the protruding cylindrical monopole structure to one involving a planar printed monopole. The wire monopole (modeled as a cylinder) is transformed to the printed monopole using the well known formula $\alpha = 0.25w$, where 'a' is the radius of the cylinder and 'w' is the width of the strip. This strip monopole is located at the same height as the axis of the cylindrical monopole to keep the electromagnetic relationship between the High Impedance Surface (HIS) and the monopole intact. It is not desirable that the gap between the strip monopole and the top surface be left as free-space as this leaves the monopole vulnerable to damage and also defeats the purpose of ease of manufacture. In order to avoid these problems this space is filled with a dielectric superstrate (relative to the HIS) that has the same dielectric properties as the substrate. ***Figure 10*** shows the printed monopole antenna on top of the newly added dielectric layer. The HIS is located at the boundary of the dielectric layers and can be seen in the wire frame view. A TEM mode is excited from the end of a coaxial cable, whose outer conductor terminates at the ground plane and inner conductor extends further through the substrate to excite one end of the monopole.



▲ *Fig. 10 Printed monopole antenna with the HIS between the substrate layers.*

Replacing the air layer with a dielectric substrate alters the electrical length of both the monopole and the HIS, thereby moving the resonant frequency away from the desired value of 5.8 GHz. To re-tune the antenna back to 5.8 GHz, the monopole is scaled by a factor of

$$\frac{1}{\sqrt{(\varepsilon_r+1)/2}}$$

and the HIS by a factor of

$$\sqrt{\left(\frac{\varepsilon_r+1}{2}\right)\Big/\varepsilon_r}$$

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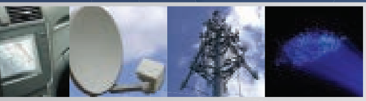

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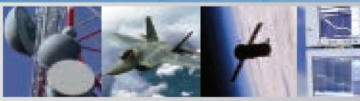

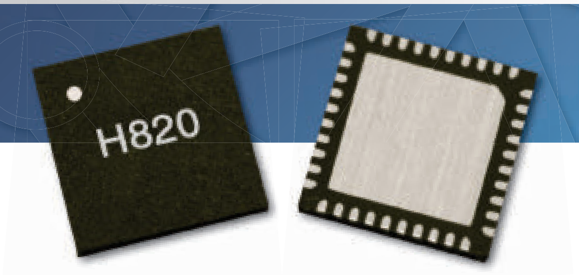

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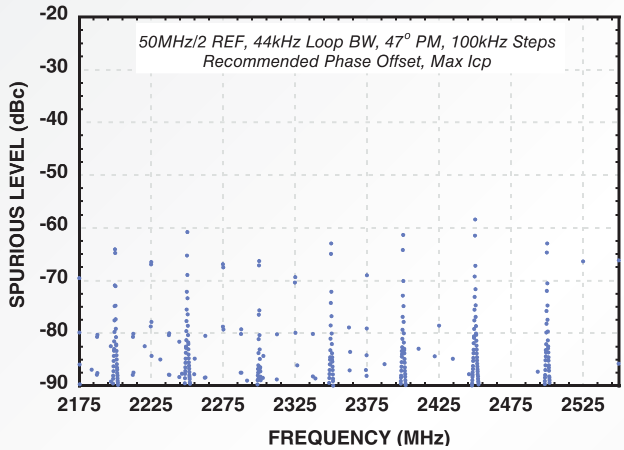

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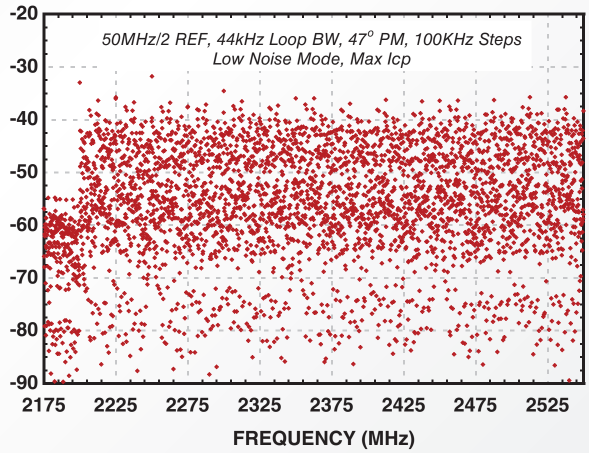

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	0.99 - 1.105	-118 dBc/Hz	-145 dBc/Hz	+10	190	0.07	HMC826LP6CE
NEW!	1.05 - 4.82	-110 dBc/Hz	-140 dBc/Hz	+7	120	0.95	HMC839LP6CE
	1.285 - 1.415	-116 dBc/Hz	-142 dBc/Hz	+10	190	0.10	HMC828LP6CE
	1.33 - 1.56	-115 dBc/Hz	-142 dBc/Hz	+10	190	0.10	HMC822LP6CE
	1.72 - 2.08	-113 dBc/Hz	-140 dBc/Hz	+10	190	0.12	HMC821LP6CE
	1.815 - 2.01	-112 dBc/Hz	-141 dBc/Hz	+9	190	0.13	HMC831LP6CE
	2.19 - 2.55	-110 dBc/Hz	-139 dBc/Hz	+10	190	0.17	HMC820LP6CE
	3.365 - 3.705	-107 dBc/Hz	-135 dBc/Hz	0	190	0.25	HMC836LP6CE
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	7.8 - 8.5	-102 dBc/Hz	-139 dBc/Hz	+13	193	0.58	HMC765LP6CE
	11.5 -12.5	-100 dBc/Hz	-134 dBc/Hz	+11	181	0.78	HMC783LP6CE
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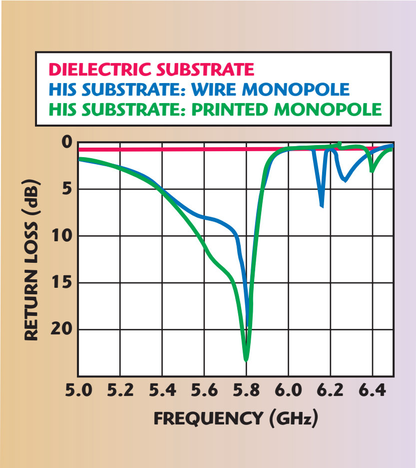
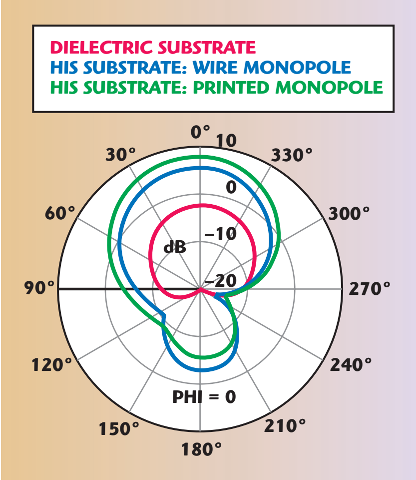
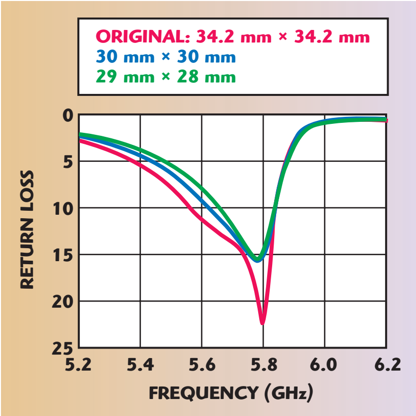


▲ *Fig. 11 Comparison of the return loss.*



▲ *Fig. 12 Monopole antenna gain for the planar and non-planar antennas at 5.8 GHz.*



▲ *Fig. 13 Effect of reducing the substrate size.*

It should be pointed out that although the scaling brings the resonance very close to 5.8 GHz, some finer adjustments of these factors is required to make the resonance fall exactly at 5.8 GHz. ***Figure 11*** compares the S_{11} of the planar design with the previous non-planar design and the non-HIS substrate. From the graph, note that the planar design leads to an increase in the return loss bandwidth (defined as being lower than 10 dB). Due to the improved impedance match at the center frequency, the gain of the antenna is increased from a value of 5.35 dB (non-planar monopole) to a value of 7.73 dB (planar monopole). ***Figure 12*** illustrates this behavior and shows the gain pattern in the elevation plane (XZ).

EFFECT OF THE SUBSTRATE LENGTH AND WIDTH

As the overall size of the antenna, including the HIS ground plane, is important for use in compact mobile devices, the effect of the substrate length and width on the impedance characteristics of the antenna was studied. ***Figure 13*** shows the variation in return loss due to a decrease in substrate size. It can be seen that decrease in substrate size narrows the impedance bandwidth. Substrate size can be used to control the impedance bandwidth.

CONCLUSION

A novel FSS structure is designed by combining the fractal and Jerusalem cross elements. The resultant structure provides more flexibility in controlling the reflection coefficient behavior. The efficiency of the optimizers can be increased by hybridizing the local optimizer with the global optimizer, which is demonstrated in the case of the proposed FSS structure. The narrowband HIS realized from the optimized FSS can be used in designing low-profile antennas. The low-profile monopole antenna on the HIS ground plane with a substrate thickness of 0.07 λ_d improves the gain of the antenna by 7.5 dB. Further improvement to the antenna can be made by transforming the design into a planar antenna, which increases the gain from 5.35 to 7.73 dB. It is found that doing so increases the return loss bandwidth of the antenna. A study of the substrate size shows that a reduction in size causes the antenna to become narrow band, but at the cost of the resonance null depth. ■

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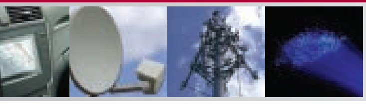

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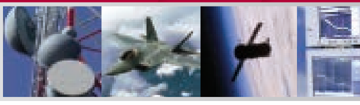

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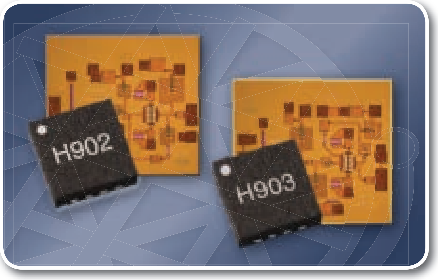

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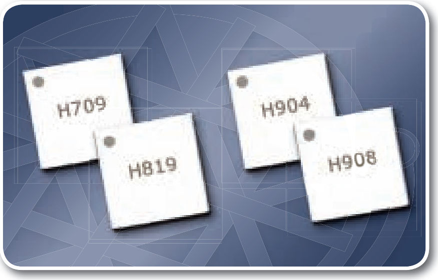

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Gopinath Gampala *received his bachelor's degree in electronics and communications engineering from Jawaharlal Nehru Technological University, Hyderabad, India, in 2005, and his master's degree in electrical engineering from the University of Mississippi in 2007. He joined EM Software & Systems USA Inc. in 2008, where he is currently working as an applications engineer.*

Rohit Sammeta *received his bachelor's degree in electrical engineering from IIT-Bombay, India, in 2004, and his master's degree from the University of Mississippi in 2007. He joined EMSS USA Inc. as an applications engineer where he provides advanced technical and modeling support for FEKO, an industry leader in EM simulation software. He is also engaged in and responsible for exploring and expanding FEKO's frontiers of applications, while simultaneously performing research in basic electromagnetics..*

C.J. Reddy *received his B.Tech. degree in electronics and communications engineering from Regional Engineering College (now the National Institute of Technology), Warangal, India, in 1983. He received his M.Tech. degree in microwave and optical communication engineering and his PhD degree in electrical engineering, both from the Indian Institute of Technology, Kharagpur, India, in 1986 and 1988, respectively. He is currently the President and Chief Technical Officer of Applied EM Inc., a small company specializing in computational electromagnetics, antenna design and development.*

THE COMING OF AGE OF THE SOFTWARE COMMUNICATIONS ARCHITECTURE

The idea of the "Software-Defined Radio" (SDR) has been circulating in industry and academia for almost 20 years, the term having been coined by Joe Mitola in a 1992 paper.[1] Since that time, many commercial and defense-oriented radio SDR products have been developed and released, most using basic technology. Until recently, however, most SDRs have used proprietary middleware to facilitate communications between their different radio components—not only within waveform applications, but also to higher layers in the communications protocol. These proprietary middleware components are often narrowly focused, resulting in rigid, monolithic radios that inhibit IP reuse, platform-independence among applications, or innovations that would significantly reduce cost and time-to-market. The Software Communications Architecture (SCA) is a software specification that tries to improve this situation, and focuses on the "software" part of a software-defined radio.

SCA was born out of requirements for the Joint Tactical Radio System (JTRS) program. It standardizes the middleware that governs the interoperation of software across all operating layers within SDRs, and ensures portability and modularity between SDR software components and hardware implementations. Thus, SCA-compliant waveforms can be assembled, loaded, run and networked into systems across radio sets. This interoperability facilitates IP re-use, lowers platform costs and development times, and lengthens the service life of platforms by improving their adaptability. SCA is realizing other secondary, indirect benefits. As an open middleware specification, it has helped create a stable SDR industry ecosystem, enabling third-party vendors to streamline development tools and provide additional middleware components. The overall result is an increase in SDR design efficiency.

Today, the SCA standard is proliferating beyond the original JTRS program into other US DoD programs and Mil/Aero SDRs around the world (such as the ESSOR initiative in Europe). This, along with continued evolution (such as the 'SCA Next' initiative under the auspices of the Wireless Innovation Forum), is evidence of the value SCA is adding to SDR design. SCA is enabling smaller and smaller

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form-factor radios, and is reaching beyond mil/aero applications into commercial telecom SDRs, such as the ETSI reconfigurable Radio Systems (RRS) effort.

METHODOLOGY FOR DEVELOPING SCA-COMPLIANT RADIO COMPONENTS

As stated, the Software Communications Architecture governs the structure and operation of software within an SDR, allowing waveform components and full radio applications to share a common control interface and signal path connections. SCA also provides common methods for radio applications to communicate across the middleware boundary. However, the development of waveform components for most SDRs still follows a very traditional design methodology when targeted to FPGA, DSP, or general purpose processors (GPP). While these methodologies produce highly efficient designs for a given target, they typically require additional manual development of interface code, as well as additional code development to revise a design if a new target device is identified. This manual process is time-consuming and prone to overdesign in order to meet given performance targets. Also, due to the disjointed nature of the various tools used in the implementation of waveform components, the final integrated system is not always fully optimized for maximum performance.

Improved methodologies now revolve around a "model-based design" paradigm. PrismTech's Spectra CX can be used to model the SCA design. For the functional design, products like Agilent's SystemVue allow waveform components to be developed quickly. Functional design starts with algorithmic construction of various signal processing functions, and then follows with mixed-signal performance analysis of baseband signal processing with realistic analog, RF and channel models, incorporating environmental waveforms and measurements as needed. SystemVue's ability to provide continuous verification throughout the design process, with a gradual transition to hardware measurements, insures that metrics are being met for performance and standards compliance. Finally, improved methodologies allow the developed, optimized, and verified IP to be quickly and conveniently targeted via a SCA-compliant waveform implementation using automatic code generation in C/C++ and/or HDL wrapper interfaces, for porting to any number of signal processing HW targets. Commercial tools enable a closed-loop, model-based design process for SCA-compliant waveforms that includes RF and measurements, as well as baseband and algorithmic validation, so that SDR waveforms can be (re)deployed faster, with greater confidence and portability, than ever before. Such a flow is depicted graphically in ***Figure 1***.

Using this improved methodology allows developers of advanced SDR waveforms to be de-coupled from their final hardware targets, allowing them to focus on high-performance design of the waveform components and overall radio application. It also facilitates a quick and convenient way to prototype and re-target a design to a new hardware platform, leading to faster deployment of radios.

HARDWARE PROTOTYPING AND MEASUREMENT

Different SDR waveforms often place conflicting requirements on the radio hardware platform, especially in the Analog/RF domain. For example,

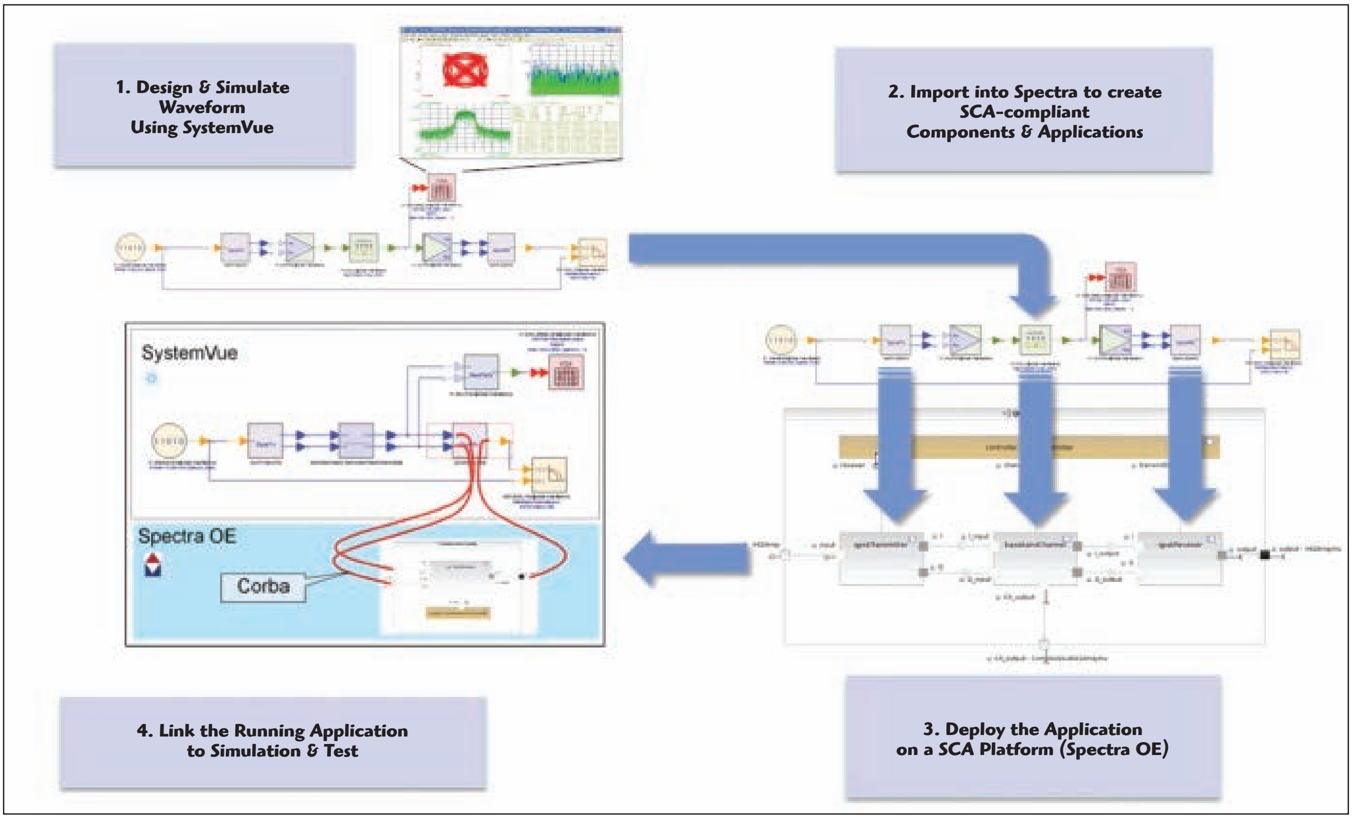
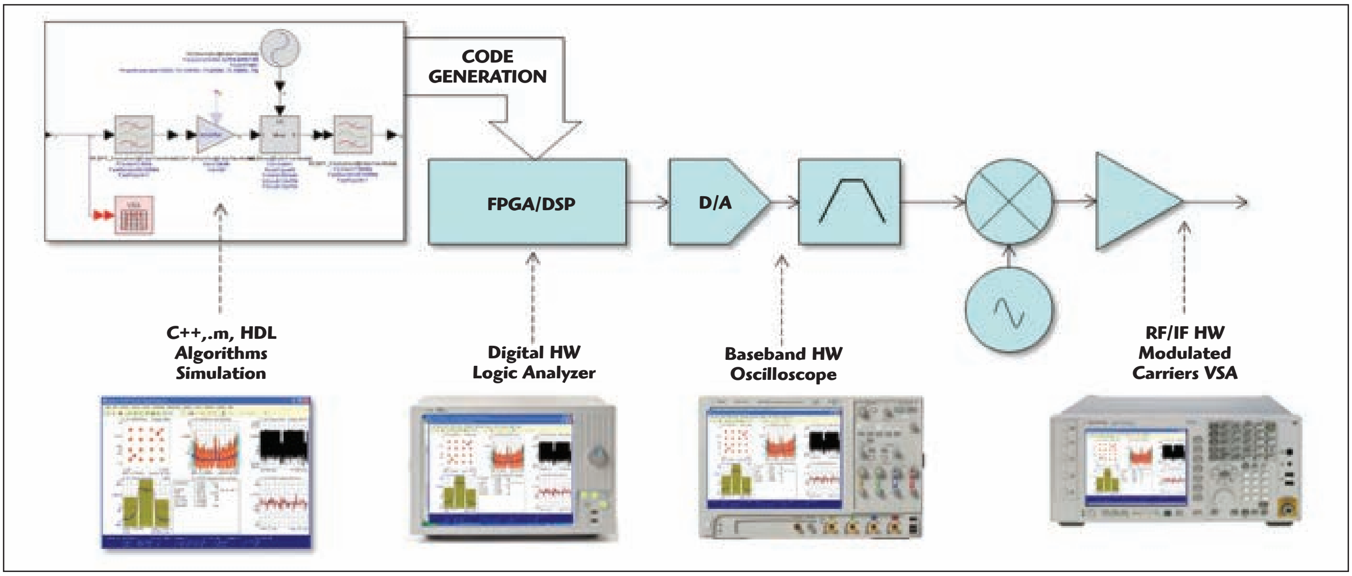


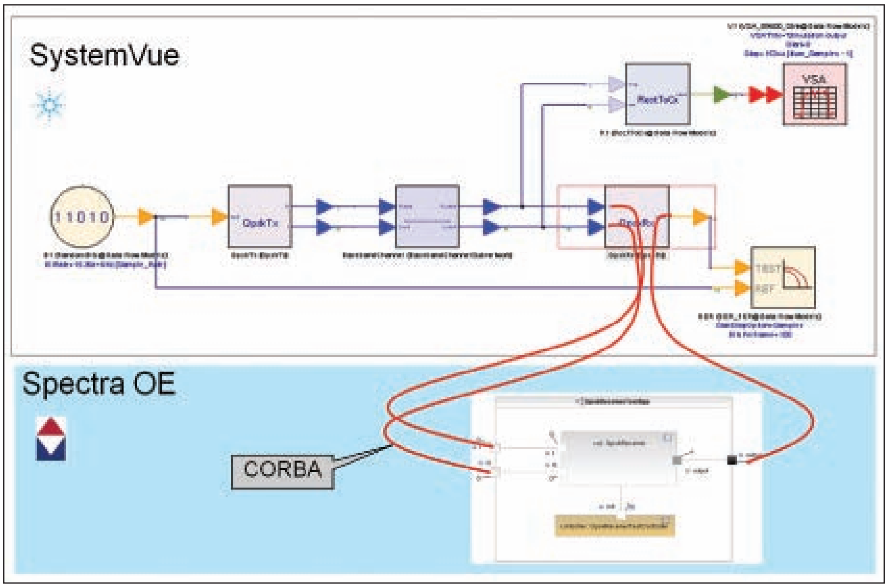
Fig. 1 Design flow for SCA-compliant waveforms.



▲ *Fig. 2 Consistent measurement algorithms throughout the signal chain and design process.*

a frequency-hopping FSK waveform may need fast local oscillator (LO) switching and settling, whereas an OFDM waveform may require low phase noise. While it may be possible to design a fast-tuning LO with low phase noise, it will likely be expensive and power hungry. An alternative to the one-size-fits-all approach is to use adjustable radio technology. In this example, the LO tuning parameters may be adjusted one way to optimize LO performance for the frequency hopping FSK signal, and adjusted another way when operating under an OFDM signal. Similar arguments can be made for the power amplifiers, internal drive levels and IF bandwidths in these analog designs.

While adjustable hardware can improve performance, lower cost and increase battery life, it also implies that the hardware settings may need to be optimized for each waveform. Adjustable hardware introduces another complication, in that each adjustable component geometrically increases the number of radio configurations. A radio with just three independently adjustable components, each with three settings, could have up to 27 usable configurations. While it may be possible to adjust radio parameters to reasonable values, simply based on the waveform characteristics, a large number of simulations and measurements will likely be required to optimize radio performance over large combinatorial sets of radio settings.



▲ *Fig. 3 Example of a SCA-compliant QPSK modulator being verified over software CORBA links.*

The flexibility of SDR baseband processing enables the use of test waveforms. Test waveforms are less complicated than regular communication waveforms allowing them to be developed more quickly, and with specific goals in mind. For example, using some of the design methodologies described earlier, one might quickly develop a simple 64 QAM radio, for the sole purpose of making BER measurements on prototype hardware. Test waveforms may also be designed specifically to make specific types of hardware measurements easier. For example, a test waveform that generates a multi-tone signal with a specific peak-to-average power statistic could be used while making adjustments to the radio hardware. It might also simplify intermodulation distortion measurements in manufacturing. These low complexity waveforms are usually less demanding on baseband resources, making them easier to implement, and highly portable if implemented within the SCA framework.

The RF performance of a software-defined radio is a function of both the hardware and software, which leads to diagnostic complexities. For example, a radio that exhibits excessive adjacent channel power (a spectral mask violation) might suffer from insufficient

numerical range or resolution in the signal processing, or it could have an analog amplifier problem. A high bit error rate could indicate a lack of receiver sensitivity, a bug in the receiver's algorithms, or a timing problem that only shows up when running on the radio platform.

Most likely, unless an SDR is seriously broken, it is difficult to isolate individual mechanisms for a particular problem. More likely, there will be several contributing factors, and each 1 dB performance problem is actually a combination of several sub-dB root causes. Identifying these root causes is exacerbated if the same measurement must be performed at different points in the radio, using different measurement algorithms. Ideally, identical measurement algorithms should be used at all stages in the signal path, and during all stages of development. Consistent measurement algorithms in the software can be used throughout the signal chain and design and verification processes, eliminating uncertainties that interfere with troubleshooting and root cause analysis of SDR performance issues that often cross domains (see ***Figure 2***). If instead, different measurement tools are used, then something as seemingly simple as a power measurement on a digitally modulated signal can give apparently different results, due to differences in the shape of the RBW filters and the methods used to average results. Fortunately, it is possible today to make identical and comparative measurements on any signal, whether simulated or real, digital or analog.

Finally, it is possible to combine design analysis with actual waveform HW using "hardware in loop" (HIL) or, using a new term, "OE in the loop" to stream live test signals into the waveform HW/Firmware as it runs in an Operating Environment (OE) on the target. With PrismTech's SpectraOE and Agilent's SystemVue, such a link has been developed allowing direct simultaneous simulation and HW "in the loop" validation. ***Figure 3*** illustrates this for a simple QPSK modulator running inside the SpectraOE.

CONCLUSION

The Software Communications Architecture is no longer a "science experiment" for SDR development. It is now a technology ready for the mainstream, whose maturity is being driven by the commercial off the shelf (COTS) products available for SDR implementers. The COTS vendor community is making SCA development productive, robust, high performance and, most importantly, affordable. For the first time the full potential of SDR is being delivered in commercially viable platforms, and a new breed of development tools is allowing rapid development of new and complex waveforms and radio applications both in aerospace/defense and commercial applications. Using these development tools, designers are moving from concept to deployed waveforms in months rather than years, with extreme portability that allows for future HW upgrades. ■

Reference

1. J. Mitola, "The Software Radio," *IEEE National Telesystems Conference*, 1992 - Digital Object Identifier 10.1109/NTC.1992.267870.

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Design of Solid-state, Wideband, High-power Microwave Amplifiers for Radiated Immunity Testing

This article illustrates how the requirements for amplifiers used in immunity testing are dictated by various EMC standards. A case is made for using solid-state devices rather than tubes. An overview of new transistor technologies is included, showing ranges of power and bandwidth typically obtainable from single devices. Key amplifier design issues, including load VSWR, thermal constraints and power combining techniques, are discussed. It is noted that a shift in amplifier design philosophy is necessitated by new device technologies, with nonlinear analysis and heat flow analysis emerging as essential design tools.

EMC standards are created to verify the reliability of electronic equipment. The standards need not only dictate the test levels and requirements, but must specify test equipment, configuration and requirements. There exist countless possible RF threats, usually in the form of transmitters, most of which are narrow band. Because it is difficult to predict exactly what sources of interference to which a particular device may be exposed, most EMC test standards specify a broad spectrum approach, including the likely frequencies of all perceived threats:

- Commercial IEC: 150 kHz to 6 GHz
- Military: MIL-STD-461: 10 kHz to 18 or 40 GHz
- Avionics: DO-160: 10 kHz to 18 GHz
- Telecom: Bell Core GR-1089: 10 kHz to 10 GHz
- Automotive: 1 MHz to 18 GHz

The standards specify the field intensity to which a product must be subjected, based on real world field measurements, past failures or even potential future threats. Based on the product's application and the level of product quality, a safety margin is often applied to the level of the perceived threat to ensure the test field exceeds that which the product may encounter in use. The required EMC amplifier power is determined based on these specifications and the gain of the antenna or transducer used to generate the specified field as well as the area to be illuminated.

- Commercial IEC: 30 V/m → 1 kW at 80 MHz

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- Military: MIL-STD-461: 200 V/m → 10 kW at 10 kHz
- Avionics: DO-160: 7.2 kV/m pulsed → kWs - MWs
- Telecom: Bell Core GR-1089: 8.7 V/m → low 100s of W
- Automotive: 600 V/m pulsed → 1 kW

Additional amplifier constraints may include limits on harmonic power and linearity since amplifiers, operating in a nonlinear region, will typically generate high harmonic power. When designing narrowband amplifiers, it is possible to realize the biasing and matching circuitry to filter this harmonic power; however, this is generally not possible with multi-octave amplifiers. Beyond this, driving an amplifier into compression leads to distortion, which may produce results that do not duplicate in another laboratory, due to unknown or unpredicted spurious or harmonic power.

A final requirement for the RF amplifiers is ruggedness, both physically and electrically. The normal EMC laboratory environment can be demanding. The antennas and transducers required to generate the field can have very severe mismatches, causing high power reflections that may damage amplifiers not designed for this specific application. Many amplifiers designed to handle poorly matched loads and high power reflections may do so by reducing, or "folding back" the amplifier output power, which may prevent the amplifier from delivering the specified power to a poorly matched antenna. This can make it impossible to meet the field requirements specified by the test standard, so it is critical that any amplifier specified for EMC testing be able to deliver full power into any antenna or transducer it may encounter, without folding back or reducing output power in any way.

THE TRAVELING WAVE TUBE

Historically, the traveling-wave tube (TWT) amplifier, with the capability to deliver very high power with extremely wide frequency at a reasonable cost, has been the answer to the needs of microwave EMC test engineers. However, increasingly stringent restrictions written into many of the EMC test standards, along with a desire to more closely and carefully control the test environment, has helped solid-state EMC amplifiers to absorb an ever larger portion of this market. The TWT amplifier, with significantly higher broadband noise and harmonic power, poor linearity and mismatch tolerance, typically cannot compete with the performance of a class A, solid-state amplifier.

THE SOLID-STATE AMPLIFIER

The explosion of wireless communications has changed the dynamics of power transistor technology development. High volume applications have provided capital for development of devices that provide higher performance than ever before. While the majority of these devices have been tailored to the specific needs of various commercial and telecom applications, a few foundries have released general-purpose transistors using each of these new technologies, allowing the design of solid-state amplifiers with power density previously available only from traveling wave tube amplifiers.

Most significant in power device technology are the development and widespread use of silicon LDMOS and silicon carbide (SiC) for use at RF frequencies (< 3 GHz), and gallium nitride (GaN) high electron mobility transistors (HEMT) operating in the lower microwave domain (1 to 10 GHz). LDMOS has gained popularity at the expense of silicon bipolar transistors and MOSFETS, while GaN HEMTs offer significantly higher power density than gallium arsenide (GaAs) pseudomorphic HEMTs (PHEMT). SiC devices have provided performance enhancements in the traditional crossover frequency range between silicon transistors and GaAs devices. GaAs PHEMTs and indium phosphide (InP) HEMTs continue to dominate at upper microwave (10 to 30 GHz) and millimeter-wave (> 30 GHz) frequencies (see ***Figure 1***).

At RF frequencies, silicon LDMOS devices offer a revolutionary change in packaging. The device structure provides for the source terminal to be the back side of the die, allowing the die to be attached electrically and mechanically to ground (the package flange). Through careful adjustments to materials and processes, it has become possible to utilize a nearly pure copper flange in some instances, providing extreme improvements in thermal performance over traditional devices, which place an insulating ce-

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AMF-2B-00030300-150-32P	0.03-3	20	2.5	15	2:1/2.5:1	32	650*
AMF-4D-00100100-30-30P	0.1-1	44	1	3	2.2:1	30	850
AMF-3B-00500100-13-33P	0.5-1	43	1.5	1.3	2:1	33	1700
AMF-4D-00500200-25-33P	0.5-2	40	2	2.5	2:1/2.3:1	33	1400
AMF-4B-00800250-50-34P	0.8-2.5	40	3	5	2:1/2.3:1	34	2700
AMF-3B-01000200-35-30P	1-2	30	1	3.5	1.8:1	30	900
AMF-3B-01000200-20-33P	1-2	35	1	2	1.5:1	33	1200
AMF-5D-01000200-15-33P	1-2	50	1.5	1.5	2:1/2.3:1	33	1500
AMF-3B-01000200-50-40P	1-2	35	3	5	2.2:1/3:1	40	4100
AMF-3D-01000400-45-30P	1-4	28	1.5	4.5	2:1/2.3:1	30	800
AMF-4D-01000400-35-30P	1-4	39	1.5	3.5	2:1/2.3:1	30	900
AMF-4D-01000800-85-30P	1-8	28	2	8.5	2.2:1	30	1100
AMF-4D-00400600-50-30P	0.4-6	34	2	5	2:1/2.3:1	30	650
AMF-3B-02000400-20-30P	2-4	35	1	2	2:1	30	950
AMF-4B-02000400-15-33P	2-4	50	1.5	1.5	2:1	33	1600
AMF-5B-02000600-70-33P	2-6	34	2	7	2:1	33	2200
AMF-4B-02000600-70-37P	2-6	35	2	7	2:1/2.8:1	37	4800
AMF-4B-02000800-80-36P	2-8	40	2.5	8	2:1/2.8:1	36	4800
AMF-3B-02001800-30-30P	2-18	35	2	3	2.2:1	30	2000
AMF-3B-02001800-60-32P	2-18	35	2.5	6	2:1/2.3:1	32	4500
AMF-3B-02002000-60-30P	2-20	40	2.5	6	2:1/2.5:1	30	4500
AMF-5B-04000800-60-30P	4-8	33	1.5	6	2:1	30	1400
AMF-4B-04000800-50-33P	4-8	36	1	5	2:1	33	1500
AMF-6B-06001800-80-33P	6-18	35	2.5	8	2.1:1/2.2:1	33	3500
AMF-2B-06001800-65-35P	6-18	45	3	6.5	2.1:1/2.2:1	35	6500
AMF-6B-06001800-120-40P	6-18	43	5	12	2:1/2.3:1	40	12,500

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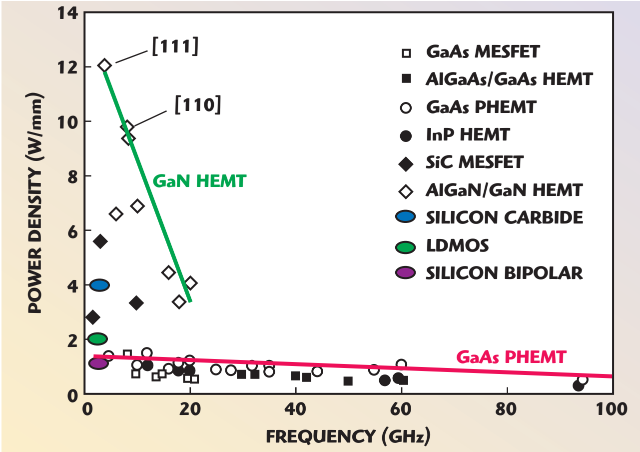
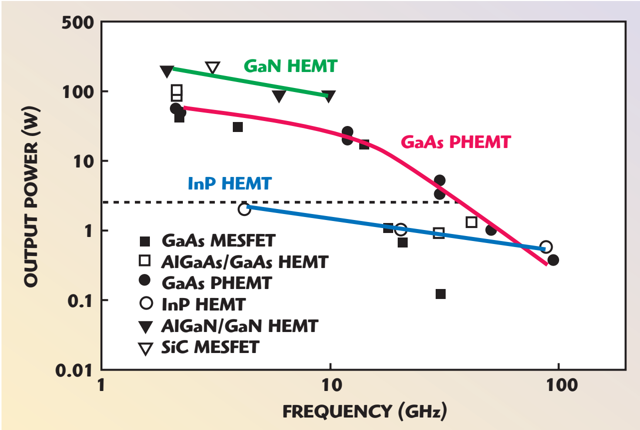


▲ *Fig. 1 Output power density vs. frequency for various FET technologies.*



▲ *Fig. 2 Output power vs. frequency for various power FET technologies.*

ramic and a less-conductive composite flange between the transistor die and the heat sink. Plastic encapsulated packages are rendered economically feasible by the volume markets associated with LDMOS devices, replacing ceramic packages at very significant cost reductions.

At lower microwave frequencies, the development of GaN HEMTs has pushed power densities to new limits[1] (see ***Figure 2***), reducing the parasitics commonly associated with large GaAs devices and alleviating many problems associated with broadband matching of high-power transistors. This increase in available power does bring increased complexity to power amplifier design, in terms of thermal management and large-signal device characterization, as it is rarely possible to bias GaN HEMTs in a true class A mode of operation without exceeding thermal constraints and damaging or degrading the device. For a generation, microwave engineers have been able to rely on simple small-signal design using S-parameters and linear simulators for designing GaAs-based broadband class A amplifiers. Many are now struggling to understand complex nonlinear behavior and large-signal design techniques required to safely and efficiently extract maximum power from the GaN HEMT, while maintaining the durability and load tolerance they have come to expect from their GaAs counterparts.

An equally important consideration to the actual device technology employed is the packaging of the device. Package material and mechanical considerations define the thermal characteristics of the packaged transistor, as well as the amount and configuration of wire bond inductances and package lead capacitances and inductances that affect the ease or difficulty with which the packaged transistor can be impedance matched for maximum power and gain over a given range of frequencies. These small parasitic inductances and capacitances produce reactances often safely neglected at RF frequencies, generally below 1 GHz, but become very problematic for broadband matching at microwave frequencies.

The thermal constraints imposed by the high drain currents and voltages possible, with many of the newer device technologies, creates problems that are altogether new to most microwave engineers used to working with devices operating at significantly lower power densities. RF engineers working below 1 GHz have worked with these constraints for many years using more powerful devices than those classically available to the microwave engineer, but are also facing new challenges due to increasing power density of SiC and LDMOS. In both cases, the primary challenge

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ZHL-5W-2G+	800-2000	45	+37	+38	8.0	+44	24	2.0	995	945
ZHL-10W-2G+	800-2000	43	+40	+41	7.0	+50	24	5.0	1295	1220
ZHL-16W-43+	1800-4000	45	+41	+42	6.0	+47	28	4.3	1595	1545
• ZHL-20W-13	20-1000	50	+41	+43	3.5	+50	24	2.8	1395	1320
ZHL-30W-252+	700-2500	50	+44	+46	5.5	+52	28	6.3	2995	2920
• ZHL-50W-52	50-500	50	+46	+48	6.0	+55	24	9.3	1395	1320
• ZHL-100W-52	50-500	50	+47	+48.5	6.5	+57	24	10.5	1995	1920

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is developing methods to dissipate more heat from smaller parts, requiring more research and development in heat sinks and heat spreaders than previously required of RF and microwave amplifier manufacturers.

KEY AMPLIFIER DESIGN CONSIDERATIONS

Because the antennas, connected to the amplifier in an EMC test environment, often present high VSWR, special consideration must be given to amplifiers designed for EMC testing applications, such that they can drive full power into loads ranging from a near-short circuit to a near-open circuit. This factor, more than any other, presents serious problems for the engineer, as the bandwidth of the amplifier is usually far too great to consider the use of circulators or other isolating devices. The problem is further aggravated by many of the newer transistor technologies, whose thermal constraints prevent the engineer from biasing the transistors in the mode classically shown to be most favorable to tolerating these conditions.

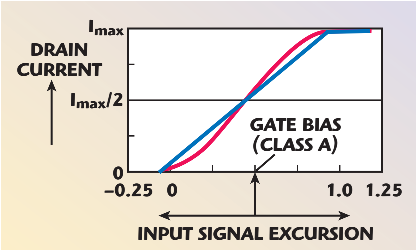
Every transistor has intrinsic characteristic input and output impedances, governed both by the material form and structure, with which the device is constructed. Extrinsic parasitic conductance and susceptance is added to this, due to the necessary interconnects on the chip and packaging surrounding the chip, adding up to a total input and output impedance that varies with frequency, bias and drive conditions, but which also must be well-matched at all frequencies for a given bias and drive condition. Once an appropriate bias is selected for a device, the primary responsibility of the RF/microwave engineer is to design circuitry that will provide the appropriate impedance matching to the input and output of the transistor, permitting the maximum transfer of power by controlling the voltage and current magnitude and relative phase.

Traditionally, this has been accomplished by measuring the S-parameters of the device, composed of the forward- and reverse-traveling voltage and current waves resulting from small-signal (that is very low power) stimulus at each device terminal, most often base and collector or gate and drain for bipolar and field-effect devices, respectively. Simple mathematical calculations allow one to correlate the magnitude and phase of these waveforms to characteristic impedances for the device at each frequency, operating at a given bias.

The characteristic behavior of most RF/microwave transistors in use over the last several decades has allowed this to work quite well by providing a "strong nonlinear" response that stays very linear from small-signal conditions to a level very close to the maximum power of the device, before sharply transitioning into current saturation. For years, only RF/microwave engineers designing high-efficiency power amplifiers had to give special consideration to nonlinear effects, and even then, design from S-parameters was most often sufficient.

Unfortunately, many of the newer devices discussed herein display a "weak nonlinearity," in which the device gradually transitions from a linear small-signal response into saturation over a wide range of drive conditions (see **Figure 3**). The strongly nonlinear device (solid line) has well-defined break points with an entirely linear relationship between drain current and gate voltage from I_d to I_{max}, whereas the weakly nonlinear device (dashed line) has poorly-defined break points and a gradual roll-off in I_d from bias to I_{max}. This all but eliminates the possibility of finding ideal matching conditions based on S-parameters alone, confounding many engineers used to working with more traditional device technology. Rather than working directly from S-parameters or using linear circuit simulators, it is necessary to construct complex nonlinear device models and employ long-forgotten methods to find the ideal matching conditions for extracting maximum power or efficiency from this new breed of transistor.

Thermal considerations further



▲ *Fig. 3 Strong and weak nonlinearity, as related to a FET.*

complicate the development process, especially for those designing broadband amplifiers around these new device technologies. Thermal resistance and junction temperature constraints rarely allow the engineer to bias the device in a true class A mode of operation. Unfortunately, traditional techniques developed for eliminating the harmonics generated when driving a device under large-signal conditions cannot be employed in multi-octave amplifiers, as the harmonics of the lower frequencies of operation are now "in-band."

It is necessary to carefully study the behavior of the device under a wide range of bias and load conditions in order to find the ideal compromise between thermal and electrical performance, which can be extremely time consuming at best. This requires design techniques, nonlinear device models, and simulators of a complexity with which most RF/microwave engineers are not familiar. The specialized field of nonlinear device modeling, long used by engineers working on high-efficiency power amplifiers, is becoming more relevant as manufacturers of these new devices scramble to provide models of a complexity with which they are often unfamiliar. Some have employed the expertise of companies and university laboratories specializing in nonlinear device modeling, while others work to build their own internal modeling capability.

MULTIPLYING THE POWER FROM SINGLE DEVICES: DIVIDERS AND COMBINERS

While TWT amplifiers may often extract all of the required power from a single tube, solid-state amplifiers typically make use of dozens, if not hundreds, of transistors. A wide variety of power dividing and combining technologies and architectures are available to the microwave engineer, for dividing the load between various combinations of transistors, and recombining the power generated at each. A topical discussion of various combining techniques, considerations, advantages and disadvantages of various architectures, and applications for directional couplers follows.

Output power requirements dictate that a given number of transistors must share the total power, while gain requirements often necessitate multiple stages, each providing some percentage of the total gain. Various combinations of power dividers, couplers and power combiners are used to achieve this goal.

Dividers and combiners can be classified or divided along many lines of distinction, including resonant versus non-resonant, binary versus N-way, and circuit- or waveguide-based versus spatial. Couplers are often defined as directional dividers or combiners. Most large power amplifiers make use of combinations of dividers, couplers and combiners, and the possible permutations are unlimited.

Of particular importance in the amplifier design is the phasing of the combiners. Many combiner designs provide a 90° or 180° phase relationship between outputs. In these cases, it is necessary to design splitters to provide the corresponding phase relationship on the input.

Resonant structures rely on a cavity or tank, which resonate at a particular frequency or multiples of that frequency, are inherently narrowband, and thus are of little interest in the design of broadband amplifiers. All of the divider and combiner structures presented herein can be designed as non-resonant circuits, and thus offer the possibility of broadband performance.

Binary dividers and combiners are three-port networks in which power is divided (or combined) equally between two of the three ports, and in the case of lossless networks, can be cascaded infinitely to yield any combination of 2^N divided or combined (from here forward referred to as "coupled") ports (see ***Figure 4***). In practice, using components with some

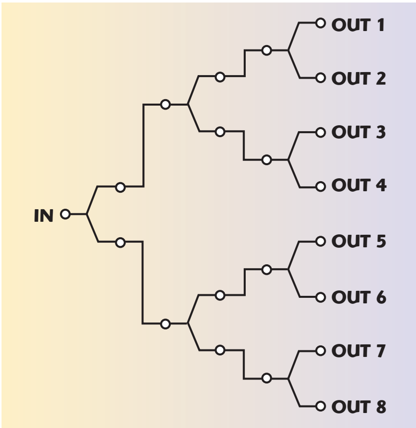


Fig. 4 Cascaded binary dividers.

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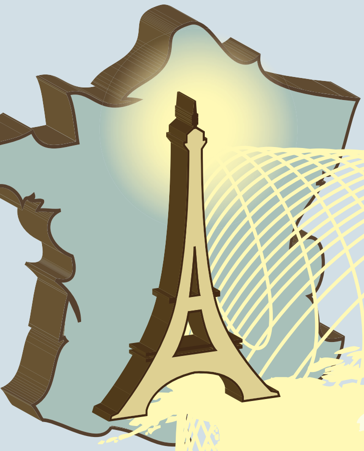

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finite loss, one reaches a point of diminishing return, where the loss of each stage outstrips the power added. Assuming the structure does not contain active or anisotropic materials, basic network theory will show that it is not possible to create a binary divider or combiner that is both lossless and matched at all three ports.[3]

In 1960, Ernest Wilkinson[4] presented an N-way hybrid power divider, which, due to complexity of construction at microwave frequencies, is most often seen in an N=2 form. While at first this appears to be an exception to the rule, as a lossless three-port network with all ports matched, it is important to note that analysis of the scattering parameters reveals that this is not actually a lossless network.[3]

N-way dividers and combiners are those structures that may contain an arbitrary number of ports at one stage or station, such as radial or spatial power dividers and combiners. These combiners have the advantage of not being limited to a specific (2^N) number of ports, and can exhibit much lower loss than corporate structures for high port counts due to their single-stage nature. As already noted, the Wilkinson power divider is one of the most well-known N-way structures, although with the exception of some relatively low-frequency applications, it is rare to find a Wilkinson divider with more than two outputs.

Both binary and N-way, resonant and non-resonant dividers and combiners may be constructed using planar circuits, coaxial line, waveguide, or spatial technology. Constraints such as insertion loss, power handling, or physical size will often favor one technology over another, although certain architectures do limit the possible choices, as is the case with radial N-way combiners. Ferrite loaded coaxial combiners are common for broadband applications extending below 500 MHz.

It is always desirable to have some degree of isolation between the coupled ports of any power divider or combiner, and this is most often provided in the form of resistors placed between the N outputs or inputs of a divider or combiner, respectively. Physical constraints often make it impossible to include these isolation resistors in power combiners, especially in the case of microwave amplifiers, so it is very common to sacrifice isolation in power combiners, including it only in the splitter.

Couplers are most often directionally-coupled four-port networks, and may be used in power amplifiers as power dividers, power combiners or for power sampling. In the case of power division and combination, power is usually divided equally between two ports of the coupler, with the signal at the two ports often 90° or 180° out of phase with one another. This provides many advantages in terms of improving VSWR, protecting the transistors from unfriendly load conditions, and more consistent loading of the bias circuitry. For power sampling, the coupler can be designed with forward- or reverse-coupled ports that typically extract a small fraction of the signal passing through the coupler, for the sake of monitoring and control of power passing into or out of the amplifier.

CONCLUSION

For a generation, amplifier engineers have relied on simplified design techniques that often now fail when applied to these newer device technologies. Thermal constraints have forced engineers attempting to use these new transistor technologies to run the devices at reduced bias, introducing harmonic and matching issues affecting performance and durability. Nonlinear transistor modeling and simulation is fast becoming a necessary skill for understanding the behavior of these new devices. ■

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4. E.J. Wilkinson, "An N-Way Hybrid Power Divider," *IRE Transactions on Microwave Theory and Techniques*, Vol. 8, No. 1, January 1960, pp. 116-118.

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REAL-TIME SPECTRUM ANALYZER PROVIDES SEAMLESS SIGNAL CAPTURE

Interference affecting RF signals is a familiar problem for development engineers working in the field of RF engineering. It may be caused by sporadic or brief events within the frequency domain, the spectral behavior of signal sources during frequency switching, or by digital circuits. Identifying the causes behind problems like these is often challenging and can be very time-consuming. To meet such demanding challenges, Rohde & Schwarz has developed the new R&S FSVR, believed to be the first instrument on the market to combine a fully fledged signal and spectrum analyzer with real-time spectrum analyzer capability.

The R&S FSVR seamlessly captures and displays the frequency spectrum over a 40 MHz bandwidth; various display formats are available. Functionality such as the analyzer's spectrogram and persistence mode ensure that no events remain hidden to users. With its frequency-selective trigger, the analyzer is also capable of detecting and examining signals that occur sporadically within the spectrum. The instrument's signal and spectrum analyzer capabilities are based on the R&S FSV. They include the full complement of functions and properties that an advanced measuring device of this kind requires to meet modern demands.

REAL-TIME SPECTRUM ANALYSIS UP TO 30 GHZ

In real-time mode, the R&S FSVR captures RF signals seamlessly in the time domain with a bandwidth of up to 40 MHz, transforms them into the frequency domain and displays them as a spectrum. To achieve high time resolution and therefore accurate level measurements, even of short-term or pulsed signals, the instrument can overlap the time windows for fast Fourier transformation (FFT) by at least 80 percent. Since all the data captured is processed in real-time without any gaps, users do not miss even very short signals. The R&S FSVR is thought to be the first analyzer to provide this real-time capability for input frequencies up to 30 GHz or, with an external mixer, up to 110 GHz.

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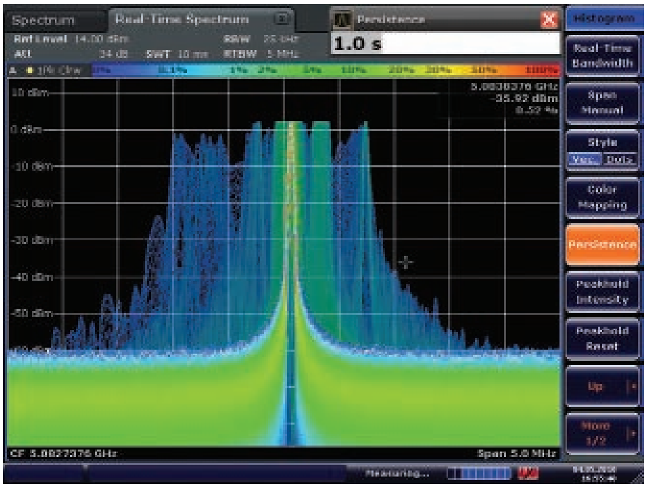
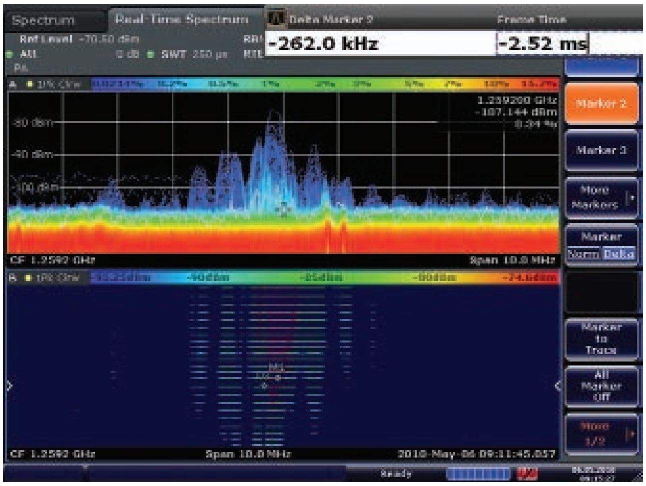


▲ *Fig. 1 Transient response of VCO for WLAN applications in persistence mode.*



▲ *Fig. 2 Airport radar signal—the spectrogram shows the pulsed structure of the signal and allows the pulse repetition rate of 2.5 ms to be measured.*

The spectrum analyzer digitizes the RF signal with a sampling rate of 128 MHz and transforms it into the frequency range, computing up to 250,000 spectra per second in the process. Since the human eye cannot register such a large number of spectra, the R&S FSVR combines the data obtained in a detector and displays the results at a refresh rate of approximately 30 times per second. This is roughly the refresh rate the human eye is capable of processing.

The peak detector ensures that no RF signal in the monitored frequency range is lost and that every signal occurring during the monitoring period is displayed. When operating in this mode, the R&S FSVR combines multiple spectra in a single trace, which significantly reduces time resolution. To provide users with a clear picture of the spectrum variation versus time, the instrument offers a variety of display and measurement functions.

PERSISTENCE MODE

The persistence mode offers an effective means of visualizing ultra-short-term signals. The R&S FSVR superimposes the gapless spectra in a diagram. Depending on how often a specific signal with a given amplitude occurs, the spectrum analyzer changes the color of the corresponding pixel on the display. Signals that are continuously present are displayed in red, for example, whereas very infrequent signals are displayed in blue. If specific signals cease to occur, they disappear from the display when the chosen persistence time has elapsed. The persistence mode represents a kind of spectral histogram. It is a useful tool when investigating signals that occur irregularly.

For example, users are now able to analyze the fast transient response behavior of phase-locked loops (PLL). Full, gapless visualization of all frequencies and amplitudes occurring, complete with probability weighting, provides a new view of the dynamic behavior of a system within the frequency domain. Users can see whether a transmitter makes rapid frequency hops or whether there are significant changes in amplitude for brief periods of time. Effects like these, which can considerably affect the behavior of an entire system, are difficult to detect using sweeping spectrum analyzers.

Figure 1 shows a typical measurement. The analyzer captures and displays even very short signals, thus providing a complete picture of the time variation of the frequencies and amplitudes occurring in the frequency domain.

SPECTROGRAM FUNCTION

The persistence mode opens up new possibilities for users to analyze errors by visualizing the time variation of signals in the frequency domain. To accurately capture this time variation, the R&S FSVR includes a spectrogram function. It assigns a color to the signal amplitude, allowing the spectrum to be displayed with just a single horizontal line. The spectrogram is created by continuously appending the horizontal lines. In real-time mode, the spectrogram provides a gapless picture of the spectrum versus time.

In spectrogram mode, the instrument captures and records up to 10,000 traces per second and writes them to a ring buffer. Here, too, the analyzer uses a detector to compact the data for on-screen display. The ring buffer memory depth is sufficient to store up to 100,000 traces. Depending on the selected update rate, the R&S FSVR can measure continuously for a period of up to five hours.

To allow completed measurements to be examined in detail, the analyzer provides markers that users can move along the time and frequency axes. For example, this makes it very convenient to measure the duration of events or the intervals between events for a given frequency (see ***Figure 2***), and thus greatly simplifies the gapless monitoring of frequency bands. This is not just valuable in the context of frequency monitoring; it is also highly useful for engineers searching for intermittent interfering signals.

Even for radio transmissions that involve frequent frequency changes (as is the case with RFID or Bluetooth®), the R&S FSVR is a valuable tool when it comes to tracking frequency hops and determining transmitter characteristics. It makes finding rare errors in the frequency processing of transmitters or sporadic interference from digital circuits much easier and greatly reduces the time required.

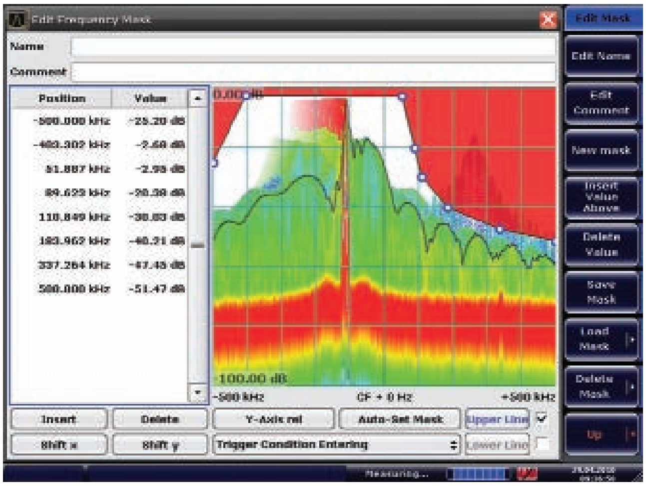


Fig. 3 Input window for setting the frequency mask trigger limit line (shown here triggering on an error signal approximately 400 kHz above the actual signal frequency of a swept source).

TRIGGERING ON EVENTS

The information acquired by means of the spectrogram can also be used to define a trigger in the spectral domain, known as a frequency mask trigger (FMT). The FMT reacts to events in the spectrum. The R&S FSVR evaluates every single spectrum—at a rate of up to 250,000 spectra per second—and compares each spectrum with a predefined, frequency-dependent mask. If a trace violates the mask, the spectrum analyzer generates a trigger event and displays the current spectrum, or makes the captured data available for further processing (in a test application, for example).

The mask for the spectral trigger can be defined easily via the R&S FSVR's touch screen. Clearly structured tables and graphics provide users with the means to adapt masks quickly to changing situations. ***Figure 3*** gives an impression of how easily and efficiently users can work with the analyzer. Users are able to define both a lower and an upper limit line. The trigger conditions just described can be especially useful when the signal being monitored has to remain within a given tolerance band.

The R&S FSVR has an I/Q memory depth of 200 Msamples. This means that, even with large bandwidths and high sample rates, it can record spectra gaplessly over prolonged periods of time.

FULL-FEATURED SIGNAL AND SPECTRUM ANALYZER

When real-time operation is not activated, the R&S FSVR operates like a sweeping spectrum analyzer or a signal analyzer. It sweeps the selected frequency range (up to 30 GHz) and displays the spectrum. It has a minimum sweep time of under a tenth of a second for the full 30 GHz frequency range. It offers a wide range of resolution bandwidths from 1 Hz to 10 MHz. Unlike in real-time mode, the resolution bandwidth is user-selectable and not linked to the selected span. In addition to the fast sweep filters, the analyzer also provides channel filters and root raised cosine filters to support mobile radio standards.

Like all of the company's spectrum analyzers, the R&S FSVR offers as standard an extensive range of measurement functions, including adjacent channel power, spectrum emission mask, third-order intercept (TOI), CCDF and spurious emission measurements. With a level measurement uncertainty of 0.4 dB up to 7 GHz, the R&S FSVR delivers precise and reliable results. With the R&S FSV-K9 option, it can also be connected directly to R&S NRP power sensors, obviating the need for a separate power meter in situations requiring especially high measurement accuracy.

The R&S FSVR provides more than 1,000 sweeps per second. This high measurement performance not only helps speed up manufacturing systems, it also reduces processing time in R&D or conformance testing in applications where large numbers of measurements have to be averaged (as required by numerous standards). In addition, the instrument offers options for measuring basic physical characteristics, including phase noise (R&S FSV-K40), noise figure (R&S FSV-K30), and the parameters of signals with analog (AM/FM/PM) and digital modulation (R&S FSV-K70).

As well as classical spectrum analysis, the R&S FSVR is suitable for verifying compliance with mobile radio standards. It currently supports the following standards: GSM/EDGE/EDGE Evo, WCDMA, TD-SCDMA, CDMA2000, WLAN 802.11a/b/g/n, WiMAX and LTE (TDD/FDD).

CONCLUSION

Combining real-time spectrum analyzer capability with full-featured signal and spectrum analysis, the R&S FSVR is a unique instrument. Its extensive, easy-to-use real-time functions mean users have new and highly effective analysis resources at their disposal, yet at the same time can continue to work with the same signal and spectrum analysis functions they are familiar with. The intuitive user interface, designed along the same lines as those of spectrum analyzers, simplifies working with the instrument and successfully integrates real-time analysis within a cohesive overall design concept.

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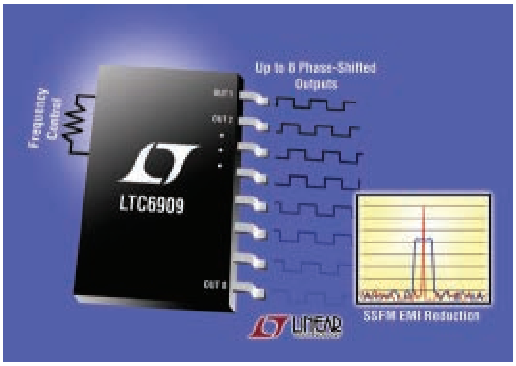

IDEAL SOLUTION FOR EMI

As the demand for energy efficiency increases, more electronics are being designed with switching regulators in place of linear regulators. Power systems with multiple switching regulators are becoming commonplace; as the number of regulators increases, the impact of electromagnetic interference (EMI) also grows. One of the simplest, most cost-effective techniques for EMI reduction is the use of a multiphase, spread-spectrum clock.

MULTIPHASE SYNCHRONIZATION

The operating frequency of most switching regulators can be controlled with an external clock, which, in turn, sets the fundamental frequency of generated EMI. This feature can be useful to set the EMI outside of a sensitive band and is a particularly valuable feature when operating multiple switching regulators together. Multiple independently running switching regulators have the potential to generate large peak EMI, as clock frequencies approach each other and create beat frequency conditions. Similarly, if multiple regulators are operated on a single clock, the EMI will be synchronized and very concentrated. One solution is for each regulator to be driven with the same clock frequency, but with different phases.

Multiphase synchronization refers to the technique of externally driving multiple switchers with a single clock frequency that has a time shift placed between each regulator. This reduces peak switching current by staggering the turn-on for each switcher such that there is input current drawn where previously there was a dead band. As a result, multiple switching regulators synchronized out of phase, versus in phase, have a lower peak current and therefore lower EMI. Also, the frequency of EMI increases after phase synchronization. As a result, EMI filtering is more effective since filtering is more effective at higher frequencies.

SPREAD SPECTRUM FREQUENCY MODULATION (SSFM)

In addition to multiphase synchronization, EMI can be improved by continuously varying

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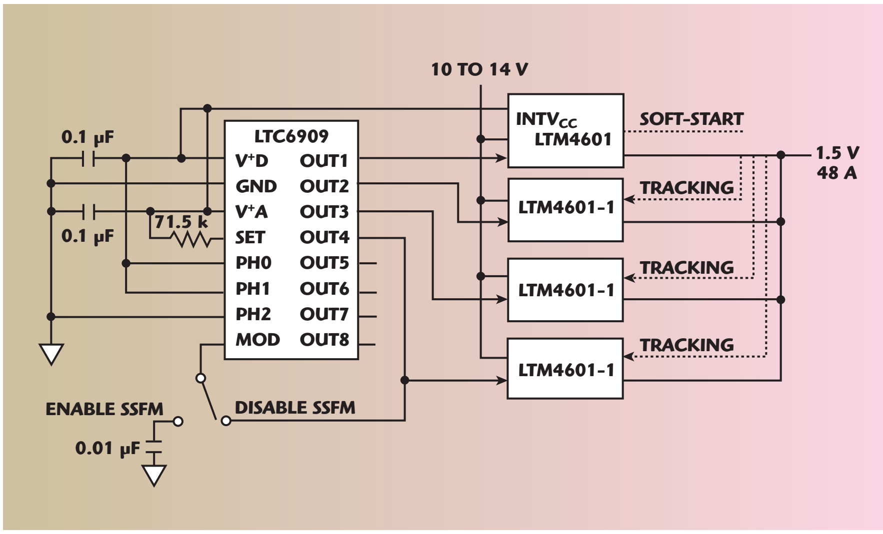
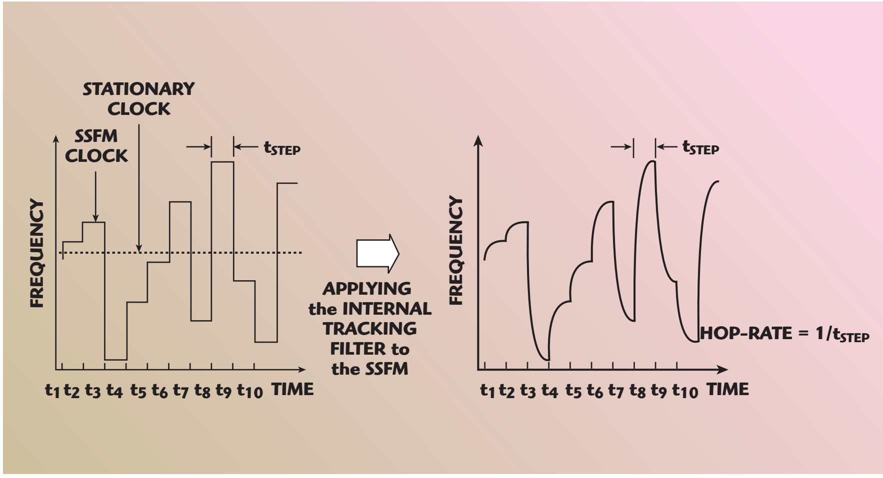


▲ *Fig. 1 Block diagram of LTC6909 multiphase silicon oscillator with spread spectrum modulation.*



▲ *Fig. 2 Pseudorandom modulation and internal tracking filter of LTC6909.*

the frequency of the switching regulator clock. This technique, referred to as SSFM, improves EMI by not allowing emitted energy to stay in any receiver's band for a significant length of time. There are four primary considerations for maximum SSFM effectiveness: The bandwidth of the impacted receiver; the method for modulating the frequency; the amount of frequency spreading; and the rate of modulation.

RECEIVER

Whenever considering EMI, the designer should understand the bandwidth of the EMI affected receiver(s). These receivers could be real system devices, or they could be receivers used for regulatory conformance per CISPR 16-1. The receiver's bandwidth determines two important characteristics: The range of frequencies for which the receiver will respond and the receiver's response time when subjected to EMI.

MODULATION METHOD

Most switching regulators exhibit ripple that varies with frequency; more ripple at lower switching frequencies and less at higher switching frequencies. As a result, a switcher's ripple will exhibit an amplitude modulation if the switching clock is frequency modulated. If the clock's modulating signal is periodic, such as a sine-wave or triangle-wave, there will be a periodic ripple modulation and a distinct spectral component at the modulating frequency. Since the modulating frequency is much lower than the switcher's clock, it may be difficult to filter out. This could lead to problems, such as audible tones or visible display artifacts, due to supply noise coupling or limited power supply rejection in the downstream circuitry. A pseudorandom frequency modulation can avoid this periodic ripple. With pseudorandom frequency modulation, the clock shifts from one frequency to another in a pseudorandom fashion. Since the switcher's output ripple is amplitude modulated by a noise-like signal, the output looks as if there is no modulation and the downstream system implications are negligible.

MODULATION AMOUNT

As the range of SSFM frequencies increases, the percentage of in-band time is reduced. If the emitting signal enters the receiver's band infrequently and for short periods, relative to its response time, significant EMI reduction occurs. For example, frequency modulation of ± 10 percent is more effective at reducing EMI than frequency modulation of ± 2 percent. However, switching regulators have a limited range of frequencies for which they can tolerate. As a general rule, most switching regulators can easily tolerate frequency variation of ± 10 percent.

MODULATION RATE

Similarly to the modulation amount, as the rate of frequency modulation increases, the time that EMI will be "in-band" for a given receiver will decrease and EMI will be reduced. There is a limit, however, to the rate of frequency change (dF/dt) that a switcher can track. The solution is to find the highest modulation rate that does not impact the switcher's output regulation.

IDEAL SOLUTION

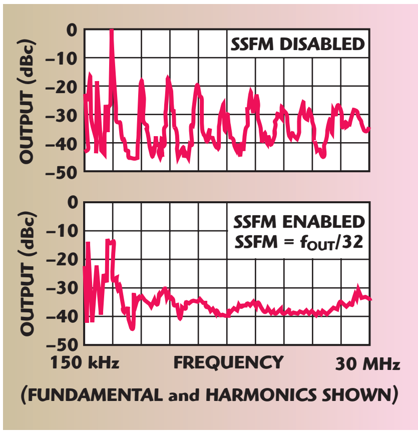
Silicon oscillators provide an ideal platform for multiphase, spread-spectrum switching regulator clocks. In addition to having an on-board clock generator, these solid-state devices can combine spread spectrum modulation and multiphase outputs.

With this in mind, Linear Technology developed the LTC6909, a precision spread spectrum silicon oscillator with eight separate multiphase outputs. A single resistor selects the output frequency from 12.5 kHz to 6.67 MHz. Three logic inputs set the output phase relationship in a range

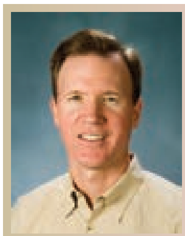
of 45° to 120°, allowing the LTC6909 to provide synchronization for up to eight phases (see ***Figure 1***). A pseudorandom spread spectrum frequency modulation can be enabled with frequency spreading of ± 10 percent of the center frequency. The user selects one of three modulation rates to ensure that the modulation rate does not exceed the regulator's bandwidth.

In addition, the LTC6909 has an innovative filter that tracks the SSFM modulation rate and provides smoothing between frequency transitions (see ***Figure 2***). Using the LTC6909 results in a significant improvement in EMI, as shown in the output frequency spectrum from 150 kHz to 30 MHz (9 kHz resolution BW) displayed in ***Figure 3***.

In summary, using multiple switching regulators in a single system can present a significant EMI concern. In addition to standard layout, filtering and shielding practices, the use of multiphase synchronization and spread-spectrum frequency modulation can dramatically improve EMI performance. Linear Technology's LTC6909 offers a straightforward solution. With little effort, this small, low power and robust silicon oscillator can easily prove its worthiness.



▲ *Fig. 3 EMI improvement using the LTC6909 with SSFM enabled.*



Greg Zimmer is a product marketing engineer at Linear Technology responsible for the management of silicon oscillators and other signal conditioning products. His background includes technical marketing, applications engineering and analog design. He received his BS degree in Electrical Engineering/Computer Science from the University of California, Berkeley, and his BA degree in Economics from the University of California, Santa Cruz.

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Milpitas, CA
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www.linear.com.

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MINIATURE FOOTPRINT VCO'S

Model	Frequency Range (MHz)	Tuning Voltage (VDC)	DC Bias VDC @ I [Typ.]	Phase Noise @ 10 kHz (dBc/Hz) [Typ.]	Size (Inch)
DCO Series					
DCO50100-5	500 - 1000	0.3 - 15	+5 @ 26 mA	-100	0.3 x 0.3 x 0.1
DCO7075-3	700 - 750	0.5 - 3	+3 @ 10 mA	-108	0.3 x 0.3 x 0.1
DCO80100-3	800 - 1000	0 - 3	+3 @ 15 mA	-105	0.3 x 0.3 x 0.1
DCO80100-5	800 - 1000	0.5 - 8	+5 @ 21 mA	-111	0.3 x 0.3 x 0.1
DCO100200-5	1000 - 2000	0.5 - 24	+5 @ 30 mA	-95	0.3 x 0.3 x 0.1
DCO1198-8	1195 - 1205	0.5 - 8	+8 @ 24 mA	-115	0.3 x 0.3 x 0.1
DCO170340-5	1700 - 3400	0.5 - 24	+5 @ 24 mA	-90	0.3 x 0.3 x 0.1
DCO200400-5 DCO200400-3	2000 - 4000	0.5 - 18	+5 @ 35 mA +3 @ 35 mA	-90 -89	0.3 x 0.3 x 0.1
DCO300600-5 DCO300600-3	3000 - 6000	0.5 - 18	+5 @ 35 mA +3 @ 35 mA	-80 -78	0.3 x 0.3 x 0.1
DCO400800-5 DCO400800-3	4000 - 8000	0.5 - 18	+5 @ 35 mA +3 @ 35 mA	-78 -76	0.3 x 0.3 x 0.1
DCO432493-5 DCO432493-3	4325 - 4950	0.5 - 11	+5 @ 17 mA +3 @ 17 mA	-88 -86	0.3 x 0.3 x 0.1
DCO450820-5	4500 - 8200	0.5 - 14	+5 @ 22 mA	-77	0.3 x 0.3 x 0.1
DCO473542-5 DCO473542-3	4730 - 5420	0.5 - 22	+5 @ 20 mA +3 @ 20 mA	-88 -86	0.3 x 0.3 x 0.1
DCO490517-5 DCO490517-3	4900 - 5175	0.5 - 5	+5 @ 22 mA +3 @ 22 mA	-88 -86	0.3 x 0.3 x 0.1
DCO495550-5 DCO495550-3	4950 - 5500	0.5 - 12	+5 @ 22 mA +3 @ 22 mA	-87 -85	0.3 x 0.3 x 0.1
DCO579582-5	5780 - 5880	0.5 - 10	+5 @ 27 mA	-91	0.3 x 0.3 x 0.1
DCO608634-5 DCO608634-3	6080 - 6340	0.5 - 5	+5 @ 22 mA +3 @ 22 mA	-86 -84	0.3 x 0.3 x 0.1
DCO615712-5 DCO615712-3	6150 - 7120	0.5 - 18	+5 @ 22 mA +3 @ 22 mA	-85 -83	0.3 x 0.3 x 0.1

Model	Frequency Range (GHz)	Tuning Voltage (VDC)	DC Bias VDC @ I [Typ.]	Phase Noise @ 10 kHz (dBc/Hz) [Typ.]	Size (Inch)
DXO Series					
DXO810900-5 DXO810900-3	8.1 - 8.925	0.5 - 15	+5 @ 26 mA +3 @ 26 mA	-82 -80	0.3 x 0.3 x 0.1
DXO900965-5 DXO900965-3	9.0 - 9.65	0.5 - 12	+5 @ 22 mA +3 @ 22 mA	-80 -78	0.3 x 0.3 x 0.1
DXO10701095-5	10.70 - 10.95	0.5 - 15	+5 @ 21 mA	-82	0.3 x 0.3 x 0.1
DXO11441200-5	11.44 - 12.0	0.5 - 15	+5 @ 23 mA	-82	0.3 x 0.3 x 0.1
DXO11751220-5	11.75 - 12.2	0.5 - 15	+5 @ 24 mA	-80	0.3 x 0.3 x 0.1

Features

- Exceptional Phase Noise
- Dimensions: 0.3" x 0.3" x 0.1"
- Excellent Tuning Linearity
- Models Available from 4 to 12 GHz
- High Immunity To Phase Hits
- Lead Free RoHS Compliant
- Patented Technology

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RoHS COMPLIANT

RF CONNECTOR SERIES OFFERS GREATER AXIAL AND RADIAL FLOAT

In response to market needs, HUBER+SUHNER has developed a new series of RF board-to-board connectors that can cope with significantly greater axial misalignment. The new series of connectors addresses the fact that continuing miniaturization and tight space constraints have resulted in the need for more board-to-board connections. Owing to the complex stack-ups and larger piece part tolerances, this growing need is accompanied by an increasing demand for the connections to have greater 'axial float' in order to cope with significantly greater axial misalignment. This is particularly true in the field of radio base stations (BTS), but is also the case in the industrial, medical, defense, automotive, test and measurement, and aerospace sectors.

In order to meet these requirements and the rise in demand, HUBER+SUHNER has further developed its well-established and proven MMBX RF connector series and extended the product portfolio with the MBX family. In particular, the MBX series has been specifically designed to satisfy ever increasing demands with regards to axial and radial misalignment.

PERFORMANCE CHARACTERISTICS

The new product family exhibits the following important performance characteristics:

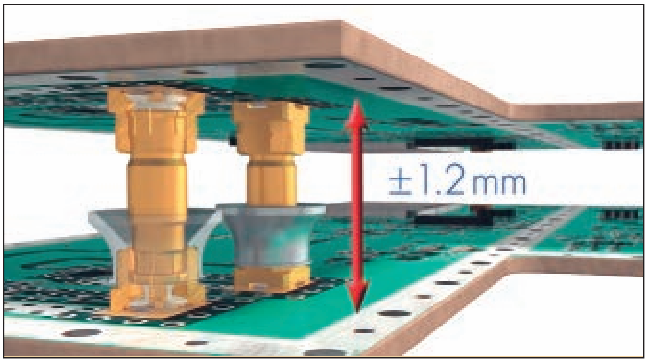
- Greater axial float (±1.2 mm is possible)
- Power up to 260 W
- Minimum board-to-board distance of 13 mm
- Robust and reliable design

The result is low total cost of ownership, high output power, and reliable mating and assembly. The connectors are also suitable for low weight modules. In addition, HUBER+SUHNER offers real added value in terms of technical support.

The basic MBX range offers the following: Straight board connections—male and female board connectors for through-hole and SMT technology; barrels for three board-to-board distances—13, 18 and 28 mm; and cable connectors (for testing)—straight and right angle. Also, a number of MBX to SMA adapters are

HUBER+SUHNER AG
Herisau, Switzerland

available for measurement purposes. A coupling/decoupling tool facilitates handling, and assembling of the within-series adapter (32_MBX) completes the range.

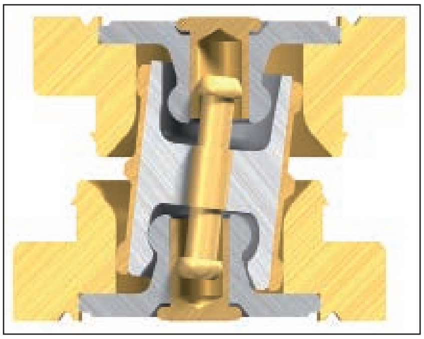


▲ *Fig. 1 The MBX connector is designed to accommodate an axial misalignment of ± 1.2 mm.*

BLIND MATEABLE CONNECTION

As a blind mateable board-to-board connection, the MBX series enables the design of direct RF connections between the boards. This design advantage enables size and weight reductions with regard to the RF modules, particularly in the case of remote radio units. As well as the previously mentioned axial misalignment handling of ±1.2 mm (shown in ***Figure 1***), other advantages include excellent power handling and the fact that the MBX product family complies with current and upcoming power specifications for radio modules.

The dimensions of the MBX interface are similar to those of the SMA connectors, which ensure robustness and good power performance. Significantly, the minimum board-to-board distance is a mere 13 mm, enabling a broad range of applications. Thanks to the 'ball joint' design (shown in ***Figure 2***), no forces act upon the piece parts or soldering joints, which ensures a high level of reliability.



▲ *Fig. 2 The ball joint design eliminates forces on the piece parts or soldering joints.*

REDUCED COST OF OWNERSHIP

The MBX Series' technical specifications, particularly the range of axial misalignment (±1.2 mm), which means that users can utilize the interface for complex stack-ups, results in a significantly lower total cost of ownership. As the mechanical tolerances can now be greater with regard to modules, boards and other individual parts, the costs naturally fall, which is a driving factor in today's economic environment with its preoccupation with cost-saving.

As has been outlined, the MBX series comprises a variety of RF connectors. The range for the product launch was defined based on the predominant market needs, but additional designs based on specific customer requirements can be realized. As HUBER+SUHNER designs, develops and produces in a user-oriented manner, customer-specific designs are available on request; for example, it can meet customer requirements for specific board-to-board distances to meet particular applications and the needs of the end-user.

HUBER+SUHNER has responded to market needs and developed a new series of RF board-to-board connectors that can cope with significantly greater axial misalignment. Miniaturization is effectively supported by having blind-mateable, direct board-to-board connections in place of assemblies. This makes smaller RF modules possible, with correspondingly reduced weight.

With the MMBX, the company introduced an interface that can handle extremely small board-to-board distances of 6.7 mm. With the new MBX, it has launched an interface that can handle the greatest axial misalignment, and features a very small board-to-board distance in the frequency range of up to 6 GHz.

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XTO-05	5-130 MHz	Ovenized Crystal	-95	-120	-140	-155	-160	-	100 MHz	11
PLD	30-130 MHz	P.L. Crystal	-95	-115	-140	-155	-155	-	100 MHz	13
PLD-1C	130-1000 MHz	P.L. Mult. Crystal	-80	-100	-120	-130	-135	-	560 MHz	13
BCO	.100-16.5 GHz	P.L. Single Loop	-65	-75	-80	-90	-115	-	16.35 GHz	13
VFS	1-14 GHz	Multiple Freq. Dual Loop	-60	-75	-110	-115	-115	-	12.5 GHz	13
DLCRO	.8-26 GHz	P.L. CRO Dual Loop	-60	-85	-110	-115	-115	-138	10 GHz	13
PLDRO	2-40 GHz	P.L. DRO Single/Dual	-60	-80	-110	-115	-120	-145	10 GHz	13
CP	.8-3.2 GHz	P.L. CRO Single Loop	-80	-110	-120	-130	-130	-140	2 GHz	13
CPM	4-15 GHz	P.L. Mult. Single Loop	-60	-90	-105	-110	-115	-130	12 GHz	13
ETCO	.1-24 GHz	Voltage Tuned CRO	-	-	-70	-100	-120	-130	2-4 GHz*	13

* Octave band.

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HFSS AND HSPICE SOLVER ON DEMAND IN ANSOFT DESIGNER 6.0

Ansoft (part of the ANSYS Inc. product portfolio) has always targeted the most challenging engineering problems in both the RF/microwave and signal integrity design space with the combination of its industry-leading 3D EM HFSS and circuit/system/planar EM Design environment—Ansoft Designer. HFSS, the general-purpose 3D EM simulator, solves components with the most complex, arbitrary geometries, while Ansoft Designer incorporates the resulting electrical model into the larger network including active devices and measurement test benches (for simulating EVM, ACPR, jitter, eye diagrams, etc.). Up until now, the products were separate entities, "dynamically-linked" through the company's proprietary technology.

Ansoft Designer 6.0, which was previewed at this year's IMS, allows HFSS to be operated completely from within the Ansoft Designer Environment. Models of RFIC layout, IC packages and PCBs can be imported to the environment using ECAD links to tools like Cadence, Mentor and Zuken. Designers can then assemble models that can be solved in HFSS without any further set up. Ansys calls this HFSS Solver on Demand. Modeling, material properties, port set up and boundary conditions are set automatically. In addition, all aspects of the models can be parameterized to explore design variations and manufacturability.

Designer 6.0 is also now linked to the popular circuit simulator HSPICE from Synopsys. While ANSYS offers its own circuit simulator called Nexxim that runs within Designer, many signal integrity engineers are locked into proprietary models and designs based on encrypted HSPICE. The new link supports simulation of HSPICE encrypted circuits and models. Engineers are now able to continue using these legacy designs with their simulation engine of choice, while integrating passive modeling results based on Ansoft's EM simulation technology. Additionally, since HSPICE is a circuit solver engine only, without schematic capture or post-processing, Designer provides HSPICE with a powerful user interface ideal for RF/microwave and high speed design.

ANSYS Inc.,
Pittsburgh, PA (412) 261-3200,
www.ansys.com and
www.ansoft.com.

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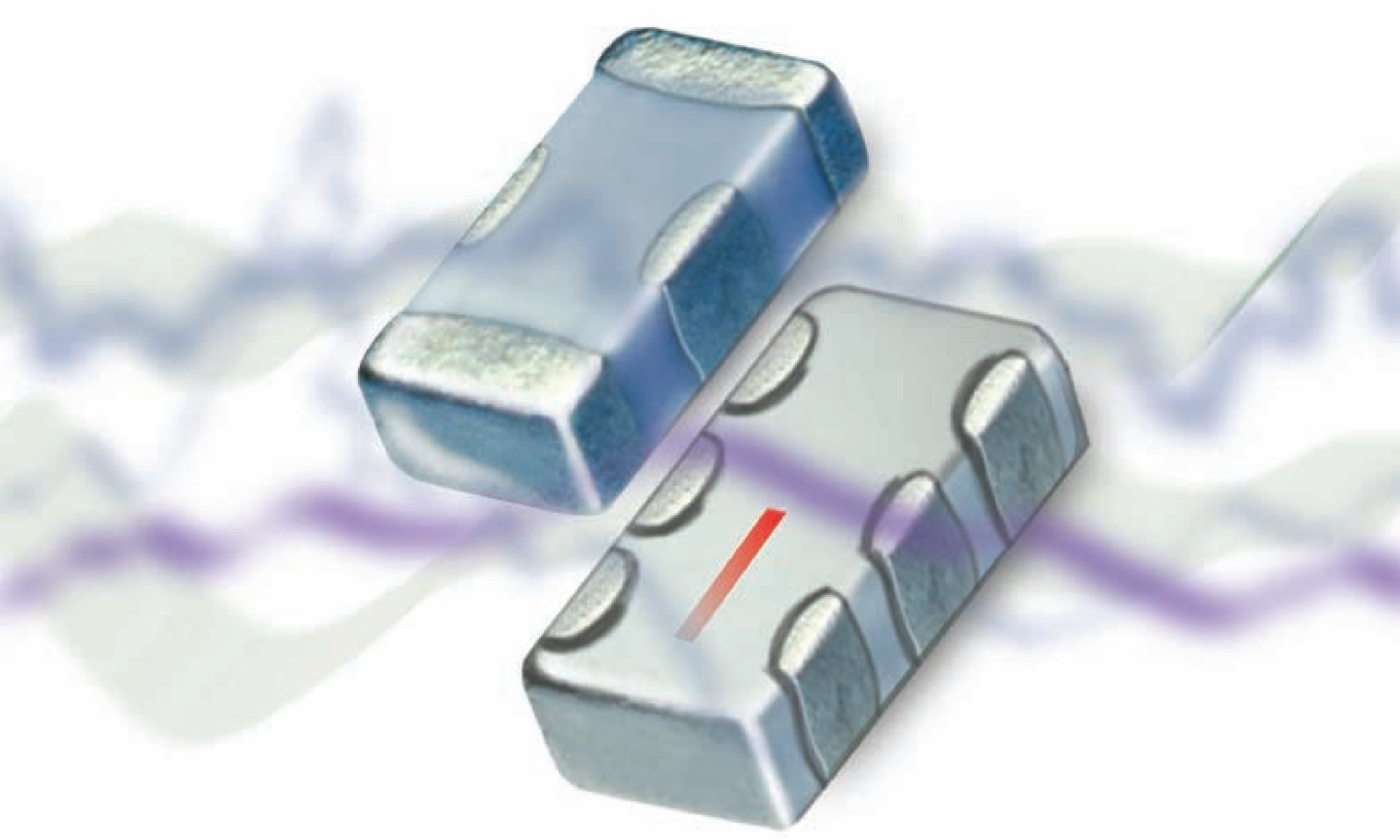

CERAMIC FILTERS

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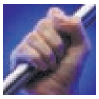

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Express Distribution Products Catalog

VENDORVIEW

This edition is packed full of Aeroflex/Weinschel products that can be shipped overnight via Argosy Component Sales. Express products include fixed attenuators (high power also), adapters, power splitter/dividers, terminations and DC blocks. This catalog also includes programmable attenuators; connector systems (Planar Crown® and Planar Blindmate®); and phase shifters.

Aeroflex/Weinschel,
Frederick, MD (301) 846-9222, www.weinschel.com.

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Application Notes

VENDORVIEW

These free application notes provide insight into solving measurement problems for both the design and manufacturing environments. The new Power of X application note topics include solutions for securing successful first-pass component design, understanding X-parameter nonlinear measurements and solutions for characterizing high power devices using X-parameters to make nonlinear measurements of high power amplifiers. To request copies of the application notes, go to www.agilent.com/find/powerofx.

Agilent Technologies Inc.,
Santa Clara, CA (800) 829-4444, www.agilent.com.

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RF Signal Generators

AnaPico offers a range of RF signal generators designed to match different customer requirements and to provide a lightweight, compact and low cost alternative to high end laboratory grade instruments. Featured in the new catalog are: the APSIN3000 and APSIN6000, which are true hand-held, low noise, fast switching instruments; the APSIN 6010 (9 kHz to 6100 MHz), the company's fastest-switching analog signal generator; the APGEN 3000 (9 kHz to 3000 MHz), with 0.1 Hz frequency resolution, good signal quality and powerful trigger capabilities; and the APPH 6000, a fully automated phase noise test system to 6 GHz.

AnaPico Ltd.,
Zurich, Switzerland +41 44 440 0051, www.anapico.com.

RS No. 313

White Paper

VENDORVIEW

A new white paper from AWR® entitled "A Plethora of Ports: Making Sense of the Different Types of Ports in EM Planar Simulators" provides a fundamental understanding of ports so that designers can select them properly in the process of circuit simulation. It traces the evolution of ports in EM simulation and examines all aspects of how they can be employed to make design simulation practical. The new white paper is a complement to "Understanding Grounding Concepts in EM Simulators," which explores the concept, definition and use of "ground" in EM simulators. Both documents can be downloaded by visiting www.awrcorp.com/axiem.

AWR,
El Segundo, CA (310) 726-3000, www.awrcorp.com.

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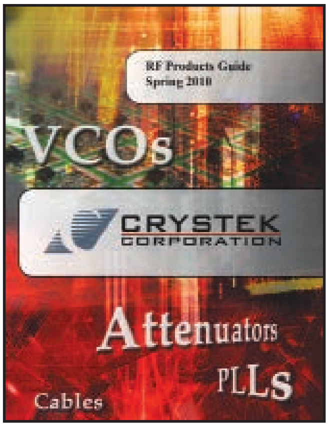

Frequency Control Solutions

Crystek specializes in providing high frequency, low phase noise solutions to the microwave and RF wireless industries. Crystek's custom engineering solutions, manufacturing capabilities and quality control are unmatched in the industry. The Crystek frequency control lineup features VCOs, VCXOs, PLLs, XOs, TCXOs and quartz crystals, along with a full line of accessories such as RF coax cable assemblies, attenuators and filters.

Crystek Corp.,
Fort Myers, FL (800) 237-3061, www.crystek.com.

RS No. 316

Product Selection Guide

VENDORVIEW

The product selection guide summarizes over 825 products including 35 new products and two new product lines. New for this publication is an expanded product line section featuring high speed clocked comparators, tunable filters, power conditioning and PLLs with integrated VCOs. Hittite's selection guide also contains a new Part Number index, product sections organized by IC products, connectorized modules and instrumentation and expanded market and application sections, and includes competitor cross reference tables. Request your copy of the selection guide at www.hittite.com.

Hittite Microwave Corp.,
Chelmsford, MA (978) 250-3343, www.hittite.com.

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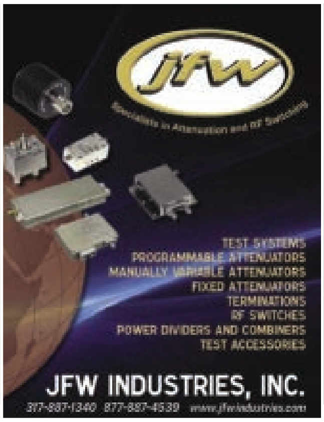

Product Catalog

VENDORVIEW

JFW Industries announced the release of the company's new, 180-page catalog. This latest edition introduces 50 new models, including an impressive series of broadband programmable attenuators that cover 0.2 to 6 GHz. Also showcased is JFW's unique selection of high power solid-state RF switches. To request your copy, call JFW at (877) 887-4539 or visit www.jfwindustries.com.

JFW Industries,
Indianapolis, IN (877) 887-4539, www.jfwindustries.com.

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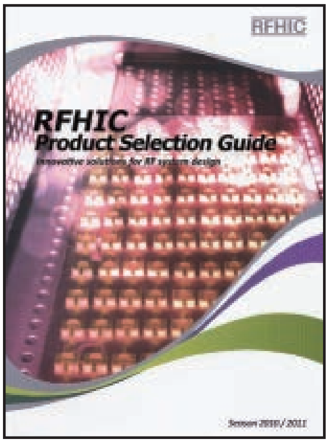

Product Selection Guide

VENDORVIEW

This catalog highlights the company's MW and RF components and provides a comprehensive product portfolio from discretes to integrated high power amplifiers. RFHIC utilizes the most sophisticated technologies including hybrid solutions of GaN, and is a cost-effective solution provider. RFHIC has a strong relationship with CREE to provide the most mature GaN technology in the market. RFHIC is an ISO9001 and 14001 certified company providing reliable and dependable products.

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Gyeonggi-do, Korea +82-31-250-5011, www.rfhic.com.

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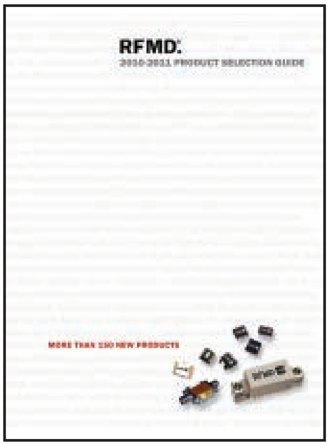

Product Selection Guide

VENDORVIEW

Visit www.rfmd.com to download the new 2010 RFMD Product Selection Guide, which provides specifications for over 850 products. The guide offers a broad portfolio of RF components for the RF industry in an easy-to-use format, and lists products servicing over 20 end-market segments. Individuals can cross-reference and search products using market application diagrams.

RFMD,
Greensboro, NC (336) 664-1233, www.rfmd.com.

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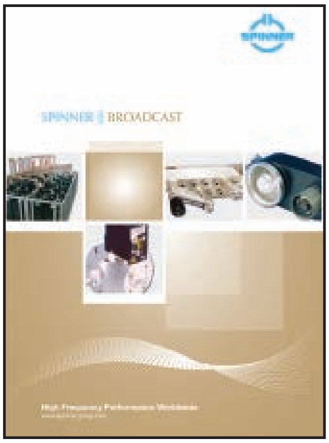
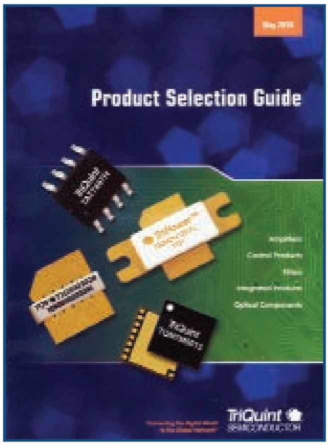


Broadcast Catalog

This catalog presents the complete SPINNER broadcast product portfolio, which includes multi channel combiners, bandpass filters, patch panels, parallel switching units, coaxial switches, RF lines, and monitoring and coaxial loads. It also includes all available information on the company's numerous new products in this field, such as components of the compact combining and switching system. The catalog is available from the company's website and is the first to utilize the new visual design that the SPINNER Group has adopted to underline its leading role in terms of technology and quality.

SPINNER GmbH,
Munich, Germany +49 89 12601-0, www.spinner-group.com.

RS No. 325



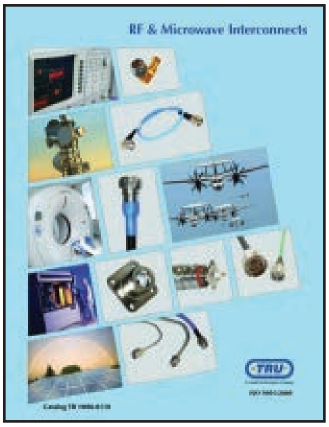
Product Selection Guide

VENDORVIEW

Download TriQuint's new and expanded product selection guide (PSG), which includes hundreds of advanced RF solutions for mobile device, 3G/4G wireless base station, optical, CATV/FTTH, WLAN, GPS/PND, defense and aerospace markets. It contains new components, modules and application block diagrams. A printed edition of this new PSG is included with the May 2010 issue of *Microwave Journal*. One can also acquire printed copies through area TriQuint Sales Representatives, or by contacting TriQuint.

TriQuint Semiconductor,
Hillsboro, OR (503) 615-9000, www.triquint.com.

RS No. 326



RF Interconnect Catalog

TRU Corp.'s new catalog, RF and Microwave Interconnects, includes various types of cable assemblies including: general purpose, quick disconnect, Cintru® flexible commercial, conformable and general purpose test. The catalog also includes a line of precision test adapters, quick change adapters, and a high power test and measurement cable kit with interchangeable connector head test adapters.

TRU Corp.,
Peabody, MA (800) 262-9878, www.trucorporation.com.

RS No. 327

Design Software

VENDORVIEW

Agilent recently announced tools for circuit-level modeling through system verification for general RF/uW, 4G Comms and aero/defense applications including SystemVue 2010.01 and Genesys 2010.05. These software platforms add X-parameter support and move X-parameters beyond RF into system-level design. The non-linear model support provides convenient and reliable design flow closure between wireless circuit designers, RF system architects, and non-analog colleagues doing communications PHY algorithms and baseband signal processing. Time Domain Reflectometer (TDR) application software option for the Agilent E5071C ENA network analyzer: This one-box solution is ideal for high-speed serial interconnect analysis and can be used by signal integrity engineers who require efficient design and verification in R&D, quality assurance and manufacturing.

Agilent Technologies Inc.,
Santa Clara, CA (800) 829-4444,
www.agilent.com.

RS No. 216

Advanced Measurement and Modeling Software

Maury Microwave Corp. and AMCAD Engineering have signed an exclusive development and distribution agreement with regards to AMCAD's advanced measurement suite, IVCAD, and its PIV/PLP family of pulsed IV systems. Development of IVCAD, which is currently available for sale, will continue over the upcoming year as a complement to Maury's long-standing ATS device characterization software. IVCAD will support multiple load pull techniques including traditional load pull using external instrumentation, VNA-based load pull, active load pull and hybrid load pull. It will perform noise parameter measurements, DC-IV and pulsed-IV measurements as well as incorporate device modeling tools. Its modern visualization capabilities give users a greater ability to view, plot and graph measurement data in an intuitive manner.

AMCAD Engineering/
Maury Microwave Corp.,
Ontario, CA (909) 987-4715,
www.maurymw.com.

RS No. 217

High Frequency EDA

VENDORVIEW

AWR recently announced new features coming in the 2010 release of Microwave Office®, AXIEM™, Visual System Simulator™ and Analog Office® design suites. New technologies such as iFilter™ lumped and distributed filter synthesis software, antenna analysis and visualization in AXIEM 3D planar EM software, and support for nonlinear behavioral models from many of the test equipment manufacturers were on display at IMS 2010. New feature highlights in Microwave Office include: nonlinear behavioral modeling support for Agilent's X-parameters® and Mesuro's Cardiff model; multi-rate harmonic balance technology (MRHB™) improvements for even faster simulation times; and constant compression/constant output power simulation for computing compression from linear gain region or max gain region. New features for AXIEM antenna analysis include: antenna patterns for linear, circular and elliptical polarizations, etc.; numerous antenna measurements including gain; and current visualization/animation. VSS features include: time delay neural network advanced amplifier behavioral models for capturing memory effects; turbo decoders supporting 3G/4G standards and custom turbo codes; and additional RF models and enhancements to RF architecture design.

AWR Corp.,
El Segundo, CA (310) 726-3000,
www.awrcorp.com.

RS No. 218

Asymptotic Solver

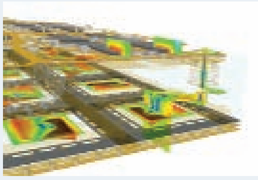
VENDORVIEW

Engineers simulating electrically large structures, either for radar cross-section analysis or for antenna placement studies, benefitted from the introduction of an asymptotic solver in CST MICROWAVE STUDIO version 2010. This solver is based on the shooting bouncing ray method. With the latest CST STUDIO SUITE 2010 service pack, significant functional enhancements have been made available to CST customers. The asymptotic solver can now use far-fields as excitation sources. These far-fields can be computed by other CST MWS solvers including the transient and frequency domain solvers. This makes the calculation of an installed antenna's far-field possible, even for an electrically large structure such as a ship. Importing more than one far-field enables the computation of the coupling between several antennas, or of the total far-field including all antennas.

CST,
Darmstadt, Germany +49 6151 7303-0,
www.cst.com.

RS No. 219

High-speed Simulation Software

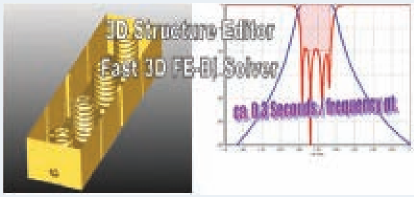


Version 5.40 of the EMPIRE XCcel™ software enables one simulation job to be distributed on multiple networked PCs, thus speeding up simulation processes. The almost infinite extension of memory-space, based on the available PC network resources, means that a greater range of complexities can be addressed, i.e. by higher resolutions and/or larger dimensions. Other features include: complete automation of distribution of files and data throughout the simulation, easy configuration capability for multiple hosts, transparent job-management by visualization of configuration and processes, and the performance and simulation-speed scaled linearly with the number of PCs.

IMST GmbH,
Kamp-Lintfort, Germany
+49 2842 981 245,
www.empire.de.

RS No. 220

Software Tool Features 3D



Version 8.0 of WASP-NET® features a new 3D structure editor, which is a convenient 3D data file import option, and two new fast 3D solvers: A finite-element/boundary integral (FE-BI) solver for arbitrary 3D waveguide, antenna and microstrip structures, and an integral equation solver for large-scale, open scattering and radiating structures. These new features combine with the CAD tool's typical high computational speeds for direct, fast EM-based optimizations that are capable of solving challenging waveguide, coaxial, microstrip and antenna design problems. The new features will support microwave design engineers with practically unlimited CAD flexibility, combined with high EM CAD optimization performance.

Microwave Innovation Group (MiG),
Bremen, Germany +49 421 22 37 96 60,
www.mig-germany.com.

RS No. 221

3D EM Simulation Software

Remcom announced Fdtd, its 3D EM simulation software. XACT Accurate Cell Technology: Accurately resolve even the most intricate designs with fewer computational resources. Benefits include faster run times and the power to simulate complex geometries. XTend Script Library: Use the pre-loaded scripts in XF7 to automate your modeling and design, customize them or request additional scripts at no cost. Multiphysics Toolset: Use XFdtd and Wireless InSite together to achieve a more complete, real-world antenna analysis.

Remcom,
State College, PA (814) 861-1299,
www.remcom.com.

RS No. 222

High Frequency EM Software

Sonnet had a preview of the Sonnet Suites Release 13, a major new release planned for later this year on display at IMS 2010. Sonnet Suites Release 13 will provide designers with new model extraction techniques and enhanced modeling capabilities.

Sonnet Software,
North Syracuse, NY (315) 453-3096,
www.sonnetsoftware.com.

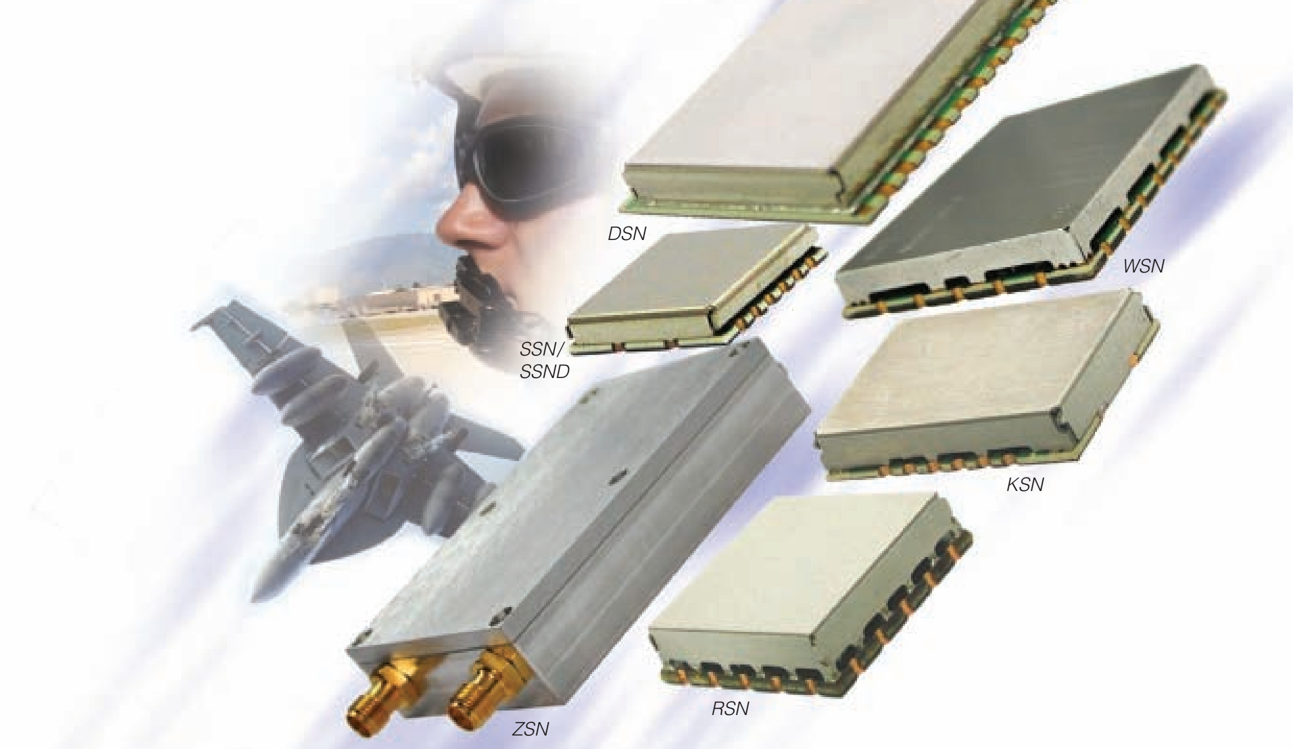
RS No. 223

Electronic Design Automation

Synopsys' latest technology enhancements to Galaxy Custom Designer and HSPICE include a demo that highlights phase noise and jitter analysis of VCOs and PLLs, RFIC simulation using the advanced Harmonic Balance and Shooting Newton algorithms, Signal Integrity analysis with the most accurate nonlinear buffer models available, combined with powerful StatEye, S-parameter and transmission line analysis capabilities.

Synopsys Inc.,
Mountain View, CA (650) 584-5000,
www.synopsys.com.

RS No. 224



DSN
WSN
SSN/
SSND
KSN
RSN
ZSN

Components

BMA and SMP Connectors

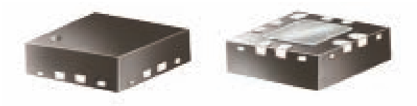
Ranges of both BMA and SMP connectors have been introduced that offer precise mating and excellent VSWR performance. Operating up to 22 GHz, the BMA connectors are designed based on MIL standards and are suitable for communication base station equipment, rack-and-panel applications with appropriate float-mounted jacks, and building block systems such as radar. SMP connectors operate up to 40 GHz and have excellent vibration and shock performance. Their design is also based on MIL standards, making them suitable for applications such as aerospace, military, broadband, instrumentation and telecoms.

GigaLane Co. Ltd.,
Gyeonggi-do, Korea
+82-31-233-7325,
www.gigalane.com.

RS No. 226

Wideband Microwave Amplifier

VENDORVIEW



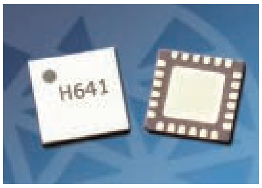
The Mini-Circuits AVA-24+ is a surface-mount, microwave amplifier and fully integrated gain block up to 20 GHz. It is packaged in Mini-Circuits' industry standard 3×3 mm MCLP (QFN) package, which provides excellent RF and thermal performance. The AVA-24+ integrates the entire matching network with the majority of the bias circuit inside the package, reducing the need for complicated external circuits. This approach makes the AVA-24+ extremely flexible and enables simple, straightforward use.

Mini-Circuits,
Brooklyn, NY (718) 934-4500,
www.minicircuits.com.

RS No. 250

SP4T MMIC Switch

VENDORVIEW



This ceramic SMT packaged GaAs PHEMT SP4T MMIC switch is ideal for industrial sensors, test and measurement, microwave radio, military EW and space applications from DC to 20 GHz. The HMC641LC4 is a GaAs PHEMT MMIC SP4T switch that is rated for operation from DC to 20 GHz. This wideband, non-reflective switch exhibits 2.1 dB insertion loss and 42 dB isolation at midband, and features an on-chip binary decoder that requires only two control lines. High P1dB and input IP3 performance of +23 and +39 dBm, respectively, make the HMC641LC4 ideal for applications requiring wide bandwidth and moderate to high linearity.

Hittite Microwave Corp.,
Chelmsford, MA (978) 250-3343,
www.hittite.com.

RS No. 239

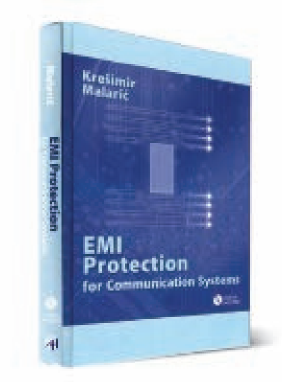
System

Thermal Platform Systems

The Next Generation Total-Temp Thermal Platforms are specifically designed to deliver fast, efficient and precisely controlled temperature conditioning to a device under test. Utilizing COTS technology to provide the successful integration of an embedded copper tube cooling channel with a high density arrangement of long life durable AC cartridge heaters, TotalTemp provides a comprehensive system able to deliver hot and cold temperature cycling and conditioning on demand with temperature ranges from -100° to +200°C.

TotalTemp Technologies Inc.,
San Diego, CA (888) 712-2228,
www.totaltemptech.com.

RS No. 249



EMI Protection for Communication Systems

Krešimir Malarić

In recent years the protection of communication services operating in the same adjacent channels has become more and more challenging. Communication systems need to be protected from natural and man-made interference. Electromagnetic interference (EMI) can be radiated or conducted, intentional or unintentional. Understanding physical characteristics of wave propagation is necessary to comprehend the mechanisms of electric and magnetic coupling in the communication signal paths. Different modulating techniques, as well as encoding and encrypting, can improve bit error rates (BER) and signal quality. Communication systems must be designed properly, so that the performance of their system capabilities is not subject to degradation or complete loss due to electromagnetic interference.

Although there are numerous books available on electromagnetic compatibility (EMC), signal processing and electromagnetic theory, not many offer a comprehensive description of technologies for the protection of communication systems, which includes discussions on the improvement of existing communication systems and the creation of new systems. *EMI Protection for Communication Systems* provides basic information and definitions of problems regarding EMI in communication systems. In addition, it gives experienced practitioners knowledge of how to solve possible problems in both digital and analog communication systems. The examples given are intended for an easier comprehension of otherwise demanding electromagnetic problems. The book's primary audience includes designers, researchers and graduate students in the area of communications. There is an accompanying program on CD that works in the LabVIEW environment on a PC Windows operating system.

EMI Protection for Communication Systems is a complete text covering all aspects of EMI and is appropriate for laymen, but also contains good instructional material for practitioners in the field to help solve problems with EMI appropriate for industry professionals, researchers and advanced students.

To order this book, contact:

Artech House
685 Canton St., Norwood, MA 02062
(781) 769-9750 ext. 4030;
or
16 Sussex St., London SW1V 4RW, UK
+44 (0) 20 7596-8750

275 pages; $129, £79
ISBN: 978-1-59693-313-2

MICRO-AD
Visit http://mwj.hotims.com/28491-(RS#)

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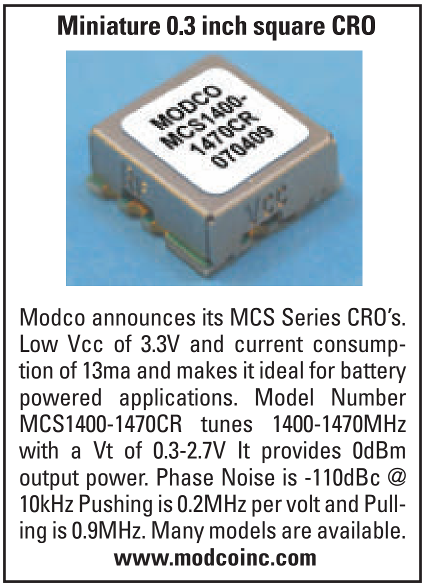

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WMS.Werbe- und Media Service
Brigitte Beranek
Gerhart-Hauptmann-Street 33,
D-72574 Bad Urach
Germany
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FAX: +49 7125 407 31 08
bberanek@horizonhouse.com

Israel
Oreet Ben Yaacov
Oreet International Media
15 Kineret Street
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Tel: +972 3 570 6527
FAX: +972 3 570 6526
obenyaacov@horizonhouse.com

Korea
Young-Seoh Chinn
JES Media International
2nd Floor, ANA Bldg.
257-1, Myungil-Dong
Kangdong-Gu
Seoul, 134-070 Korea
Tel: +82 2 481-3411
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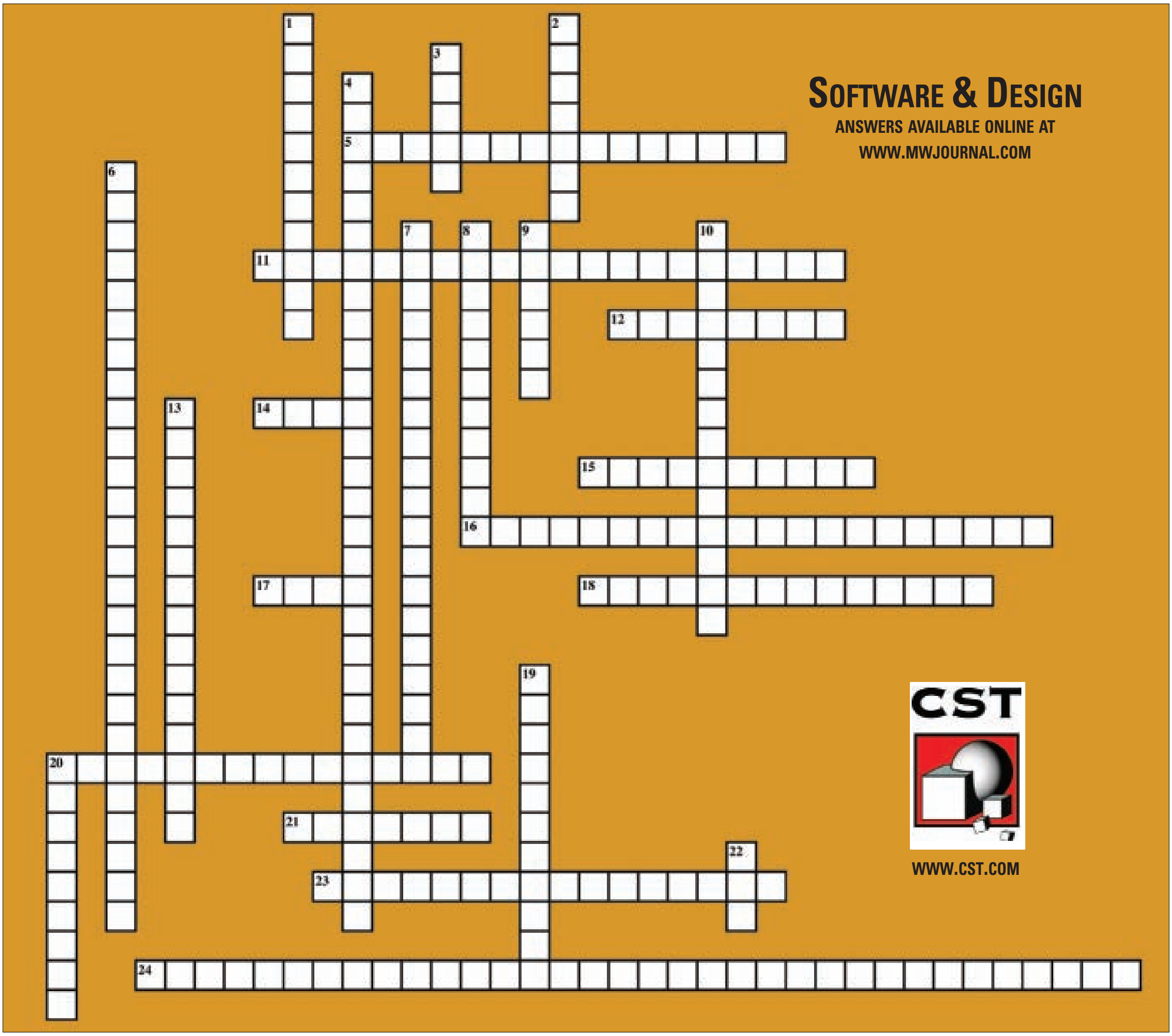
yschinn@horizonhouse.com

Japan
Katsuhiro Ishii
Ace Media Service Inc.
12-6, 4-Chome,
Nishiiko, Adachi-Ku
Tokyo 121-0824, Japan
Tel: +81 3 5691 3335
FAX: +81 3 5691 3336
amskatsu@dream.com

China
Michael Tsui
ACT International
Tel: 86-755-25988571
Tel: 86-21-62511200
FAX: 86-10-58607751
michaelT@actintl.com.hk

Hong Kong
Mark Mak
ACT International
Tel: 852-28386298
markm@actintl.com.hk



ACROSS

5 An iterative process of selectively refining the finite element mesh based on the results from a previous solution (2 words)

11 Radio in which some or all of the physical layer functions are software defined (3 words)

12 A class of methods for converting a continuous operator problem (such as a differential equation) to a discrete problem

14 Modulation technique that works by splitting the radio signal into multiple smaller sub-signals that are then transmitted simultaneously at different frequencies

15 A scalar for which there exists a nonzero vector such that the scalar times the vector equals the value of the vector under a given linear transformation on a vector space

16 Receive constellation error (3 words)

17 A grid-based differential time-domain numerical modeling method, which can be traced back to a seminal 1966 paper by Kane Yee in *IEEE Transactions on Antennas and Propagation*

18 Iterative method for solving a system of linear equations that derives approximations to the solution by minimizing the residual over the subspace formed (2 words)

20 A method used to calculate the steady-state frequency response of high-frequency electrical circuits, which include nonlinear and passive distributed elements (2 words)

21 A text-based file that describes the connectivity of an electronic design

23 An operation that transforms the time domain information into the frequency domain (2 words)

24 A software standard for SDR that is proliferating beyond the original JTRS program into other programs around the world (3 words)

DOWN

1 A widely used bipolar junction transistor model originally developed in 1970 and frequently used to model HBTs (hyphenated)

2 System simulation engine co-developed by HP and UC Berkeley, which facilitates co-simulation of time, frequency and data flow technologies

3 An agency of the United States DoD responsible for the development of new technology for use by the military, responsible for funding the MIMIC program

4 A method of combining two amplitude-modulated (AM) signals into a single channel (3 words)

6 Two-dimensional arrays of periodic resonant elements that interact with EM waves within certain frequency band(s) (3 words)

7 Factorization of a matrix into some canonical form, used for solving complex systems of linear equations (2 words)

8 A hardware description language (HDL) used to model electronic systems (2 words)

9 Most frequently cited phase noise model

10 Type of function used to solve inhomogeneous differential equations subject to boundary conditions (2 words)

13 A type of simulation for high-frequency amplifiers, mixers, oscillators and subsystems that involves transient or modulated RF signals, introduced with HP-EEsof ADS (2 words)

19 The "A" in API, the programming interface (API) implemented by a software program that enables it to interact with other software

20 Practice of splitting the design into pieces, each piece becoming a "definition" that can be used as instances in the design; complex designs are often composed of these pieces known as sub-circuits

22 Determines whether the physical layout of a particular chip layout satisfies a series of recommended manufacturing parameters, a major step during physical verification signoff

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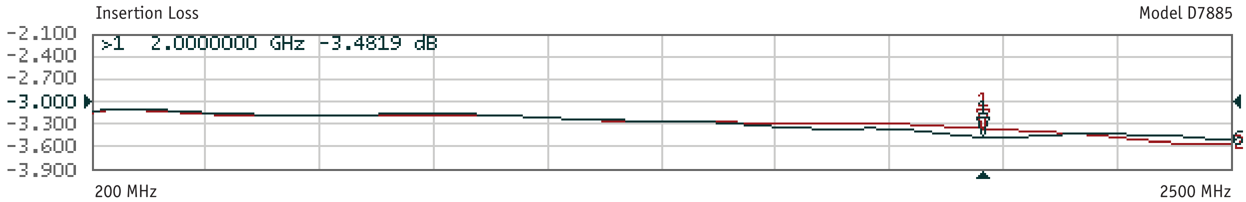

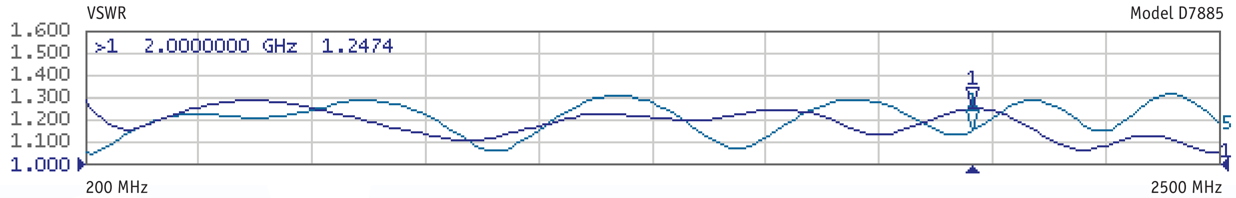

www.werlatone.com

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D7823	2-Way	500-2500	200	0.4	1.35:1	15	4.7 x 2.0 x 0.8
D7630	2-Way	800-3000	200	0.4	1.35:1	15	3.7 x 1.9 x 0.87
D7539	4-Way	800-2800	200	0.6	1.35:1	17	5.5 x 4.1 x 1.1
D7695	4-Way	900-1300	100	0.4	1.30:1	20	4.0 x 3.3 x 0.8