Vol. 52 • No. 2

February 2009

Microwave Journal

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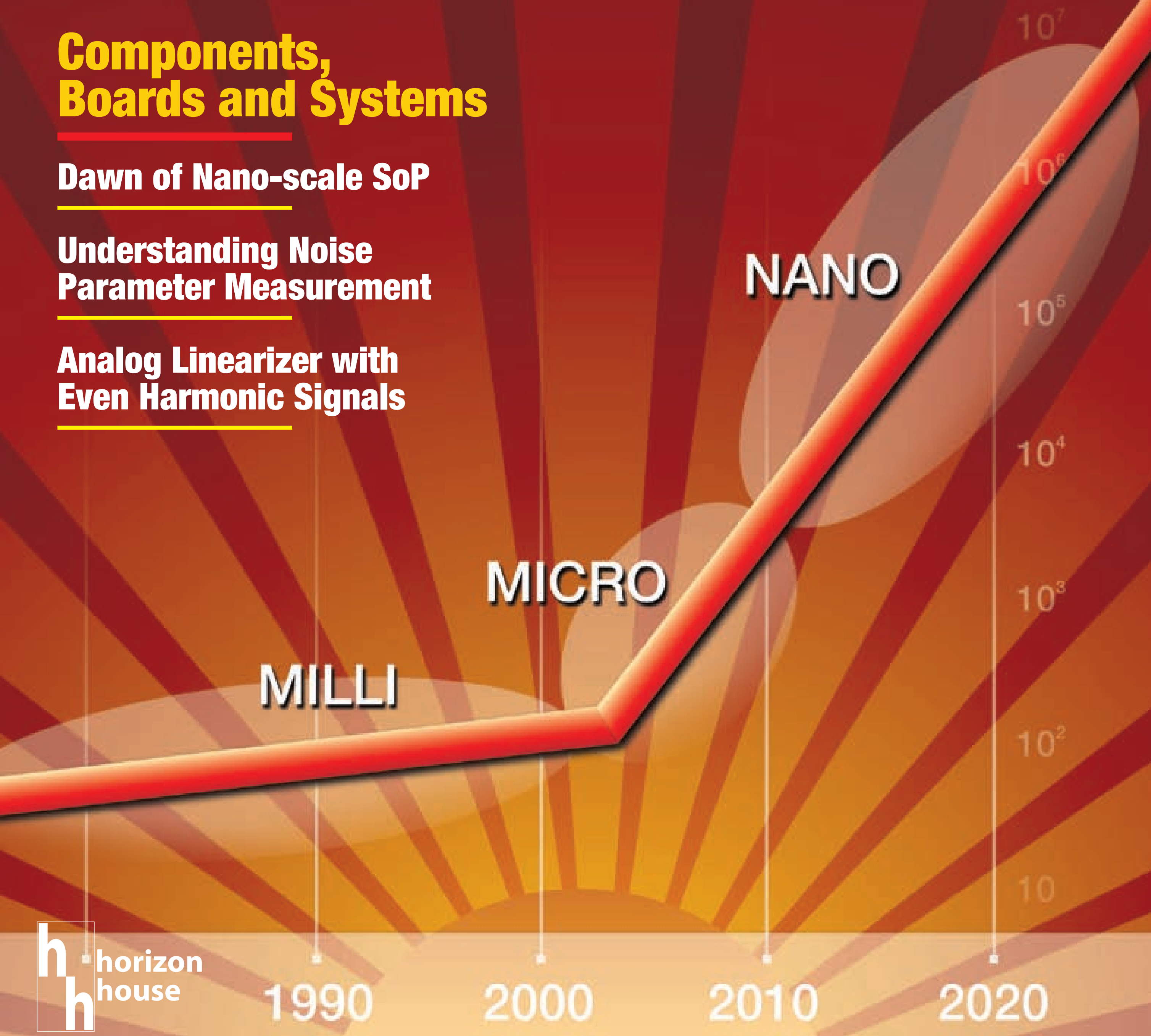
Components, Boards and Systems

Dawn of Nano-scale SoP

Understanding Noise Parameter Measurement

Analog Linearizer with Even Harmonic Signals



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FEATURES

NOTE FROM THE EDITOR

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Microwave Journal (USPS 396-250) (ISSN 0192-6225) is published monthly by Horizon House Publications Inc., 685 Canton St., Norwood, MA 02062. Periodicals postage paid at Norwood, MA 02062 and additional mailing offices.

POSTMASTER: Send address corrections to *Microwave Journal*, PO Box 3256, Northbrook, IL 60065-3256 or e-mail mwj@omeda.com. Subscription information: (847) 291-5216. This journal is issued without charge upon written request to qualified persons working in that part of the electronics industry, including governmental and university installation, that deal with VHF through light frequencies. Other subscriptions are: domestic, $120.00 per year, two-year subscriptions, $185.00; foreign, $200.00 per year, two-year subscriptions, $370.00; back issues (if available) and single copies, $10.00 domestic and $20.00 foreign. Claims for missing issues must be filed within 90 days of date of issue for complimentary replacement.

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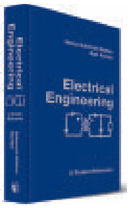
Per Viklund, Mentor Graphics and How-Siang Yap, Agilent

Part II: 3G/4G Multimode Handset Challenges: Implications for Front End Architecture Options
Kevin Walsh and Jackie Johnson, RFMD

Expert Advice

Dr. Lawrence P. Dunleavy is a co-founder of Modelithics Inc., co-developer of the University of South Florida's innovative Center for Wireless and Microwave Information Systems (The WAMI Center) and maintains a part-time position as a Professor within USF's Department of Electrical Engineering. Dr. Dunleavy shares his thoughts on the benefits of outsourcing complex RF data and model requirements.



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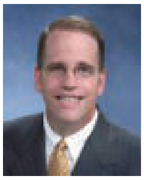
MWJ Blog

Microwave engineers see the world in frequency and wavelength. We know that - size matters. This month's MWJ blog expands our lead story on the art of RF board and package miniaturization ("The Dawn of Nanoscale SoP") with additional items from contributors and related news. Read http://microwavejournal.blogspot.com/ and add your comments.

Executive Interview



MWJ talks individually to **Jeremy C. Wensinger**, President Designate of **Cobham Electronic Defense Systems** and **Joe Thomas**, President of **M/A-COM Technology Solutions**. In 2008, Cobham acquired M/A-COM to enhance its solutions portfolio in the defense electronics market. The commercial portion of M/A-COM will emerge as an independent company. Wensinger discusses Cobham's strategy behind this acquisition, while Thomas tells us what is in store for M/A-COM Tech's future.

THE OPTIMIST

Call me an optimist. Despite the current recession and concern about business prospects for at least the first half of 2009, I believe the microwave industry will persevere and become stronger. The proliferation of communication systems in our personal and professional lives gives me confidence that the demand for affordable fixed and mobile bandwidth will be with us for some time. Apparently, analysts looking at a number of wireless markets agree (see the January MWJ blog), which should help a segment of the industry. Defense spending will undoubtedly help some more. Yet, it is not a surprise that the current global economy has thrown many companies into a state of caution, reducing spending by significant levels.

Predictably, winners will be the manufacturers whose products help save money or are the "enabling technologies" to enter new markets. Replace a more expensive part or reduce the bill of materials through integration and the business could be yours. Cutting costs is a familiar means to success—accelerated for the times we live in. Our industry understands that smart investments in research yields innovations that provide the market with more for less (make sure your marketing department remembers to get the word out). But make no mistake, in the immediate future we may all be working harder for a smaller piece of the pie.

Innovation defines this month's lead story, which focuses on the state-of-the-art in multi-chip devices known as System-on-Package (SoP). This technology allows manufacturers to produce the highly integrated devices touted by the analyst predicting a brighter economic future. The *Journal* spoke to leaders in advanced package research, RF chip/module manufacturers, design engineers, CAD and EDA application engineers, and product managers. From these many sources, we have compiled an insider's view of System-on-Package technology in 2009 and the latest in design flow support.

The contributors to this story were asked to comment on specific areas of the SoP engineering problem from their unique perspectives. From the Packaging Research Center at Georgia Tech, we received input from Venky Sundaram, Raj Pulugurtha, Rao Tummala and Mahadevan Iyer. From Kevin Walsh and Ben Thomas at RFMD, we received information on that company's microshield technology as well as insight on driving factors in the multi-chip market (also thanks to Irma Swain and Alston Skinner). On chip/package co-design we talked with Per Viklund of Mentor Graphics (with help from Suzanne Graham and the Mentor Graphics PR team), How-Siang Yap and Hee-Soo Lee from Agilent (with help from Lisa Hebert and Georgia Marszalek) and Mike Heimlich from AWR (with help from Sherry Hess). Their complete responses to our questions can be found this month on the *Microwave Journal* web site. Thank you all.

The articles appearing in the *Journal* this and every month reflect the innumerable technical accomplishments that take place within our community. This is how the industry has survived tough times in the past and it is how I suspect we will survive and prosper in 2009. But hey, I'm an optimist. ■

David Vye

MARCH 2009

SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31	1	2	3	4

March 2–6: Georgia Tech — **Georgia Tech Space-based Radar**, Atlanta, GA

March 4–5: CST — **CST MICROWAVE STUDIO® Antenna and Microwave (MWS A&M)**, Framingham, MA

March 8–12: **ACES 2009 The 25th International Review of Progress in Applied Computational Electromagnetics**, Monterey, CA

March 16–18: **Georgia Tech Radar Cross Section Reduction**, Atlanta, GA

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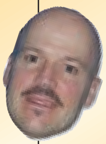
March 23–27: **EuCAP 2009 3rd European Conference on Antennas and Propagation**, Berlin, Germany

March 24–27: **SATELLITE 2009** Washington, DC

March 24: **MWJ/Besser Webinar: RF/MW Power Amps**

David Vye



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March 24–27: **Georgia Tech Modeling and Simulation of RF Electronic Warfare Systems**, Atlanta, GA

March 30–April 4: Oklahoma State University — **Reverberation Chamber Theory and Experiment Short Course**, Stillwater, OK

April 1–3: International CTIA Wireless 2009 / RF Microwave Zone 2009 — **CTIA Wireless RF/Microwave Zone**, Las Vegas, NV

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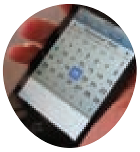

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MIE 2009
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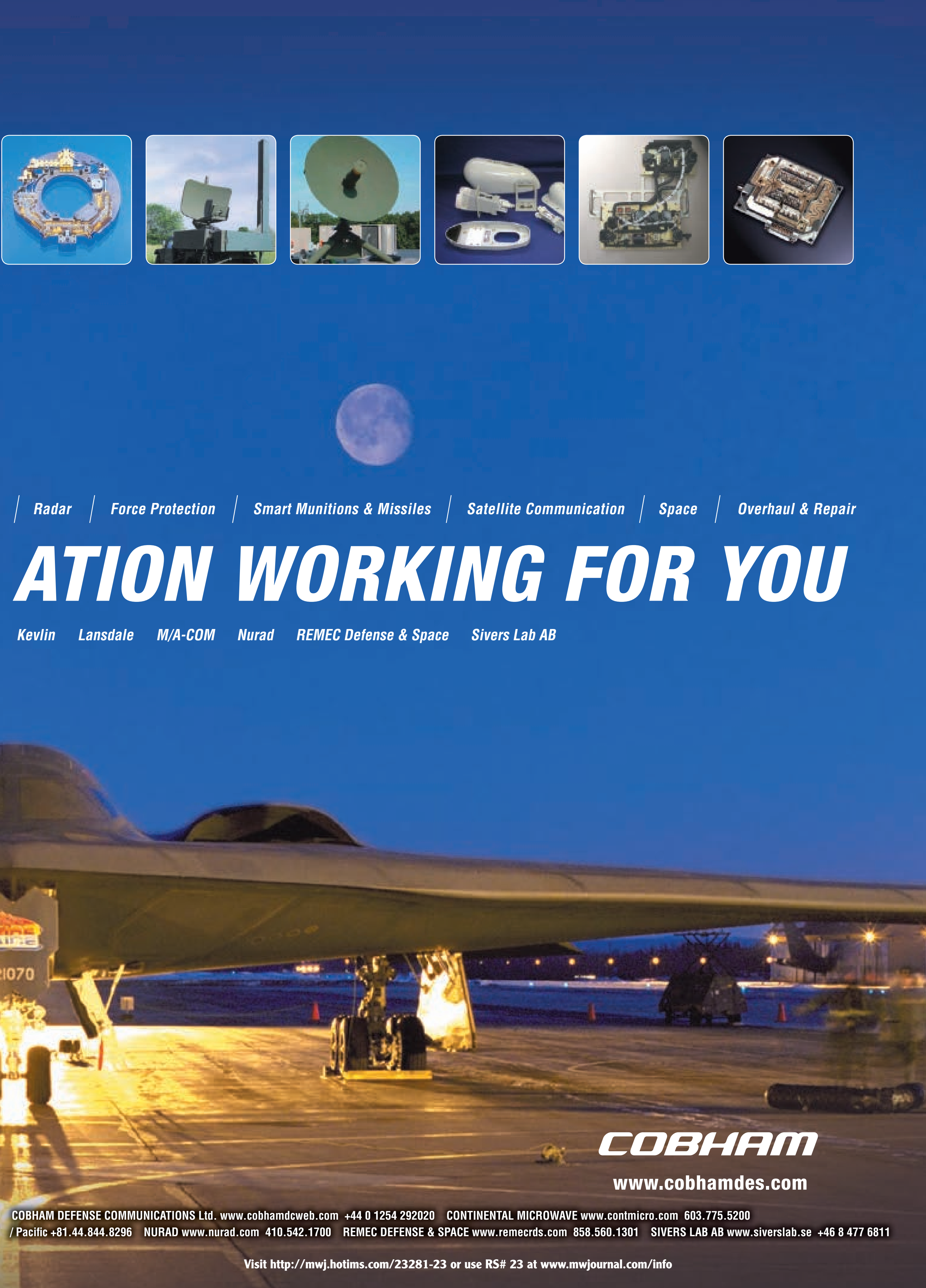
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THE DAWN OF NANO-SCALE SYSTEM-ON-PACKAGE

Much of today's R&D in high-frequency electronics is concerned with squeezing more functionality into a smaller package at an affordable price. While large, complex ICs known as System-on-Chip (SoC) are the choice when production volume is high, multi-chip integration often wins for lower volume and speedier time-to-market. The multi-chip approach allows designers to match the optimum IC technology to the required functionality achieving the best performance vs. cost. Better yet, multi-chip design can combine diverse technologies while still delivering a single integrated package or module. But as multi-chip packaging grows in capability, so does the complexity. The prospects for multi-chip design lies in the industry's ability to adopt the design efficiency and performance that has fueled the IC market. In this report, we will examine the state-of-the-art in miniaturization and advanced high density RF/microwave package design.

BENEFITS OF MULTI-CHIP AND DENSE PACKAGE DESIGN

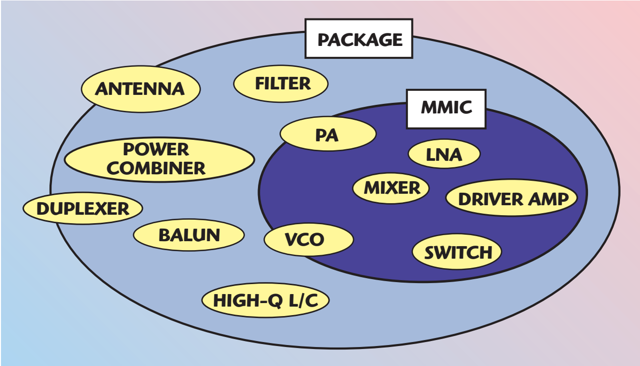
With the challenges facing the wireless industry, typified in the latest 3G multimode handset developments, companies such as RFMD, a leading provider of multi-chip devices, anticipate that new processes and enabling technologies such as high-linearity PHEMT, silicon on insulator (SOI), GaAs E/D PHEMT, GaAs HBT and GaAs BiFET will need to be combined with new packaging technologies such as hermetically sealed wafer level packaging (WLP) and integrated RF shielding in order to achieve size reduced solutions. Examples of these more highly integrated cellular product categories include switch filter modules, switch duplexer modules, single placement front-end modules and other high-performance RF components for cellular handsets. Wireless infrastructure, wireless connectivity, broadband/consumer and aerospace & defense applications will also benefit from these enabling technologies as well as another key enabler, gallium nitride (GaN). "Optimum technology matching" is the term coined by RFMD to describe how it aligns various semiconductor technologies to attain the optimum performance for a given RF function.

MCM, SIP AND SOP

The terminology describing multi-chip packaging has evolved with the technology itself. Multi-chip modules (MCM) were initially

DAVID VYE
Editor, Microwave Journal

developed for mainframe computers back in the 1980s. These modules combined chips and/or chip-scale packaged devices on a small printed circuit board (PCB) meant to mimic the package footprint of an existing chip package. MCM technology evolved to accommodate fully custom chip packages integrating many die on a High Density Interconnection (HDI) substrate. According to Mentor Graphic's Per Viklund, while some MCMs had been designed with more than 100 die over 10 years ago, MCMs with more than 10 die are very rare.



▲ *Fig. 1 RF system on package roadmap.*[2]

MCMs come in three flavors: laminated MCM (MCM-L), which utilize a laminated multi-layer PCB substrate; deposited MCM (MCM-D), wherein the modules are deposited on the base substrate using thin film technology; and ceramic substrate MCMs (MCM-C), such as LTCC. The System-in-Package (SiP) enhanced traditional MCMs with key technologies such as wafer thinning, chip stacking and 3-D interconnects enabling improved performance by reducing interconnect length and thus power consumption, shrinking the form factor and thus increasing device density. Today, vertical chip stacking can be performed as chip-to-chip (C2C), chip-to-wafer (C2W), or wafer-to-wafer (W2W) processes.

Although SiPs incorporate digital, analog/mixed-signal and RF functions, as well as embedded passives, high-speed digital devices do not combine well with RF devices, or with opto-electronic components. The main reasons are the widely different specification requirements among digital, RF and optoelectronic components for power dissipation, passives types and values, thermal and electrical stability, noise and impedance tolerances, and substrate materials. In the more complex SiP designs, significant challenges have emerged, including problems caused by die thinning, reliability issues in silicon substrate-to-package integration, and new materials and processes required to keep costs down and yields high. In advanced cellular applications, a front-end transmit module can be integrated into a SiP with the transceiver, baluns and filters to make a complete radio front-end that readily connects to the baseband processors.

System on a Package (SoP) development originated in the mid-1990s at the Packaging Research Center (PRC) at the Georgia Institute of Technology with funding from the National Science Foundation (NSF).[1] SoP was conceptualized as a continuous merging of different integrated thin film technologies replacing the assemblage of discrete MCM components. The SoP concept would require a "co-design" approach and fabrication that simultaneously considered the digital, optical, RF and sensor functions in both IC and the package. SoP designs distinguish which function is best accomplished at the IC level and at package level. As shown in ***Figure 1***, SoP technology uses ICs for transistor density and selected active function integration while the package typically provides the RF passives, optical and certain digital-function integration. How co-design is addressed by several EDA tools will be examined later in this article.

FOCUS ON SOP

In a system such as a cell phone, ICs make up only 10% of the components and the remainder is devoted to passive components, boards and interconnections. SoP addresses the space occupied by that 90% to improve the "System Integration Law," which is measured in functions or components per cubic area. SoP reduces the scale

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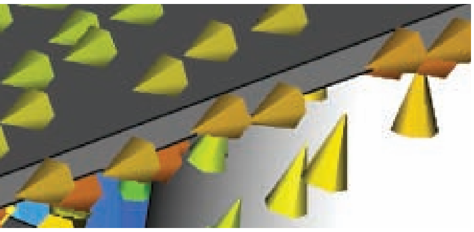

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CHANGING THE STANDARDS

of discrete components to the micro or nano scale by embedding thin-film components, which reduce system size by 1,000 to million times, and looks at a much broader set of mixed-signal system components than current SiP modules. In 2009, system integration is nearing the 1000 components per square centimeter milestone as packaging technology transitions from the micro to nano scale (see **Figure 2**).

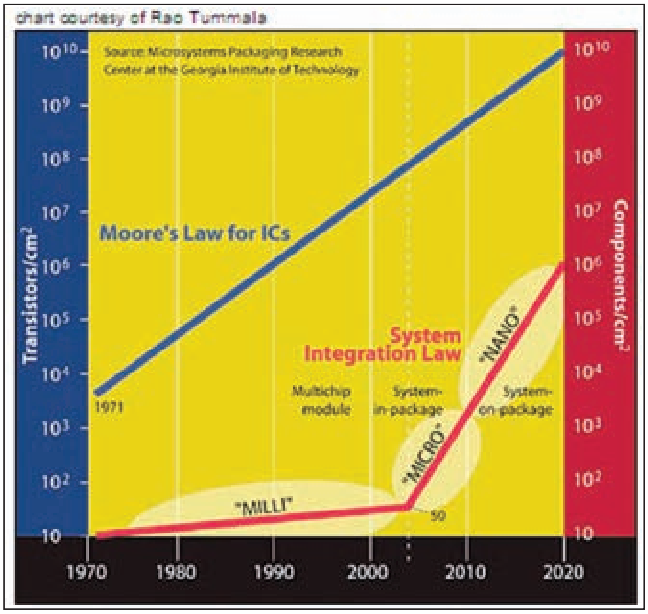


Fig. 2 Functional or component density timeline for SoP mixed-signal system integration (courtesy of Rao Tummala).

In 2006, the Packaging Research Center of Georgia Institute of Technology reported on the use of Si-matched low CTE, high modulus C-SiC composite core substrates to fabricate a SOP4 baseline process test vehicle. The goals of the testbed are to explore optical bit stream switching up to 100 GHz, digital signals up to 5 to 20 GHz, decoupling capacitor integration concepts to reduce simultaneous switching noise of power beyond 100 W/chip, design, modeling and fabrication of embedded components for RF, microwave and millimeter-wave applications up to 60 GHz. The baseline process demonstrated several leading-edge technologies including new processes for low-loss substrate material, high density build-up wiring, embedded RF components and thin film passives, novel interconnects and wafer-level packaging[3] shown in **Figure 3.**

A semi-additive plating process was used to produce multi-layer "micro-vias" with diameters of 15 to 30 microns. The substrate build-up utilized 10 micron thick benzocyclobutene (BCB) dielectric films with dielectric constant of 2.65 and a low loss tangent of 0.0008 at GHz frequencies. This build-up was achieved without the use of any vacuum deposition or polishing/CMP processes and was also demonstrated using commercially available medium CTE organic laminates. Low cost electroless and electrolytic plating processes using plasma surface

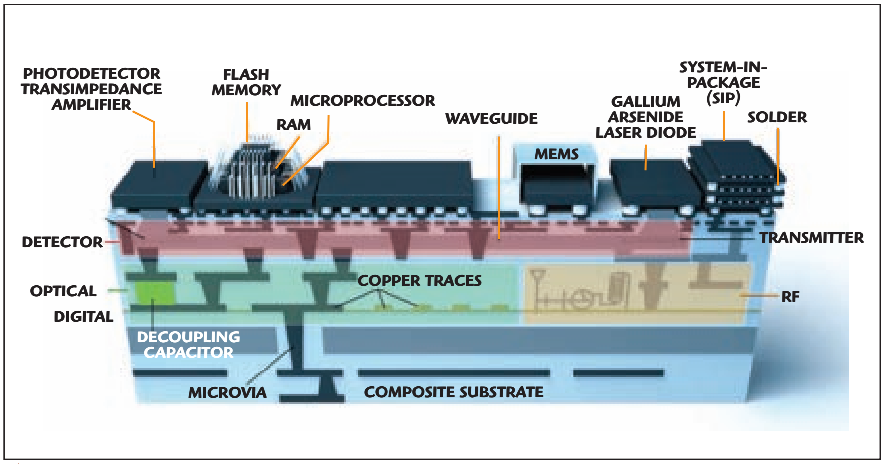
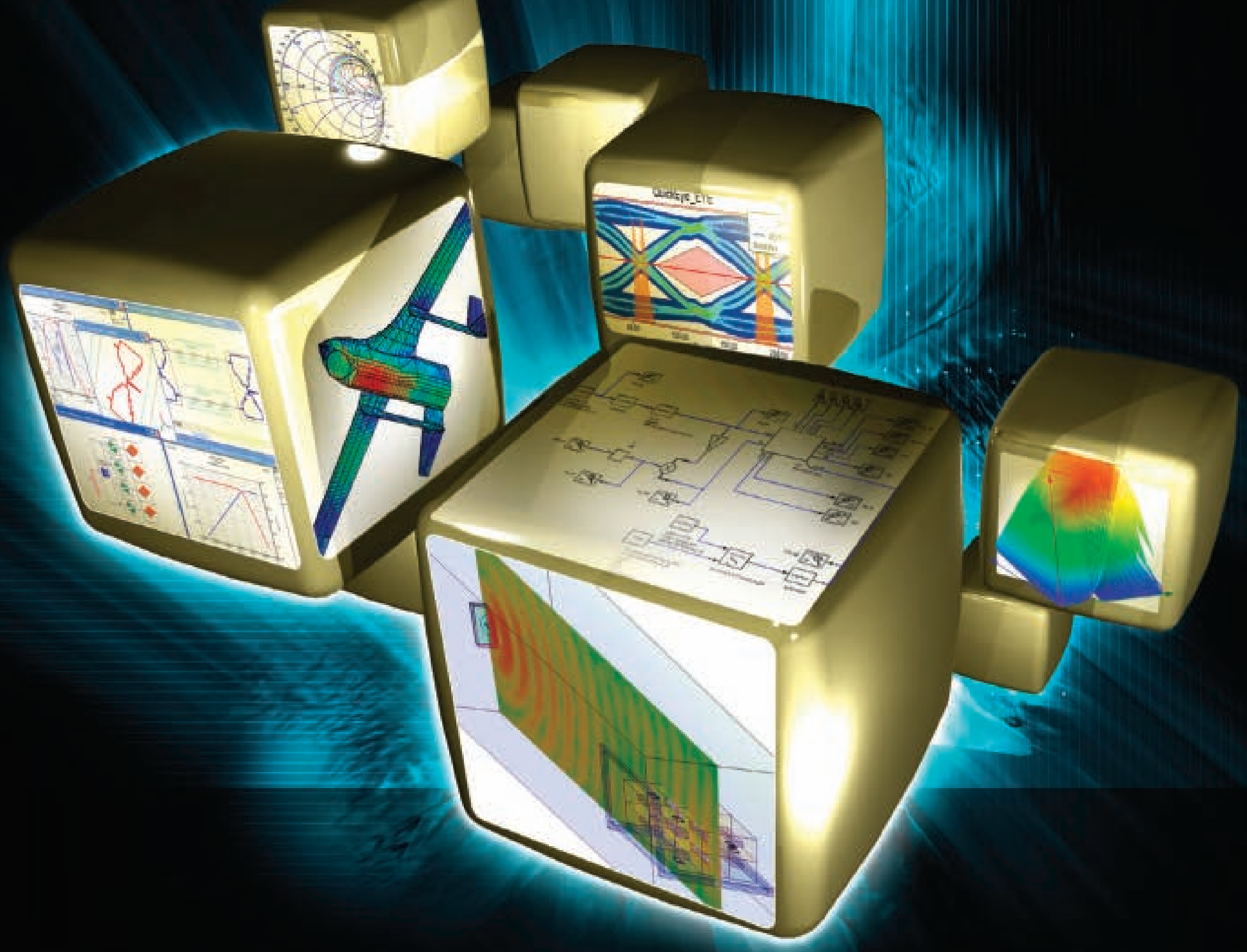


Fig. 3 SoP integration of digital, RF and optical functions into a single package (courtesy of Bryan Christie Design).



treatment were able to achieve 6 to 8 micron line widths and spaces.

SOP/SIP PLATFORMS AND COMMERCIALIZATION

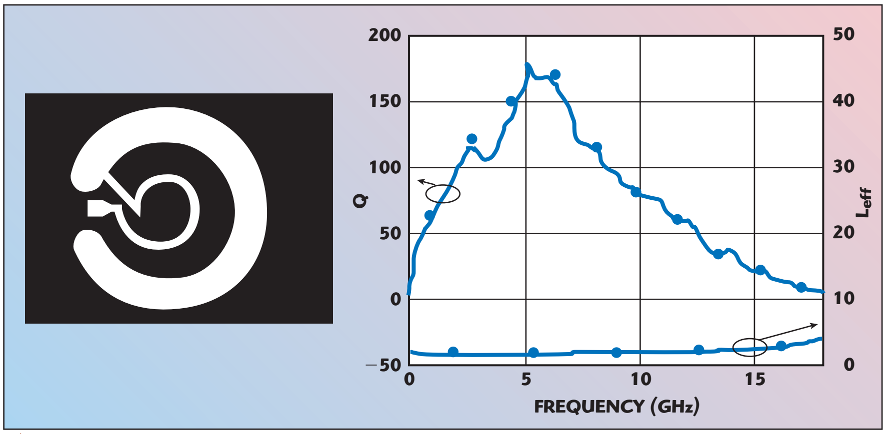
SiP and SoP approaches for RF and microwave multi-component modules are being developed on three major substrate platforms: (a) ceramic or LTCC, (b) multilayer organic (MLO) or build-up organic laminates, and (c) thin film on silicon. MLO substrates use an inexpensive substrate such as FR-4 and a low-cost advanced epoxy or other low loss polymers as dielectrics. These substrates are being adopted in high-volume applications well into the GHz frequency range. The key to properly simulating such substrates —especially for digital signals—is an accurate, wideband dielectric model. Such a model must capture detailed frequency-dependent behavior from DC to many tens of GHz. From an accuracy perspective, frequency-independent or other simplistic approximations are problematic across the wide range of frequencies found in today's digital signaling; a better fit to realistic behavior is required. Yield is also affected by the quite loose tolerances of materials like FR-4. Such effects should be studied by statistical simulations with varying material properties.

Motorola, a founding partner with the Packaging Research Center, uses parts of SoP technology in two models of its GSM/GPRS quad-band cell phones to gain about a 40 percent reduction in board area. The module contains all the critical cell phone functions: RF processing, baseband signal processing, power management, and audio and memory sections. Not only does the module free up space for new features, it is also the foundation around which new cell phones with different shapes and features (camera or Bluetooth, for instance) can be rapidly designed. The company reports it has shipped more than 20 million SoP-based phones.

With the advance of SoP processes and materials, RF components such as capacitors, filters, antennas and high-Q inductors can be better fabricated on a package substrate other than silicon, giving SoP the upper hand over SoC and silicon-based SiP. High-speed, board-level optical interconnects are moving to the package as chip-to-chip, high-speed interconnections replace copper, addressing both the resistance and cross-talk issues of electronic ICs (yet micro-miniaturization re-introduces this issue at the package level). In addition, waveguides, gratings, detectors and couplers can all be embedded in the SoP substrate, allowing SoP to integrate micro-miniaturized electronic and bio-electronic systems, such as nano-bio-sensing elements, control/feedback electronics, display, and RF/wireless components up to and including an integrated antenna. For these capabilities, SoP is emerging around the globe particularly in Japan where the historical chip-centric SoC methodology is frequently replaced with a cheaper, faster-to-market IC-package-system co-design flow.

EMBEDDED RF PASSIVE AND ACTIVE COMPONENTS IN SOP

SoP and SiP designs partition the passive components to the less-costly board/package. Passives include fun-



▲ *Fig. 4 Photograph of multi-layer 36 mil CPW inductor (~2 nH) and performance graph (presented at 2001 IMS).*

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Broadband Low Noise Amplifiers							
AML016L2802	0.1 – 6.0	28	±1.25	1.3*	+7	2.0:1	190
AML48L3001	4.0 – 8.0	30	±1.0	1.2	+10	1.8:1	150
AML412L3002	4.0 – 12.0	30	±1.5	1.5	+10	1.8:1	150
AML218L0901	2.0 – 18.0	9	±1.0	2.2	+5	2.5:1	60
AML0518L1601-LN	0.5 – 18.0	16	±1.0	2.7	+8	2.2:1	100
AML0126L2202	0.1 – 26.5	22	±2.25	3.5*	+8	2.2:1	170
AML1226L3301	12.0 – 26.5	33	±2.0	2.8	+8	2.5:1	200
Broadband Medium Power Amplifiers							
AML0016P2001	0.01 – 6.0	21	±1.25	3.2*	+23*	2.0:1	480
AML26P3001-2W	2.0 – 6.0	28	±2.5	6	+33	1.8:1	1500
AML28P3002-2W	2.0 – 8.0	30	±2.0	5.5	+33	2.0:1	2000
AML218P3203	2.0 – 18.0	32	±2.5	4	+25	2.0:1	450
AML618P3502-2W	6.0 – 18.0	35	±2.5	4	+33	2.0:1	1850
Narrow Band Low Noise Amplifiers							
AML23L2801	2.8 – 3.1	28	±0.75	0.7	+10	1.8:1	150
AML1414L2401	14.0 – 14.5	24	±0.75	1.5	+10	1.5:1	130
AML1718L2401	17.0 – 18.0	24	±0.75	1.6	+10	1.8:1	150

Low Phase Noise Amplifiers

Part Number	Frequency (GHz)	Gain (dB)	Output Power (dBm)	Phase noise (dBc/Hz) at offset 100Hz	1KHz	10KHz	100KHz
AML811PN0908	8.5 – 11.0	9	17	-154	-159	-167	-170
AML811PN1808	8.5 – 11.0	18	18	-152.5	-157.5	-165.5	-168
AML811PN1508	8.5 – 11.0	15	28	-145.5	-153.5	-158.5	-164.5
AML26PN0904	2.0 – 6.0	9	20	-150	-165	-165	-178
AML26PN1201	2.0 – 6.0	11	15	-155	-160	-160	-175

High Dynamic Range Amplifiers

Part Number	Frequency (MHz)	Gain (dB)	P1dB (dBm)	OIP3 (dBm)	DC
AR01003251X	2 – 32	21	32	52	+28V @ 470mA
AFL30040125	50 – 500	23	28	53	+28V @ 700mA
BP60070024X	20 – 2000	32	30	43	+15V @ 1100mA

*Above 500MHz.

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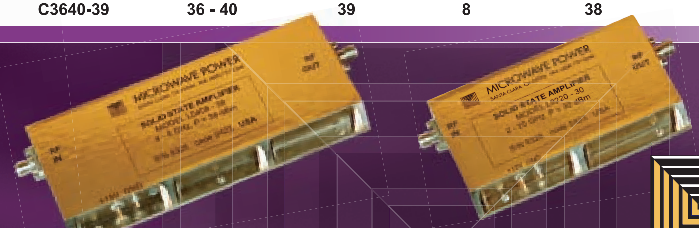
Model	Frequency (GHz)	Psat (dBm)	Psat (W)	P1dB (dBm)	Gain (dB)	DC Current(A) @ +12V or +15V
Broadband Microwave Power Amplifiers						
L0104-43	1 - 4	42.5	17.8	41.5	45	14
L0204-44	2 - 4	44	25	42.5	45	14
L0206-40	2 - 6	40	10	38.5	40	8.5
L0208-41	2 - 8	41	12	40	40	17
L0218-32	2 - 18	32	1.4	31	35	5
L0408-43	4 - 8	43	20	41.5	45	17
L0618-43	6 - 18	43	20	41.5	45	22
L0812-46	8 - 12	46	40	45	45	28
Millimeter-Wave Power Amplifiers						
L1826-34	18 - 26	34	2.5	33	35	4
L1840-27	18 - 40	27	0.5	26	30	2
L2240-28	22 - 40	28.5	0.7	27	30	3
L2630-39	26 - 30	39	8.0	38	40	15
L2632-37	26 - 32	37	5.0	36	38	10
L2640-31	26 - 40	31	1.2	30	30	5
L3040-33	30 - 40	33	2.0	32	33	9
L3337-36	33 - 37	36	4.0	35	40	12
L3640-36	36 - 40	36	4.0	35	40	10

High-Power Rack Mount Amplifiers

Model	Frequency (GHz)	Psat (dBm)	Psat (W)	P1dB (dBm)	Pac (kW)	Height (in)
C071077-52	7.1 - 7.7	52.5	170	51.5	1.8	10.25
C090105-50	9 - 10.5	50	100	49	1	8.75
C140145-50	14 - 14.5	50.5	110	49.5	2	10.25
C1416-46	14 - 16	46	40	45	0.35	5.25
C1820-43	18 - 20	43	20	41.5	0.25	5.25
C2326-40	23 - 26	40	10	39	0.25	5.25
C2630-45	26 - 30	45	30	44	0.45	5.25
C3236-40	32 - 36	40	10	39	0.25	5.25
C3640-39	36 - 40	39	8	38	0.24	5.25



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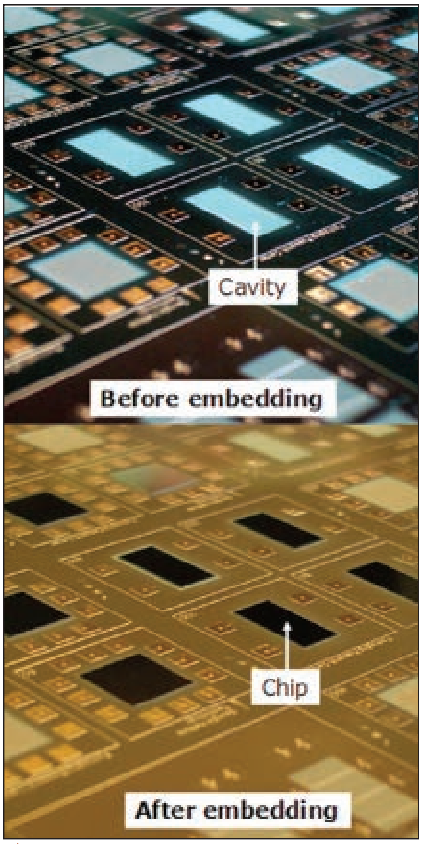
damental electrical components such as inductors, capacitors and resistors as well as passive building blocks including high-performance filters, baluns, couplers and integrated antennas.

Multi-layer Inductors

Perhaps chief among these passives are the inductors that would otherwise take up a lot of expensive real-estate on the ICs. High-Q on-chip inductors are difficult to accomplish because of the high parasitic capacitance of thin film dielectrics, high conductor resistance and lossy substrate. The challenge is to utilize the 3D nature of SoP to produce miniaturized, multi-layer inductors with high-Qs over the required frequency range. One example from 2002 is the CPW spiral inductor, depicted in ***Figure 4,*** which avoids via losses, reduces dielectric losses and results in an increased self resonance frequency (SRF). The thick copper metallization in the packaging process decreases the shunt parasitic capacitance and reduces the eddy current flowing in the ground plane, which produces a negative mutual inductance effect, resulting in a Q of 182, SRF of 20 GHz, L_{eff} of 1.97 nH for a 36 mil diameter.[7] Ongoing research efforts have led to similar results with much smaller components.

The PRC has been working in partnership with more than 15 semiconductor and supply chain companies since 2007 on a consortium research program on embedded active and passive components (EMAP). As part of this research, this past year, Rao Tummala, Venky Sundaram and Mahadevan Iyer at the PRC and partners at the Institute of Microelectronics in Singapore, presented a paper, "Ultra High Q Embedded Inductors in Highly Miniaturized Family of Low Loss Organic Substrates" at the ECTC conference discussing for the first time the design and fabrication of embedding ultra miniaturized RF inductors in ultra thin (100 to 150 microns thickness) organic substrates. The substrate described belongs to a new family of ultra low profile organic laminates with a loss tangent of about 0.0034 to 0.0045 and a dielectric constant of 3.4. The innovative design resulted in unloaded quality factors of about 100 to 150 in the frequency range of 1 to 15 GHz using line widths in the range of 2 to 4 mils and occupying an area of 0.062 to 0.64 mm^2.



▲ *Fig. 5 Chip-last embedded IC in organic substrate cavity demonstrated by the PRC EMAP Consortium.*

Also this past year, Jacket Micro Devices Inc. (JMD), a commercial provider of embedded passive technology, and a spin-off from SoP technology developed at the PRC, developed a novel method of fabricating multi-layer inductors using its proprietary Multi-Layer Organic (MLO™) and Low Temperature Laminated Organic (LTLO™) processes. Using their technique, JMD has demonstrated Q factors of over 150 at 2 GHz, making them ideal for a wide variety of wireless applications where high Q is critical.

Embedded ICs

The EMAP program has also demonstrated a novel "chip-last" embedded IC technology that overcomes the yield and business model concerns associated with current embedded IC approaches by embedding thinned ICs into a high precision cavity in the organic substrate build-up layers using standard flip-chip assembly methods (see ***Figure 5***).

Embedded Decoupling Capacitors

A thin film technology based on barium titanate ($BaTiO_3$) epoxy polymer nanocomposites has been developed to manufacture high performance embedded capacitors. The technology is able to produce high capacitance density (10 to 100 nF/inch^2), large area, thin film capacitors (see ***Figure 6***) with controlled thickness from about 2 to 25 microns for a series of $BaTiO_3$ epoxy nanocomposites. The SoP test vehicle from the PRC demonstrated embedded decoupling capacitors with capacitance density of > 500 nF/cm^2 integrated into the build-up layers using synthesized $BaTiO_3$ thin films that were deposited on copper foils and integrated using vacuum lamination and subtractive etch processes. The loss tangent of the films was measured to be 0.03 at 100 MHz. The electrical properties of capacitors fabricated from $BaTiO_3$-epoxy nanocomposites showed a stable capacitance and low loss over a temperature range of 25° to 100°C. The capacitance change was less than 10%.

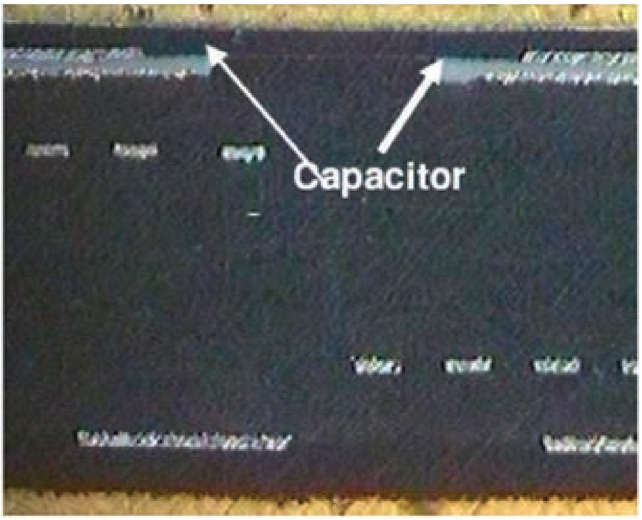


Fig. 6 Cross-section of embedded capacitors.

Embedded High Q RF Capacitors

Current and future RF designs require a capacitance density of above 100 nF/cm^2, Q of greater than 200 and high tolerance. In addition, the capacitance value has to be stable within 0.3% over 100°C range of temperature to meet the performance requirements. Current organic-compatible embedded capacitor technologies such as epoxy-based composites with ceramic fillers (shown in Figure 6) are not suitable for high performance microelectronic devices such as embedded RF capacitors with high Q and low temperature coefficient of capacitance (TCC) requirements. They may not achieve dielectric loss less than 0.02 and TCC within 300 ppm/sq, even with the best ceramic fillers. RF capacitors from low loss polymers such as liquid crystal polymer (LCP), bisbenzocyclobutene (BCB) and poly tetrafluoro ethylene (PTFE) are being pursued; however, they are limited in capacitance density due to the low dielectric constant polymers.[3-4]

Nanostructured ferroelectric and ferromagnetic materials show superior dielectric and magnetic properties from superior exchange coupling between the domains, absence of leakage, smaller relaxation time for dipole switching, absence of domain wall assisted relaxation, etc. These materials show superior microwave properties and can be processed at organic compatible low temperatures leading to low cost microwave device integration. A new set of high k paraelectric particles have been investigated by PRC to enhance the RF performance of polymer composites.[5] These composites have permittivity of 10 to 20 while meeting the TCC and loss requirements, which can be further enhanced with the nanostructured ferroic materials. For RF capacitors based on inorganic thin films, PRC also pioneered low temperature processes to integrate pyrochlore based barium and strontium titanium oxides that are reactively grown by solution chemical treatment and oxygen ion irradiation at organic compatible temperatures. These high k phases have higher permittivity than silicon oxynitrides or tanatalum oxide capacitors while meeting other microwave requirements. For emerging microwave applications, PRC is developing novel nanocomposite formulations to

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U2001B	10 MHz to 6 GHz	-30 dBm to +44 dBm	$594
U2001H	10 MHz to 6 GHz	-50 dBm to +30 dBm	$458
U2002A	50 MHz to 24 GHz	-60 dBm to +20 dBm	$628
U2002H	50 MHz to 24 GHz	-50 dBm to +30 dBm	$696
U2004A	9 kHz to 6 GHz	-60 dBm to +20 dBm	$441

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further enhance both the permittivity and permeability at GHz frequencies. Nanocomposite technology, coupled with metamaterial designs, can lead to small microwave components leading to complete system integration.

Resistors

The PRC test vehicle demonstrated two methods of manufacturing embedded thin film resistors in the substrate. Thin metal alloy resistor films were integrated into the SoP substrate using NiCrAlSi thin films (25 ohms per square) deposited on copper foils (Gould Electronics) laminated on the build-up layers with a two-step etch process for resistor definition. The researchers also used an electro-less plated Ni-W-P thin film (resistance values ranged from 70 ohms to a few kilo ohms per square) on the BCB dielectric by plasma surface treatment and activation. The process was reported to exhibit uniform resistor thickness in the sub-micron range, offering a low profile and excellent adhesion to BCB dielectric while providing a potential seed layer for any subsequent direct electroplating of copper traces. The process was also compatible with the package substrate manufacturing infrastructure.[6]

PART II: DESIGN CONSIDERATIONS

According to Hee-Soo Lee of Agilent Technologies, critical issues such as wideband and low-loss interconnects, high-Q multi-layer passives including R, L and C, board-compatible embedded functions (antennas, MEMS), low-loss and low-cost boards, efficient partitioning of MMICs, low-cross talk single-moded packages, as well as design rules for vertically integrated transceivers are among the issues that have to be addressed accurately over a very wide frequency range. In addition, there exists a significant gap in the area of hybrid CAD needed to model novel functions that require fast and accurate modeling of electromagnetic, circuit, solid-state, thermal and mechanical parameters. Full acceptance of RF-SoP requires cost effectiveness and reliability, features which are being addressed by the RF EDA community.

Mentor Graphics' Viklund states that his company sees little difference between MCM, SiP and SoP. Their customers did stacked die MCMs with thin film passives many, many years ago before anyone even dreamed up the acronym SoP. Viklund comments, "Companies use the technology necessary to get the job done and this means that sometimes an MCM suffices while the next design would qualify as a SoP. The need for embedded thin film passives in the substrate varies from design to design within the same company so Mentor Graphics talks about 'Advanced Packaging Tools' having all the capabilities needed to meet the varied design challenges our customers are facing today." That said, multi-layer embedded passives are a specific technology that requires specific EDA support to be viable.

When embedding ICs, an EDA flow is required that can place parts on inner layers and manage unique sets of manufacturing documents for each placement layer. In addition, parts have to automatically drop into cavities without having to build special versions of the library. It also offers challenges to the 3D wire bond and parts Design Rule Checking (DRC). As mentioned, DRC has to be real-time and with parts on inner layers, it becomes so much more critical that the tool directs users to follow the design rules.

For example, Mentor Graphics' embedded passive technology manages the entire design flow from material parameters, manufacturing process related parameters to automatic synthesis of passive thin and thick film components and real time DRC helps ensure first turn success. In this flow, simulation and analysis are vital components, initially as early planning tools, but as the design is getting closer to completion, a gradual transition from first-level simulation to full electro-magnetic analysis. Shortcuts in this process are known to cause re-spins and current simulation integrations allow very fast and seamless data transfer between design and simulation to make it practical to run simulations whenever needed.

INTERCONNECT AND EMBEDDED PASSIVE MODELING

The complex and highly dense nature of SoP embedded passives and interconnects lead to parasitics that will limit the performance unless ad-

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150-75-3	dc-18.0	0-75/5	
150-70	dc-18.0	0-70/10	
150-70-1	dc-18.0	0-70/10	
151-11	dc-4.0	0-11/1	
152-90-3	dc-26.5	0-90/10	
150T-11	dc-18.0	0-11/1	◆
150T-15	dc-18.0	0-15/1	◆
150T-31	dc-18.0	0-31/1	◆
150T-62	dc-18.0	0-62/2	◆
150T-70	dc-18.0	0-70/10	◆
150T-75	dc-18.0	0-75/5	◆
150T-110	dc-18.0	0-110/10	◆
151T-110	dc-4.0	0-110/10	◆
152T-55	dc-26.5	0-55/5	◆
153-70	dc-40	0-70/10	*New*
153-110	dc-40	0-110/10	*New*

Model	Frequency Range (GHz)	Attenuation Range (dB)	Notes
3200-1	dc-2.0	0-127/1	
3200-2	dc-2.0	0-63.75/.25	
3200-1E-2	dc-3.0	0-127/1	
3200-2E-2	dc-3.0	0-63.75/.25	
3201-1	dc-2.0	0-31/1	
3201-2	dc-2.0	0-120/10	
3206-1	dc-2.0	0-63/1	
3200T-1	dc-2.0	0-127/1	◆
3206T-1	dc-2.0	0-63/1	◆
3250T-63	dc-1.0	0-63/1	◆ X
3406-55	dc-6.0	0-55/1	*New*
3408-55.75	dc-6.0	0-55.75/0.25	*New*
3408-103	dc-6.0	0-103/1	*New*
4216-63	0.8-3.0	0-63/1	
4218-127	0.8-3.0	0-127/1	
4238-103	.01-2.5	0-103/1	

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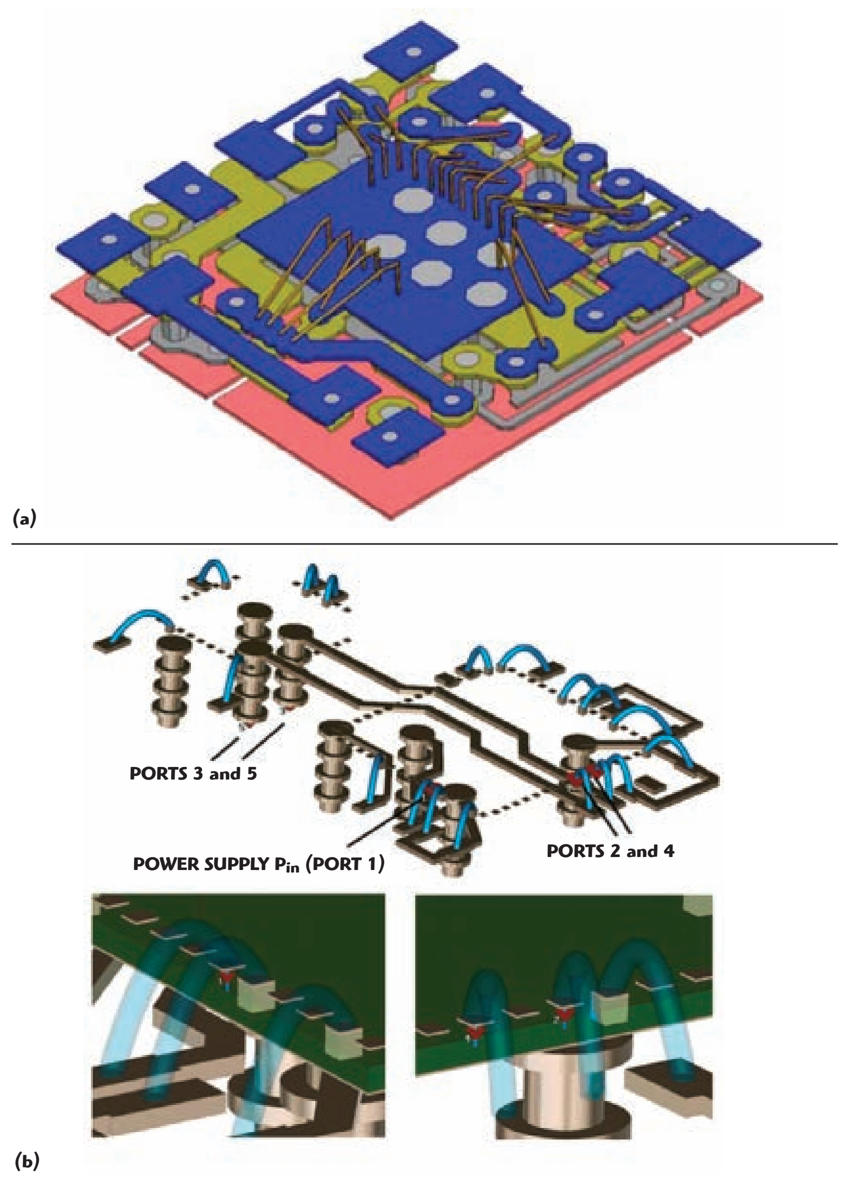

▲ *Fig. 7 3D EM model (HFSS) of SiP interconnects and vias, courtesy of Ansoft LLC and Skyworks Solutions (a), and SiP model with port definitions for CST transient simulation, courtesy of CST and AET Japan Inc. (b).*

equate steps are taken via co-design. For instance, the serial inductances as well as mutual capacitances have a serious influence on the signal quality. In particular, they affect the signal's shapes and lead to crosstalk problems, which are best predicted using a full 3D field simulation such as Ansoft HFSS, CST MICROWAVE STUDIO® (CST MWS) (see ***Figure 7*** or EMPro from Agilent). Both can analyze these complex structures and deliver information in both the time and the frequency domains (S-parameters), each offering different approaches to circuit co-design.

What are some of the simulation issues with using these materials and high-density multi-layer substrates? Agilent's How-Siang Yap states, "The frequency domain linear simulation technology that produces S-parameters was the primary simulation technology for conventional RF/MW circuit designs. The analytical circuit models such as microstrip, stripline, and co-planar are extensively used in the simulations; however, it assumes the physical structure to be simulated must be as close as the structure modeled, for example ground planes and enough spacing to other adjacent

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traces. Due to the smaller form factor for high volume applications, it is practically impossible to avoid the parasitic behavior of multilayer designs. The two most important simulation issues in the multilayer designs are the inclusion of imperfect grounding effects and coupling due to the proximity between parts to parts and traces to traces or even for traces to the ground planes. All of these can be addressed by brute force complete EM simulations. Nevertheless, the ultimate design challenge from multilayer circuit designers' standpoint will come from how to pin-point the source of the problem area. The reason is because the traditional EM simulation only provides final results on whether the structure is working or not (black box S-parameters). A more elegant technique called Coupling Analysis, pioneered by Agilent EEsof EDA, enables different combinations of suspect coupling structures to be simulated by including or excluding certain objects and setting up different coupling distances, and the resultant S-parameters and visualization of current field plots provide a way to identify the impact of parasitic behavior (loss, coupling, radiation, etc.) AND where it is occurring so that the designer can fix it."

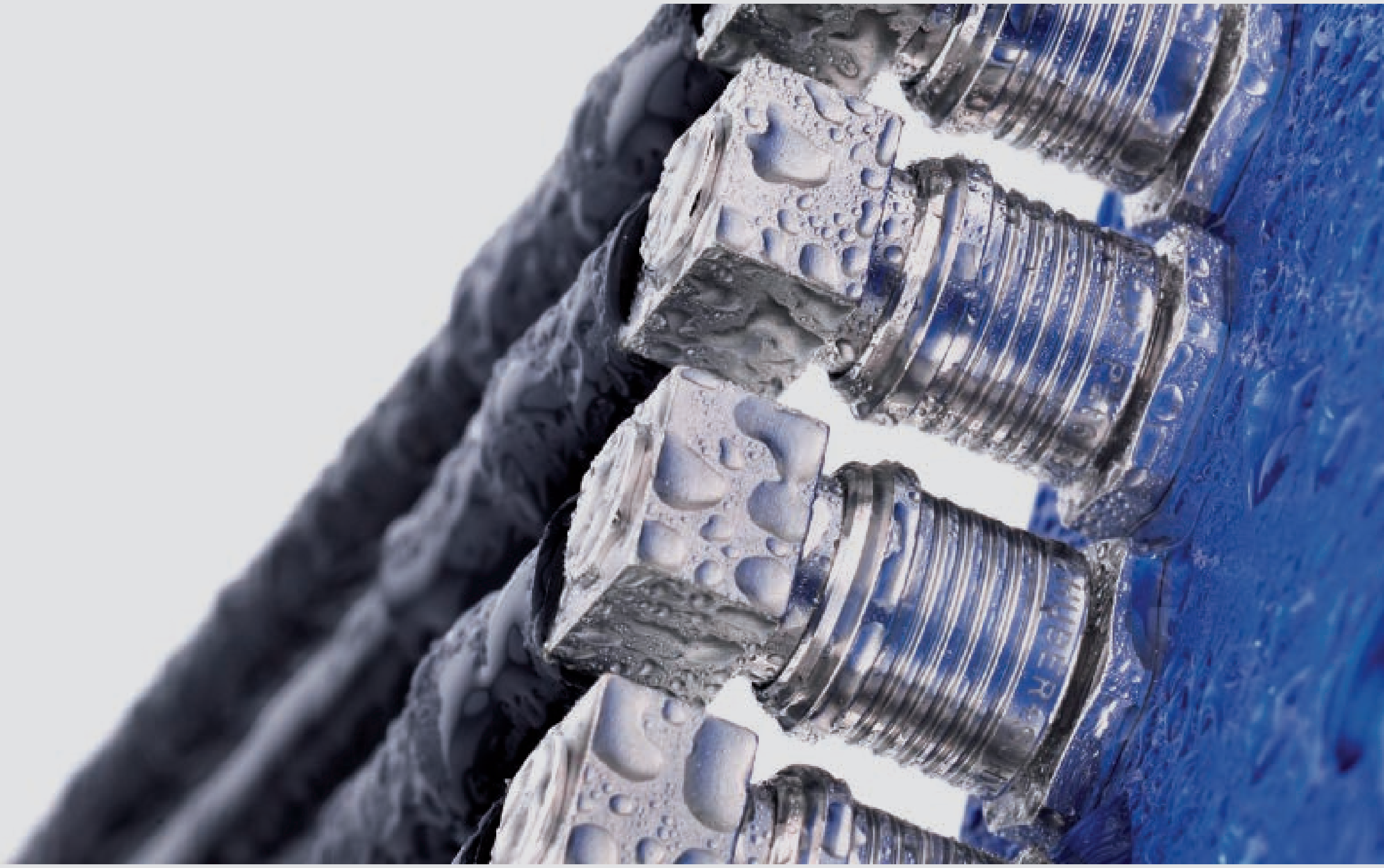
With so many buried and embedded components, what seems to be the most practical ways for an engineering team to achieve successful integration of multiple die, passive on-board components and interconnects into one module? After working closely with their design customers, the application engineers at AWR feel that, "You have to partition the circuit into workable sub-circuits that lend themselves to a top-down, parametric design capability as far into the product development cycle as possible. Once the initial topological selection is performed for complex circuits like MCM or SoP, the designer often switches to an analytical, bottom-up design style based more on EM solvers than on parametric circuit simulation. The design team can forego concurrently designing the coupled sub-circuits if the partitioned sub-circuits can be designed independently. That is, it can be performed by representing their coupling to other sub-circuits or parasitic design elements as definable parametric elements (non-ideal harmonic loads or lumped/distributed models), respectively."

Both AWR and Agilent felt the ultimate solution for passives and interconnects is the full module verification via EM simulation; however, this only makes sense for final design verification due to the extremely time consuming simulation processes. According to AWR, "The entire design ultimately must be verified electrically via EM simulation and for manufacturing via DRC, LVS and DFM. If the team has thoroughly explored the design before verification to understand couplings and sensitivities, it may not be necessary to place the entire design into an EM solver for verification. Instead, the SoP or MCM design can be electrically verified by selective EM analysis. However, it is essential to conduct parametric exploration of the circuit throughout the design process to gain an understanding of the critical dependencies, sensitivities and couplings." Agilent concurred, stating, "A more practical approach for an engineering team is a piecemeal approach but brings all of them into co-design platform for analyzing and optimizing the dynamic interactions between them. To speed up the passive circuit design process for the piecemeal approach, the technique that builds parameterized scalable EM models for passive structures based on accurate EM simulation using the patented technology called Multi-dimensional Adaptive Parameter Sampling (MAPS) technology of AMC (Advanced Model Composer) can be also used."

LAYOUT AND DESIGN RULES

To adequately simulate some of these structures, it is important to go beyond simulation itself and look at the entire design. The SoP structures are most often layout-driven, so to adequately simulate them, you need a seamless flow from layout to simulation. How is multi-layer passive component design and embedded ICs changing the requirements for CAD automation? According to Mentor Graphics, multi-layer embedded passives are specific technology that requires specific EDA support to be viable.

According to Agilent, the CAD requirements for the physical imple-



mentation are: a) unified stack-up; b) connectivity support; c) electrical rule check (ERC); d) design rule check (DRC); and e) assembly rule check across chip, module and board. For simulation, an example is moving large spiral inductors off an RF chip to become an embedded multi-layer component to reduce the cost of semiconductor area used. The impact on CAD automation means that it now has to support co-design of the chip and module with simulation to accurately account for the 3D interconnects such as wire bonds or solder-bumps along with the embedded active system or circuit ICs. Co-design requirements necessitate the tight integration of system, circuit and 3DEM simulators under the same co-design platform. Standalone 3DEM tools cannot support this kind of flow.

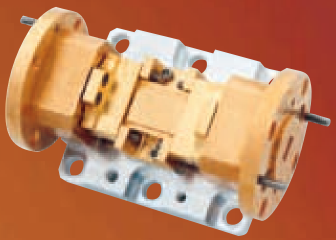
According to AWR, engineers really don't want to abandon parametric, top-down design because they have a great deal of comfort with the approach as no one actually wants to repeatedly move lines and/or resize components and then run EM simulation for half a day. With this in mind, AWR has developed new technologies specifically designed to solve this problem. For example, EXTRACT is an automated, schematic-driven EM capability that lets users use the schematic- or layout-driven parametric approach to design, but does not require them to manually run the EM solver and then stitch back the resulting, high pin-count S-parameter block into the schematic.

Is the EDA associated with SiP or SoP design evolving in a way similar to IC or SoC design with regards to design kits, LVS and DRC? According to Mentor Graphics' Viklund, "This is a classic question. Still, the challenges in SiP and SoP design are unique and do not lend themselves to borrow methodology from other technology. Clear, however, is of course that design kits, which really are just protected templates of proven technology, are being used both to save time and to mitigate the risk of errors. In terms of LVS and DRC, the keyword in SiP design is "real time DRC" and this is true even for 3D related physical and manufacturing rules. It's simply too late to find errors using batch LVS and batch DRC processes even though the batch checks are used as a final sign off process."

Agilent's How-Siang Yap pointed out the difference between IC design flow and those required for SoP design. "As we discussed in the previous questions, more challenges exist in multiple technologies used in SoP than IC or SoC designs. Therefore the EDA technology is evolving more to the co-design concept which can be divided into front-end co-design for simulation perspective and back-end co-design for layout/assembly/packaging perspective. For the front-end co-design, the trend is in the integration of different simulation domains into a single unified design platform which can be called high frequency and high speed co-design platform. For the back-end co-design, the trend is in the integration of different back-end tools which has different technology files and design/assembly rules."

MILLIMETER WAVE COMPONENTS

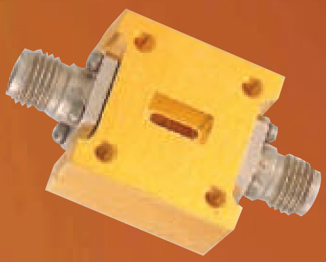
AMPLIFIERS • MIXERS • MULTIPLIERS



AMPLIFIERS

Model Number	Frequency (GHz)	Gain (dB, Min.)	Gain Flatness (±dB, Max.)	Noise Figure (dB, Max.)	In/Out VSWR (Max.)	Output Power at 1dB Comp. (dBm, Typ.)
JSW4-18002600-20-5A	18-26	34	1.5	2.0	2.0:1/2.0:1	5
JSW4-26004000-28-5A	26-40	25	2.5	2.8	2.2:1/2.0:1	5
JSW4-18004000-35-5A	18-40	21	2.5	3.5	2.5:1/2.5:1	5
JSW4-33005000-45-5A	33-50	21	2.5	4.5	2.5:1/2.5:1	5
JSW5-40006000-55-0A	40-60	18	2.5	5.5	2.75:1/2.75:1	0

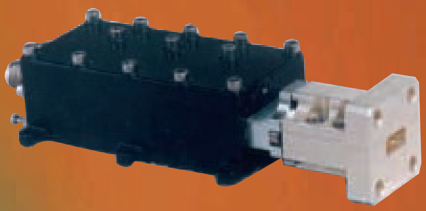
Higher output power options available.



MIXER/CONVERTER PRODUCTS

Model Number	Frequency (GHz)			Conversion Gain/Loss (dB, Typ.)	Noise Figure (dB, Typ.)	Image Rejection (dB, Typ.)	LO-RF Isolation (dB, Typ.)
	RF	LO	IF				
LNB-1826-30	18-26	Internal	2-10	42	2.5	25	45
LNB-2640-40	26-40	Internal	2-16	42	3.5	25	45
IR1826N17*	18-26	18-26	DC-0.5	11	9.5	25	25
IR2640N17*	26-40	26-40	DC-0.5	11	9.5	25	25
SBW3337LG2	33-37	33-37	DC-4	-7.5	8	N/A	25
TB0440LW1	4-40	4-42	.5-20	-10	10.5	N/A	20
DB0440LW1	4-40	4-40	DC-2	-9	9.5	N/A	25
SBE0440LW1	4-40	2-20	DC-1.5	-10	10.5	N/A	20

* For IF frequency options, please contact MITEQ.



MULTIPLIERS

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

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AWR more or less agreed, while adding, "SoP design is evolving this way in the sense that each IC and packaging technology has a PDK or design kit with LVS, DRC, and support for AWR routing and interconnect technologies such as bridge code automatic via insertion and iNet automated routing. The same demands are being placed on laminate and IC kit development, and perhaps even more as these technologies can be concurrently co-designed, co-simulated, and co-verified within the AWR UDM. However, it is not evolving this way in the sense that the integrating technology is PCB-based and not IC-based. The company sees a tremendous demand for simultaneously running real-time PCB DRC and using PCB DFM while still verifying RF and microwave electrical performance at the circuit or system level. The Agilent Mentor DA and AWR Connected for Mentor Graphics Expedition flow supports real-time integration so that the PCB aspects are being altered in the DRC context while the electrical characteristics are simultaneously verified to ensure that performance has not been sacrificed. This is all performed at the parametric, circuit, or system level without reducing the design to 'dumb metal' and just subjecting everything to EM simulation."

CAD data and simulation data (structure geometries for EM) are not necessarily compatible. So, what is the state-of-the-art in sharing information between the CAD group and electrical design group from the perspective of sharing information between environments? Agilent responded by stating that, "Yes, it is true that CAD data and structure geometry data for EM are not necessarily compatible. One example is via holes. Via hole in CAD data format is true representation of physical structure, for example very small arc resolution for circles. However, the required via holes in EM simulation don't have to be that complex since it creates more simulation burden without improving the accuracy of simulation. The state-of-the-art for design flow integration is intelligence of CAD data translation process. As demonstrated in Agilent EEsof EDA design tools, the via holes from the CAD environment can be simplified into rectangular or polygonal vias for faster EM simulations without manual CAD manipulation. Also it is important to automatically import substrate stack-up information without manual intervention."

IC MODELING

Multi-chip devices also contain active devices and ICs that need to be accounted for in the design process. What level of MMIC and RFIC model detail is necessary and available (in the case of vendor supplied die) for designers simulating a multi-chip module? Often, there is insufficient data being supplied at this level. According to Agilent, "The most accurate model available with full IP protection is the X-parameter model and can be generated by measurement with Agilent NVNA or simulation with ADS. X-parameters are the mathematically rigorous extension of S-parameters to fully capture nonlinear behavior that includes frequency conversion and impedance mismatched harmonics of cascaded nonlinear components. When measured or simulated with load pull termination, the X-parameter models are valid across a wide range of terminating impedances. Today, measurement-based X-parameter models are limited to two ports due to available hardware instrumentation, but simulation-based X-parameters can be generated for multi-port non-linear components such as mixers and transceivers. Early beta customers representing IC design houses and major handset vendors are fully embracing X-parameter models because it provides a compact accurate language to communicate and simulate nonlinear behavior of MMIC, RFIC, PAM and FEM between design partners."

AWR sees additional complexity to the problem: "Many MMIC and RFIC customers have to do their own application-specific testing and then use the results at the SoP or system level. The problem is very complex because the loads presented to some of these ICs are not normally characterized by IC vendors. Compounding this, because of the small form factor of the SoP or MCM, is die-to-die coupling. Once you have couplings that cannot be represented at the boundary of a die, you need a circuit-level description of the die to get at some of these problems. A behavioral or compact model of the die is no longer adequate." Furthermore, multi-chip co-design may likely call for analysis in both time and frequency domains.

CONCLUSION

Multi-chip design is an evolving technology that offers faster time-to-market and lower development costs compared to single IC solutions yet can still deliver functionality and reduced size. SoP is the leading multi-chip technology today, whereby embedded passive components are approaching the 1000 components per square centimeter milestone. As process technology transitions from the micro to nano scale in the 2010 timeframe, SoP will deliver more capability in ultra-miniaturized packages. This development must occur hand-in-hand with increased capabilities in EDA design flows and simulation technologies as well as a growing knowledge of how to address the complexities of IC/package co-design among engineering teams. ■

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Raytheon Team Completes Major Milestones on GPS Control Segment

Raytheon Co. has successfully completed two significant milestones for the US Air Force's next-generation Global Positioning System Control Segment, or GPS OCX, establishing a solid foundation and roadmap to keep the program on track and on schedule.

"These mark major accomplishments for our entire team and significantly burn-down the execution risk on the program," said Bob Canty, Raytheon GPS OCX vice president and program manager. "Our team of industry experts worked seamlessly together to reach and complete these critical tasks and looks forward to meeting all future customer requirements."

The segment design review was a comprehensive review of the team's progress in systems engineering, systems architecture and program management. Successful completion demonstrates that the design is sufficiently mature and the level of residual risk is acceptable to proceed to the program's next phase. In keeping with the "back-to-basics" approach, the team demonstrated the ability to command modernized GPS signals, provide situational awareness and expose data on the network through the modernized capability engineering model demonstration. The Raytheon team also demonstrated time-certain delivery by achieving all model objectives on time and within budget. Canty added, "Both milestones allowed us to show the customer that we have met their requirements, significantly reduced program risk and are well-positioned to deliver our GPS OCX solution. Our back-to-basics approach to developing our GPS control segment demonstrates our understanding and alignment with the needs of our US Air Force customer." The Raytheon-led team is on track to complete the remaining program milestones and is working under a $160 M Phase A system design and risk reduction contract. The contract was awarded by the Air Force Space and Missile Systems Center, Los Angeles Air Force Base, in November 2007 to produce the new control segment for the current and future GPS systems.

The completion of the segment design review and modernized capability engineering model is an accomplishment of Raytheon Co., ITT, The Boeing Co., Infinity Engineering Systems, Jet Propulsion Laboratory, SRI International and Braxton Technologies.

Lockheed Martin Receives Contracts for PAC-3 Missile Program

Lockheed Martin has received contracts totaling $774 M from the US Army Aviation and Missile Command for hardware and services associated with the combat-proven Patriot Advanced Capability-3 (PAC-3) Missile program. These contracts include Fiscal Year 2009 missile production for the US Army as well as the first sale of the PAC-3 Missile Segment to the United Arab Emirates (UAE). The UAE becomes the first Middle East customer and the fourth international customer for the PAC-3 Missile, joining The Netherlands, Germany and Japan in fielding the system. Lockheed Martin expects in excess of $1.8 B in PAC-3 Missile-related business over the life of the initial UAE program.

The FY09 contracts include production of 172 hit-to-kill PAC-3 Missiles, 42 launcher modification kits, spares and other equipment, as well as program management and engineering services. Production of all equipment will take place at Lockheed Martin manufacturing facilities in Dallas and Lufkin, TX, Chelmsford, MA, Ocala, FL, and the PAC-3 All-Up Round facility in Camden, AR. Deliveries on the contracts will be completed by July 2011.

"The PAC-3 Missile's proven hit-to-kill lethality provides an unprecedented level of protection to the Warfighter," said Mike Trotsky, vice president, Air & Missile Defense Programs at Lockheed Martin Missiles and Fire Control. "We continue to see interest in the PAC-3 Missile Segment around the world, and Lockheed Martin remains focused on producing this vital technology for our customers."

"The PAC-3 Missile offers the UAE combat-proven hit-to-kill lethality to protect critical capabilities and national assets," said Dennis Cavin, vice president, International Air & Missile Defense Strategic Initiatives at Lockheed Martin Missiles and Fire Control. "PAC-3 Missile Segment performance and lethality are the premier technologies available to provide defense against the threats facing our forces and allies today and well into the future." As part of these contracts, Lockheed Martin will produce and deliver equipment to begin upgrading all US Army Patriot fire units with the capability for firing the PAC-3 Missile. The US Army initiatives, called "Pure Fleet" and "Grow the Army," were launched in 2006 and will provide consistency across the fleet for the user anywhere Patriot is deployed or trained.

Lockheed Martin is the prime contractor on the PAC-3 Missile Segment upgrade to the Patriot air defense system. The PAC-3 Missile Segment upgrade consists of the PAC-3 Missile, a highly agile hit-to-kill interceptor, the PAC-3 Missile canisters (which each hold four PAC-3 Missiles, with four canisters per launcher), a fire solution computer and an enhanced launcher electronics system.

The PAC-3 Missile is the world's most advanced, capable and powerful theater air defense missile, and currently is the only fielded pure kinetic energy air defense missile. It defeats the Patriot Air Defense System threat: tactical ballistic missiles, cruise missiles and fixed and rotary winged aircraft. PAC-3 Missiles significantly increase the Patriot system's firepower, with 16 PAC-3s loading out on a single Patriot launcher.

Lockheed Martin achieved the first-ever hit-to-kill intercept in 1984 with the Homing Overlay Experiment, using force of impact alone to destroy a mock warhead outside of the Earth's atmosphere. Further development and testing produced today's PAC-3 Missile, which won a competition in 1993 to become the first hit-to-kill interceptor produced by the US government. The PAC-3 Missile has been the technology pathfinder for today's total conversion to kinetic energy interceptors for all modern missile defense systems.

Northrop Grumman's Fire Control Products Play Key Role in Successful Missile Defense Test

Northrop Grumman Corp.'s advanced fire control products played a key role in the most challenging test to-date of the nation's Ground-based Midcourse Defense (GMD) system, the nation's only defense against long-range ballistic missiles. In the system's first intercept test using multiple sensors (past tests have used only one sensor) to track and hit a live target, the GMD fire control products (GFC) integrated data from several globally-dispersed sensors to help coordinate the overall engagement sequence and more precisely track and ultimately destroy the target. In addition, Northrop Grumman's command launch equipment (CLE) software effectively launched the interceptor.

"The Northrop Grumman fire control products demonstrated a leap in capability today," said Karen Williams, sector vice president and general manager of the Missile Defense Division for Northrop Grumman's Mission Systems sector. "In pulling data from four sensors, versus one, the GFC had to perform the challenging task of correlating a multitude of different track data to decide on a trajectory that would correctly position the interceptor to hit the target. This is an extremely complicated effort, and I congratulate our team for again raising the bar and successfully meeting the objectives for every test to date."

During the GMD flight test, known as FTG-05 and conducted by the US Missile Defense Agency and The Boeing Co., a ground-based interceptor was launched from Vandenberg Air Force Base (VAFB), CA against a target missile threat fired from a launch complex in Kodiak, AK. The test employed four sensors located at-sea and along the West Coast. The fire control system—at Ft. Greely, AK and in Colorado Springs, CO—integrated data from these sensors to help identify, track and shoot down the target. The in-flight communication system data terminal, located at VAFB, provided target-track updates during the interceptor's flight to the target. "Our advanced software algorithms made sense of the information provided by these sensors, determined the best interceptor path, and put the kill vehicle in the right spot to make the hit," said Steve Owens, GMD Systems program director for Northrop Grumman in Huntsville, AL. ■

NanoKTN Supports Micro and Nanotechnology in UK

The Nanotechnology Knowledge Transfer Network (NanoKTN), one of the UK's primary knowledge-based networks for micro and nanotechnologies, has announced its support for one of the largest funding rounds that has been made available to the sector. A combined total of at least €250 M in co-funded grants is available to UK organisations wishing to submit collaborative R&D proposals directly relevant to micro and nanotechnology research in the next 12 months. This money is a combination of European Commission, UK Technology Strategy Board and the UK Engineering and Physical Science Research Council. The opportunities cover a wide range of activities from basic research through to full industrial implementation and also activities to cover risk and engagement elements.

Nanotechnologies offer the next generation of solutions to existing engineering problems through the development of new materials, new manufacturing processes and measurement techniques. These can be either explicitly researched or embedded into wider project initiatives. The UK national, regional and devolved administrations offer support through the UK NanoKTN as well as the official National Contact Point (NCP) Service and the European Enterprise Networks (EEN).

Choosing the right call is critical for UK organisations to expand their ambitions over the next two to five years. The NanoKTN is dedicated to helping its members understand how to write a successful proposal and identify suitable partnerships for collaborative work. By offering continuing support to its members, the NanoKTN hopes to be able to assist them in developing strategies, writing proposals and understanding what general funding areas and themes are relevant.

Indra Provides France with Tactical SATCOM Systems

Indra has been awarded a €3.9 M contract to provide the French Ministry of Defence with 25 mobile tactical SATCOM systems, which will be connected to the Syracuse III satellite network for communications. The network allows solid and safe communication between France and forces deployed across the planet.

One of the main advantages of the systems lies in the possibility of using either military or civil frequency bands. Besides this, the systems are transportable and easy to deploy and to take down; it would only take two operators 15 minutes to have them ready.

Each of the tactical communication systems is equipped with the necessary subsystems that position them in the right direction to make contact with the satellites. The systems are provided with GPS, spectrum analysers, inclinometers and anemometers for backup. The Syracuse III satellite system is regarded as the communications centre of the French Army and was designed to be difficult to interfere with.

The systems to be delivered by Indra are built to establish voice and data bidirectional communications at 2 Mbps. This speed is one of the highest to be found among this type of satellite and shows the company's capability to develop customised solutions for cutting-edge technology projects.

Partnership for Thales Alenia Space and Lockheed Martin

Thales Alenia Space Italy and Lockheed Martin Space Systems Co. are forming a strategic partnership. The initial focus of the partnership is to combine the experience and capabilities of each company to offer new, highly-responsive and agile space radar solutions for a variety of customers. The joint business agreement leverages each company's resources, talents, programmes and customer partnerships in a way that allows both to expand their respective remote sensing product areas and businesses.

Thales Alenia Space is a leader in developing, manufacturing, and delivering turnkey remote sensing systems, including satellites, platforms and payloads that feature Synthetic Aperture Radars for civilian, defence and dual use applications. Lockheed Martin Space Systems Co. has a long history in small satellite production and systems integration expertise.

The agreement is based on a framework the two companies established in 2007 and has expanded as part of this new phase of development. The two companies are actively completing their integrated design based on proven, technology-ready components and expect production cycle and pricing to be highly competitive while offering customers a space radar with high utility, great flexibility and strong reliability.

Mahindra & Mahindra and BAE Systems Joint Venture

Following approval from the Government of India's Foreign Investment Promotions Board, Mahindra & Mahindra and BAE Systems will set up a Joint Venture in India focused on land systems for the Indian market.

This approval is a key step in setting up the joint venture, and in accordance with current Foreign Direct Investment regulations, the equity split will be 74 percent with Mahindra & Mahindra and 26 percent with BAE Systems. The two companies will now finalise detailed planning and structural arrangements with a view to commencing joint venture operations as early as Q2 2009. Headquartered in Delhi, with manufacturing in Faridabad, the joint venture will initially employ 50 to 60 people.

Ian King, chief executive of BAE Systems, said, "This is an exciting opportunity and is the first step in BAE Systems' plans to grow long-term businesses in India in multiple sectors across the breadth and depth of the company's global capabilities in land, sea, air and security. The ever strengthening relationship between Mahindra & Mahindra and BAE Systems is an excellent basis on which to develop a company that is founded with the express purpose of serving the Indian armed forces and the Indian economy through the creation of high quality jobs, the development of innovative technologies and system integration skills, and the leadership of two world class companies."

DOCOMO Moves Step Closer to LTE with LSI Chip

NTT DOCOMO Inc. has successfully developed a trial large-scale-integration (LSI) chip that consumes less than 0.04 W of power yet supports multiple-input multiple-output (MIMO) signal detection and decoding for downlink transmissions at 100 Mbps, the speed required for the forthcoming mobile system known as Super 3G, or LTE, approved by the 3rd Generation Partnership Project (3GPP). Compared with chips currently used in handsets compatible with the company's High Speed Downlink Packet Access (HSDPA) service, which have a maximum downlink rate of 7.2 Mbps, the new chip will enable downlinks that are more than ten times as fast.

The new chip demodulates OFDM signals transmitted in the 20 MHz bandwidth from two antennas and detects MIMO signals based on Maximum Likelihood Detection technology, which ensures relatively high quality communication even in bad environments for signal reception. The chip also includes error correction decoding, which requires almost the same level of complexity as MIMO signal detection.

In the new chip, which is made with 65 nanometer processing, the circuits have been further optimized, particularly by eliminating redundant circuits for computationally complex processes such as MIMO-signal detection and error-correction decoding.

DOCOMO will incorporate this new LSI chip technology in ongoing research and development of LTE and International Mobile Telecommunications-Advanced (IMT-Advanced) systems, as well as in its active support of the establishment of related international standards. ■

UWB Market Sees Major Setbacks, but Some Progress

2008 was a tough year for ultra-wideband (UWB) technology, reports In-Stat. There are now four fewer UWB chip makers than there were in the middle of 2008, the high-tech market research firm says. Focus Semiconductor declared bankruptcy; WiQuest shut its doors; Intel stopped its program; Artimi and Staccato Communications merged at the urging of their venture capitalists.

"This consolidation has been expected, but in combination with continued slow UWB device shipments, it raises the specter of the failure of UWB technology in the marketplace," says Brian O'Rourke, In-Stat analyst. "On the bright side, UWB-enabled mobile PCs showed impressive percentage growth, albeit from a very low starting point. Another positive development in 2008 was the settling of the worldwide regulatory structure and the consequent development of worldwide UWB chip stock keeping units (SKU) from a number of chip makers."

Recent research by In-Stat found the following:

- PCs are the leading UWB segment in 2008, with 265,000 devices expected to ship.
- Aftermarket UWB hubs and adaptors comprise all of the UWB peripheral shipments in 2008.
- The first UWB-enabled digital televisions shipped in 2008 in Japan.

The research, "UWB 2008: Short-Term Problems and Long-Term Potential," covers the worldwide market for ultra-wideband technology, both WiMedia and proprietary versions. It provides forecasts for UWB penetration in major product categories, UWB-enabled cards and dongle shipments, UWB network port shipments, and UWB-enabled device shipments through 2012. It also provides analysis of market segments and profiles of silicon and IP competitors.

What Isn't Going to Happen in 2009

For the fourth consecutive year, ABI Research puts a different twist on the traditional December activity of surveying the year just past and speculating about what the new one will bring, with a white paper titled "What's Isn't Going to Happen in 2009." The paper is available for free download from the company's web site. Given the global recession, lots of things won't happen in 2009, of course. So ABI Research's analysts focused on several of the company's core areas of expertise, including mobile marketing and mobile banking, near-field communication, digital media, IPTV, transportation, navigation and location-based services, mobile phones and mobile telecoms, intellectual property, Wi-Fi, WiMAX and other networks, with a special look at Asia.

Any contrarian look at what won't happen naturally sheds light on what might. While many markets are undeniably in turmoil, there are opportunities as well as challenges, and surprising bright spots amid the gloom. Will mobile marketing hit the big time? No; but the mobile Internet is powering ahead and creating a foundation for the future. Will IPTV replace traditional broadcast TV? Absolutely not. But some markets are robust and some providers are prospering. Will the "location industry" get lost? No: in fact 2009's climate may have a bracing effect in the longer term. With its mix of expert opinion, informed assessments and wry humor, "What Isn't Going to Happen in 2009" makes for a lively and informative read.

To download the white paper in Adobe PDF format, go to www.abiresearch.com and click on the "What Isn't Going to Happen in 2009" ad button.

Rationalization of Communications Services Will Headline Communications Industry Trends

The economic downturn will slow growth and innovation in many areas but will create attractive investment opportunities in the communications and media sectors in the New Year, according to M/C Venture Partners, which released its annual list of the Top-10 communications and media industry trends to watch in 2009. Consumer segmentation, increasing enterprise bandwidth requirements, expanded uses of virtualization and increased adoption of personal mobile services will also be at the forefront of the industry next year, according to the venture capital firm's list. M/C Venture Partners created the list as part of its ongoing research to understand industry trends and discover investment opportunities in the communications, media and information technology sectors.

The leading trend going into 2009, according to the firm's list, is an accelerating shift in consumer spending toward wireless services and replacement of landline services. "Wireless services have historically cannibalized landline services, and in this economic climate, we see the value of mobility accelerating as consumers try to rationalize their communications services expenses," according to James Wade, managing general partner, M/C Venture Partners. "The fundamental characteristics of mobile wireless services make them increasingly essential in tight economic times with customers choosing more pre-paid or unlimited service offerings over maintaining their landline services. This trend will affect wireless operators at the expense of telcos and cable companies."

Other trends on the M/C Venture Partners' list include:

1. Driven by the success of smartphones like the iPhone, Samsung Instinct and Blackberry Curve, consumer adoption of mobile data services will continue to accelerate. These and other smartphones targeted at the wireless mass market will offer a much richer user experience resulting in consumers moving beyond SMS to using their mobile device for the Internet, video, so-

cial networking, maps and other data intensive applications.

2. Maturing communications services will drive consumer segmentation. Cable, telephony and wireless markets will continue to mature in 2009, reducing the impact of technology innovation as a driver of demand. As a result, service providers increasingly will utilize segmentation of consumer offerings to drive demand and profitability. Prepaid and unlimited offerings are key examples of growth by segmentation.
3. Smaller carriers will see an improved competitive landscape. With the broad consolidation of communications companies over the past few years, and further consolidation frozen by the financial markets, smaller carriers will have room to differentiate themselves with innovative products and services.
4. Consumer and mobility-driven video content consumption will drive network operators to revise their network deployment strategies to profitably accommodate changing usage patterns. Innovations in this area will question current network norms and usher in new strategies that can deliver near-term profits with the required performance enhancements needed to meet demand. Examples of these changes include distributed antenna systems, wireless backhaul, higher capacity access concentrator devices, increased use of fiber networks and more aggressive capacity planning by network operators.
5. Enterprise bandwidth needs will drive redundancy and quality requirements. Ever-increasing enterprise consumption of bandwidth will highlight the need for more reliable and diverse network solutions. These increasing bandwidth requirements will further expose reliability weaknesses of existing copper networks and the relative advantages of fiber and fixed wireless networks.
6. Virtualization will continue its trend of deepening penetration of the enterprise, as maturity of virtualization at all layers of infrastructure can now genuinely support dynamically scalable data services to the enterprise. Furthermore, with a slowing economy, enterprises will lower costs and improve operational flexibility through virtualization, which enables IT innovation during difficult economic conditions.
7. With a slowdown in advertising media spending, scrutiny of media effectiveness will increase, thereby accelerating the movement away from traditional media outlets and toward measurable media and tools for more effective media usage. Out-of-home media will become more local and direct. As technology improves, so too will efforts to tailor out-of-home advertisements to smaller, more specific consumer segments.
8. New leadership at the FCC and Congress will create a more innovation-friendly regulatory environment for smaller competitors. CLEC and wireless services in particular should benefit from broader opportunities to reach consumers with flexible product offerings and richer user experiences.
9. "Personal wireless broadband" will become more widespread. The increasing number of Internet-capable devices combined with lower monthly subscription costs will feed demand in spite of overall economic conditions. ■

INDUSTRY NEWS

■ **AWR**, a leader in high-frequency design software, expanded its relationship with **Rohde & Schwarz**, a leading test equipment manufacturer, to provide expanded sales channels for AWR products such as Microwave Office® in China, Taiwan, Singapore and Malaysia. The expanded sales distribution partnership will boost AWR's presence and the use of its software in the Asia Pacific region, and takes effect immediately. The two companies recently announced a similar agreement in Japan, and the expanded partnership further strengthens this relationship.

■ **Hesse & Knipps**, a manufacturer of high-speed, fine pitch wedge bonders for the back-end semiconductor industry, will partner with **MEW Consulting**, recently founded by Michael Whitehead, to provide technical support for third-party wedge and wire bonding equipment being phased out by the original manufacturers. Through the partnership, Hesse & Knipps and MEW Consulting will provide various support services including: high level technical and process/applications support; wire/wedge bonding equipment repairs; automatic wedge bonder rentals that protect against extended machine down-time situations; training programs; and maintenance programs.

■ **ETS-Lindgren** announced the opening of its new Acoustic Research Laboratory featuring state-of-the-art chambers for acoustic test services. With its hemi-anechoic chamber, two reverberation chambers, impedance tubes and supporting acoustic test equipment and software, the laboratory now offers product noise emission testing and structural/architectural acoustic testing. Acoustic field testing services are also available upon request. The laboratory is ISO 17025 accredited under the US Department of Commerce NIST National Voluntary Laboratory Accreditation Program (NVLAP).

■ **Emerson** has strengthened its Connectivity Solutions portfolio by bringing together the **Midwest Microwave**, **Vitelec Electronics**, **Johnson Components** and **Stratos Optical** brands under one new trading name, **Emerson Network Power Connectivity Solutions Ltd.** The original brand names will continue to be used. Under the new Connectivity Solutions umbrella the combined product lines will deliver RF, microwave and fibre optic interconnect components and assemblies for wireless communications, telephony and data networks, CATV, defence, security systems, healthcare and industrial facilities.

■ **Ducommun Inc.** announced that it has acquired **DynaBil Industries Inc.**, a privately held company based in Coxsackie, NY. DynaBil is a provider of titanium and aluminum structural components and assemblies for commercial and military aerospace applications. DynaBil's sales in calendar year 2008 are expected to be approximately $43 M. The purchase price for DynaBil was approximately $46.5 M in cash and notes, and remains subject to adjustment based on a closing balance sheet. DynaBil will become a part of Ducommun AeroStructures Inc. (DAS), an existing Ducommun subsidiary. The close similarities between DAS and DynaBil, especially in the areas of manufacturing, engineering, supply chain management, and sales and marketing, benefit both businesses by broadening their combined capabilities as a leading supplier of aerostructures to the aerospace industry.

CONTRACT

■ **Comtech Telecommunications Corp.** announced that its Maryland-based subsidiary, **Comtech Mobile Datacom Corp.**, received an order for $282.0 M under its Movement Tracking System, or MTS contract, with the US Army. This order is the largest single order in Comtech's history. Total orders received to date against the company's $605.1 M IDIQ MTS contract increased to $426.2 M.

NEW MARKET ENTRY

■ **Reynard Corp.**, a global supplier of optical components and custom thin film coatings, announced custom photolithography services to manufacture patterned optics. The company's contact exposing technique can achieve geometries as small as 5 microns utilizing a variety of thin film coating materials. Metallic or dielectric materials are selected based on the application's transparent, reflective and/or conductive opto-electrical requirements. Patterns can be applied to most substrate materials, including plastic sheeting.

PERSONNEL

■ Inphi® Corp., a fabless, high-speed analog semiconductor company, announced the addition of **Tsugio Makimoto** as an advisor for the company in Japan. Makimoto is well recognized as one of the leaders in the semiconductor industry. After receiving his MSEE degree from Stanford University and his PhD degree from the University of Tokyo, Makimoto spent most of his career with Hitachi Ltd. in the field of semiconductors in various roles, including senior executive and managing director in 1997. In addition, Makimoto held a corporate senior executive vice president position at Sony.

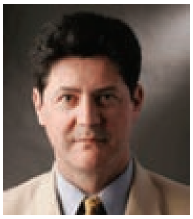
■ JPSA Laser announced the appointment of **Charles E. Cuneo** as its new president, based at the company's headquarters in Manchester, NH. Cuneo takes over responsibilities as president from Jefferey P. Sercel, founder, who will continue at the company as chairman and chief technology officer. Cuneo was most recently executive vice president of ERG Global, a company providing interim and temporary executive management resources to companies worldwide. Prior to this position, he was COO of Gibson Guitars of Nashville, TN. He has served as president and chief operating officer for software company

▲ *Charles E. Cuneo*

NeuMath Inc. He was also president and chief operating officer for Unitek Benchmark, a manufacturer of hermetic sealing systems for microelectronics, a subsidiary of laser manufacturer Unitek Miyachi Corp. Cuneo has held management positions for several other technology companies in the Northeast, including Waters, Millipore Corp., ADE Corp., Credence Systems and Teradyne Inc.

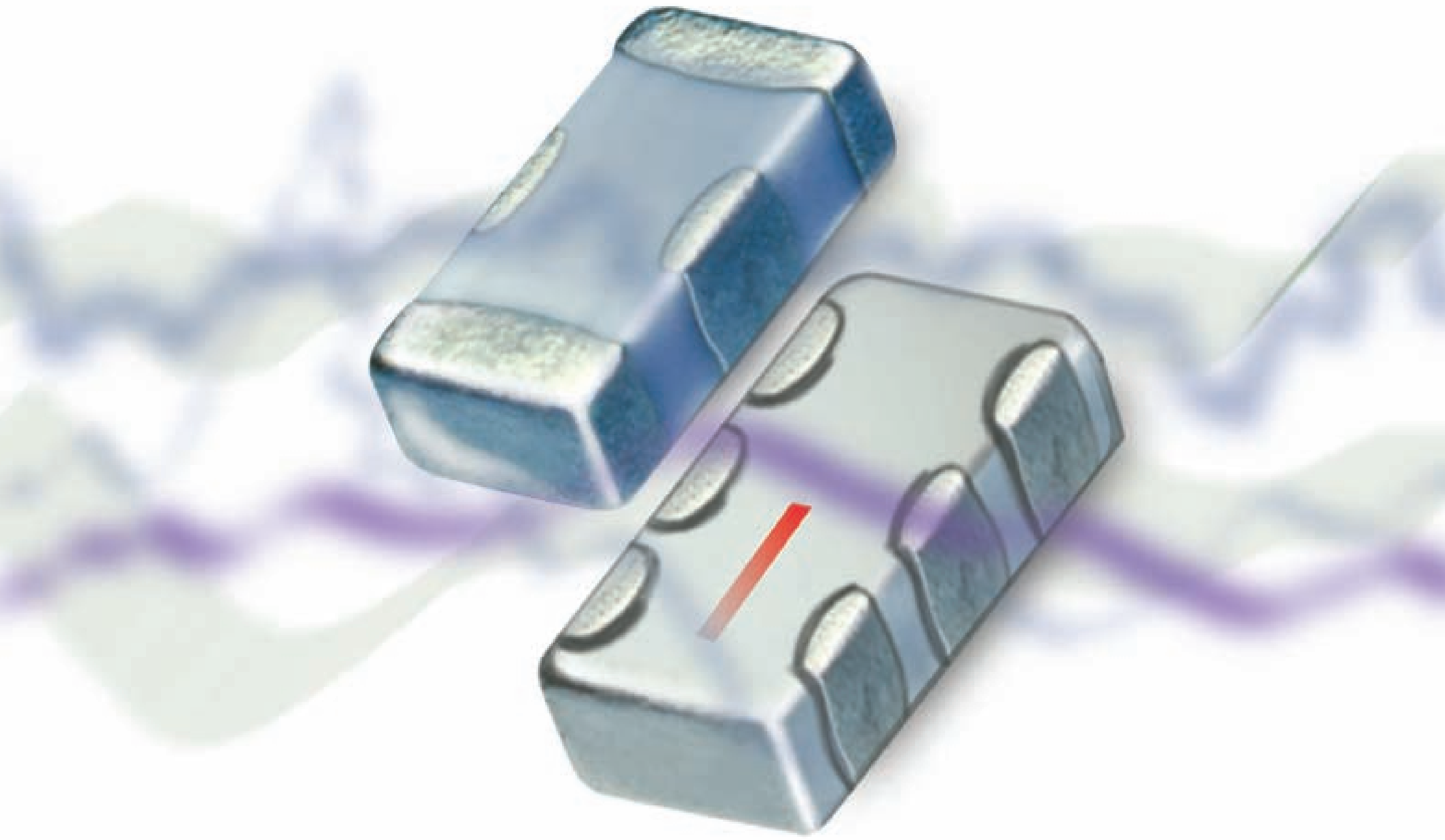
■ Cadence Design Systems Inc. announced the promotion of three senior leaders to executive management positions in R&D and worldwide sales and field operations. **Chi-Ping Hsu** was named senior vice president of research and development for the Implementation Products Group. Hsu has previously served as chief strategist of products and technologies and corporate vice president and general manager of both synthesis solutions and digital IC implementation. **Nimish Modi** was named senior vice president of research and development for the Front End Group with responsibility for products and solutions in the areas of logic design, systems design, verification, SoC IP integration and hardware/software co-validation. Prior to joining Cadence in 2006, Modi spent 18 years at Intel Corp., where he was most recently a vice president in the Enterprise Platforms Group with responsibility for the company's server CPU development. **Tom Cooley** was named senior vice president of Worldwide Field Operations. Cooley is responsible for worldwide sales, product marketing and technical field operations. Cooley is an EDA industry veteran with over 23 years of experience in sales and marketing. He joined Cadence in 1995 and has held various positions, including leading the company's sales activities in the regions of North America, Europe, the Middle East, Africa and India.

■ Linear Technology Corp., an independent manufacturer of high performance linear integrated circuits, announced the promotion of **Tony Armstrong** to the position of director of product marketing for Power Products. In his expanded role, Armstrong will have responsibility for the management of all aspects of product marketing for both integrated circuits and power µModule™ regulators, including product pricing, advertising and related marketing campaign development. Armstrong brings 27 years of industry experience to his new role, including over eight years at Linear as product marketing manager. Prior to joining Linear, he held marketing, management and sales positions with various companies, including Siliconix, Semtech, Fairchild and Intel.



▲ *Tony Armstrong*

■ Renaissance Electronics announced the promotion of **Charles Nashef** to international sales manager. Nashef has over 16 years in business development for manufactured components on a national and international level with extensive experience working with the aerospace, defense, telecom, industrial and medical industries. Nashef manages the international markets for all of Renaissance product offering along with leading the marketing campaign for both national and international.



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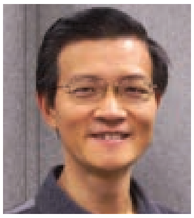
IF/RF MICROWAVE COMPONENTS

432 Rev B

■ MI Technologies, a worldwide supplier of microwave test and measurement products, systems and service, has appointed **Charles Liang** of Duluth, GA, to the position of strategic account manager for Asia. In this new position, Liang will be responsible for the company's new business efforts for the Asian region working with in-country partners and the MI Technologies' engineering and business resources to accelerate the growth of the company's business in the region. Prior to this appointment, Liang served as a program manager for MI Technologies being responsible for the profit and loss of key initiatives and coordinating a number of successful test and measurement installations in the United States and Asia.


▲ Charles Liang

REP APPOINTMENTS

■ **Technical Communities**, a service provider for technical organizations that sell to US government agencies, military organizations and prime federal contractors, announced a new exclusive government services partnership agreement with **LadyBug Technologies**, a manufacturer of the PowerSensor+™ line of "no-cal, no-zero" USB power-measurement instruments. The agreement authorizes Technical Communities to provide government organizations with LadyBug Technologies' PowerSensor+ line of miniaturized USB power meter-sensors.

■ **Digi-Key Corp.** announced that it has recently signed an agreement for the worldwide distribution of **Murata Power Solutions** products. Murata Power Solutions is a manufacturer of DC-DC converters, AC-DC converters, high-reliability power supplies, digital panel meters, magnetics and data acquisition devices for applications that include telecommunications, computing, industrial and other high-tech applications.

■ **Mouser Electronics Inc.** announced it has signed a distribution agreement with **Hirose Electric Co.**, a specialty manufacturer of high-quality connectors. Mouser has access to Hirose's full product portfolio and is stocking rectangular, circular and coaxial connectors, as well as FFC/FPC connectors.

■ **Lorch Microwave** announced it has appointed **Sands Technical Sales** located in Chandler, AZ, as the exclusive representative for all RF and microwave products in Arizona and New Mexico.

■ **Carlisle Interconnect Technologies**, a division of Carlisle Companies Incorporated, announced the appointment of **Tactron Elektronik** as its International Sales Representative in Germany, Austria and Switzerland. Founded in 1984, Tactron Elektronik focuses on the military and aerospace, telecommunication, safety technology, fibre optic and software industries.

DUAL CHANNEL DETECTOR

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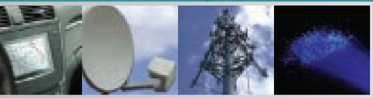
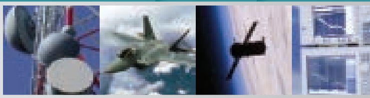
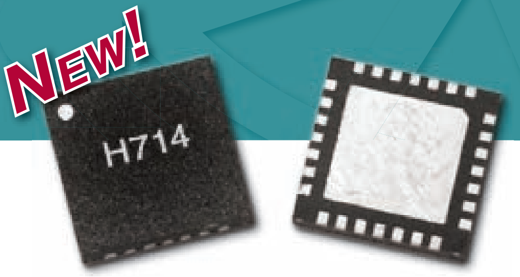


Analog & Mixed-Signal ICs, Modules, Subsystems & Instrumentation





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HMC714LP5E Dual Channel RMS Power Detector, 100 MHz to 3.9 GHz

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- *Input Dynamic Range: -55 dBm to +15 dBm*
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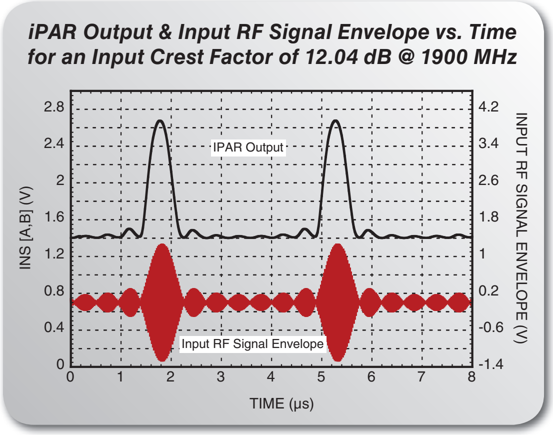

RF Input Power @ -20 dBm

IN-STOCK POWER DETECTORS: LOG, RMS (Dual) / PAR & SDLVA

	Frequency (GHz)	Function	Dynamic Range (dB)	RSSI Slope (mV / dB)	RF Threshold Level (dBm)	Bias Supply	Package	Part Number
	50 Hz - 3.0	Log Detector / Controller	74 ± 3	+19	-66	+3.3V @ 29mA	LP4	**HMC612LP4E**
	0.001 - 8.0	Log Detector / Controller	70 ± 3	-25	-61	+5V @ 113mA	LP4	**HMC602LP4E**
	0.001 - 10.0	Log Detector / Controller	73 ± 3	-25	-65	+5V @ 103mA	Chip	**HMC611**
	0.001 - 10.0	Log Detector / Controller	70 ± 3	-25	-65	+5V @ 106mA	LP4	**HMC611LP4E**
	0.01 - 4.0	Log Detector / Controller	70 ± 3	19	-68	+3.3V @ 30mA	LP4	**HMC601LP4E**
	0.05 - 4.0	Log Detector / Controller	70 ± 3	19	-69	+3.3V @ 29mA	LP4	**HMC600LP4E**
NEW!	0.1 - 2.7	Log Detector / Controller	54 ± 1	17.5	-52	+5V @ 17mA	MS8	**HMC713MS8E**
	DC - 3.9	RMS Power Detector	69 ± 1	37	-60	+5V @ 65mA	LP4	**HMC610LP4E**
NEW!	0.1 - 3.9	Dual RMS / PAR Power Detector	70 ± 1	37	-55	+5V @ 138mA	LP5	**HMC714LP5E**
NEW!	0.1 - 3.9	RMS / PAR Power Detector	71 ±1	37	-58	+5V @ 75mA	LP4	**HMC614LP4E**
	0.1 - 20	SDLVA	62	14	-57	+3.3V @ 83mA	LC4B	**HMC613LC4B**
	Connectorized Power Detector Modules							
NEW!	0.01 - 2.0	RMS Power Detector	70 ±1	37	-58	+12V @ 95mA	C-6 / SMA	**HMC-C054**
NEW!	1 - 20	SDLVA	59	14	-67	+12V @ 86mA	C-10 / SMA	**HMC-C052**

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RELATIONSHIPS BETWEEN COMMON EMITTER, COMMON BASE AND COMMON COLLECTOR HBTs

Analytical expressions for the relationships between common emitter, common base and common collector HBTs are presented in this article. Further simplified expressions for noise parameters in the low frequency range are given. This technique is based on the combination of an equivalent circuit model and a conventional two-port network signal/noise correlation matrix technique. The derived relationships have universal validity, but they have been verified with InP/InGaAs DHBTs with a 5 × 5 μm² emitter area. Good agreement has been obtained between calculated and measured results.

InP-based heterojunction bipolar transistors (HBT) have shown excellent microwave and noise performance and are very attractive for millimeter-wave and optoelectronic applications, such as low noise amplifiers (LNA), mixers, oscillators and other RF sub-system components. HBTs are almost exclusively operated in a common emitter configuration (CE) in amplifier design. However, a common base configuration (CB) has the advantages of ease of broadband impedance matching with a better gain and is more suitable for optical and microwave broadband communication applications.[1-4] At the same time, the common collector configuration (CC) has been widely used as an isolator and buffer in microwave monolithic integrated circuits.[5]

A complete characterization of the transistor (CE, CB and CC) in terms of noise and scattering parameters is necessary for the computer-aided design (CAD) of microwave circuits. The S- and noise-parameters for each configuration can be obtained by measuring the test patterns of CE, CB and CC configurations. However, this method requires two special test structures (CB and CC) for each device size on the wafer, and the non-uniformity across the wafer has to be ignored. Alternatively, analytical expressions for the relationships between common emitter, common base and common collector HBTs are very attractive and useful for understanding the relation between the different configurations. The direct transformation technique for microwave FET devices has been discussed in more detail previously.[6-8] However, a comprehensive analytical expression for the different HBT configurations has not yet been published.

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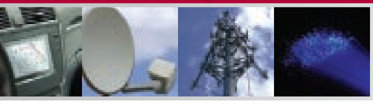
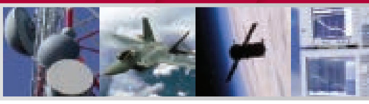
HIGH SPEED ICs

HIGH SPEED COMPARATORS & HIGH SPEED DIGITAL LOGIC!

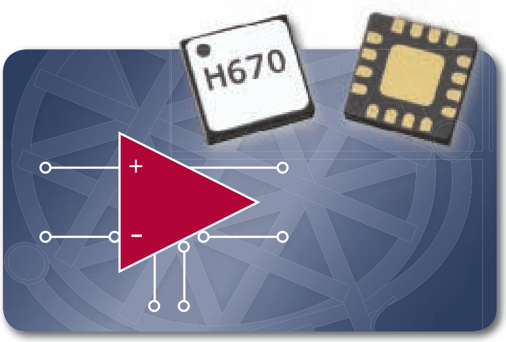


Analog & Mixed-Signal ICs, Modules, Subsystems & Instrumentation



High Speed Comparators

- ***RSPECL, RSCML & RSECL Versions***
- ***Low Propagation Delay: 130 ps***
- ***9.7 GHz Equivalent Input Rise Time Bandwidth***
- ***Low Overdrive & Slew Rate Dispersion: 10 ps***



HIGH SPEED COMPARATORS

Input Clock Rate (GHz)	Function	Deterministic Jitter (ps)	Propagation Delay (ps)	Output Voltage Swing (Vdc)	DC Power Consumption (mW)	Vcc, Vee Power Supply (Vdc)	Package	Part Number
9.7	Latched Comparator-RSPECL	10	130	0.4	180	+3.3, -3.0	LC3C	**HMC674LC3C**
9.7	Latched Comparator-RSCML	10	130	0.2	120	+3.3, -3.0	LC3C	**HMC675LC3C**
9.7	Latched Comparator-RSECL	10	130	0.4	120	+3.3, -3.0	LC3C	**HMC676LC3C**

High Speed Digital Logic

- ***Low Jitter: 2 ps Peak-to-Peak***
- ***Low Power Dissipation, ≅ 230 mW***
- ***User Selectable Output Amplitude***
- ***-40 to +85 °C Operation***

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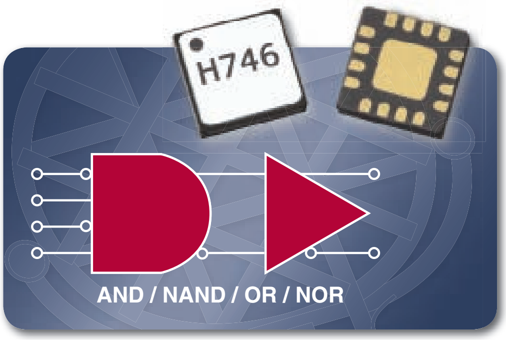

IN-STOCK HIGH SPEED DIGITAL LOGIC ICs

	Data / Clock Rate (Gbps/GHz)	Function	Rise / Fall (ps)	Deterministic Jitter (ps)	Differential Output Voltage Swing (Vpp)	DC Power Consumption (mW)	Vee Power Supply (Vdc)	Package	Part Number
NEW!	13 / 13	Fast Rise Time 1:2 Fanout Buffer*	22 / 20	2	0.6 - 1.2	290	+3.3	LC3C	**HMC744LC3C**
NEW!	13 / 13	2:1 Selector*	22 / 22	2	0.6 - 1.2	250	+3.3	LC3C	**HMC748LC3C**
NEW!	13 / 13	Fast Rise Time AND/NAND/OR/NOR*	22 / 21	2	0.6 - 1.2	230	+3.3	LC3C	**HMC746LC3C**
NEW!	13 / 13	Fast Rise Time D-Type Flip-Flop*	22 / 20	2	0.7 - 1.2	264	+3.3	LC3C	**HMC747LC3C**
NEW!	26 / 26	T Flip-Flop w/ Reset *	18 / 17	2	0.6 - 1.2	270	+3.3	LC3C	**HMC749LC3C**
NEW!	13 / 13	Fast Rise Time XOR/XNOR*	21 / 19	2	0.6 - 1.2	240	+3.3	LC3C	**HMC745LC3C**

** These products feature programmable output voltage.*

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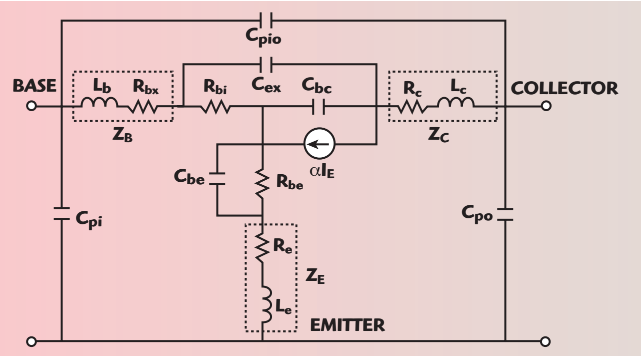


▲ *Fig. 1 Small-signal equivalent circuit model in CE configuration.*

In this article, a simple but efficient transformation technique for microwave HBT devices is proposed. This technique is based on the combination of an equivalent circuit model and a conventional two-port network signal/noise correlation matrix technique. The signal and noise parameters of the CB and CC configurations can be obtained directly by using a simple set of formulas from the CE signal and noise parameters. All the relationships provide a bi-directional bridge for the transformation between CE, CB and CC HBTs, respectively.

THEORETICAL ANALYSIS

Small-signal Model

The conventional hybrid-T type small-signal equivalent circuit model in the CE configuration is shown in ***Figure 1***. Since the T-shaped equivalent circuit is more closely related to the original derivation of the common base Y parameters of bipolar transistors, and involves less simplifying assumption than the π equivalent circuit, it is usually employed in the literature for the purpose of small-signal parameter extraction of HBTs. The circuit is divided into two parts, that is the outer part containing the extrinsic elements, considered as bias independent, and the inner part containing the intrinsic elements, considered as bias dependent.

In the small-signal equivalent circuit model, C_{pi}, C_{po} and C_{pio} represent the pad capacitances, L_b, L_c and L_e represent the inductances of the base, collector and emitter feed lines, R_{bx} and R_{bi} are the extrinsic and intrinsic base resistances, R_c and R_e are the collector and emitter resistances, C_{ex} is the extrinsic base-collector capacitance, and C_{be} and C_{bc} are the intrinsic base-emitter and base-collector capacitances, respectively. It is noted that the extrinsic base-collector resistance R_{ex} is neglected in this model, because the value of R_{ex} is very large and does not affect the frequency response as long as only forward operation is concerned with.

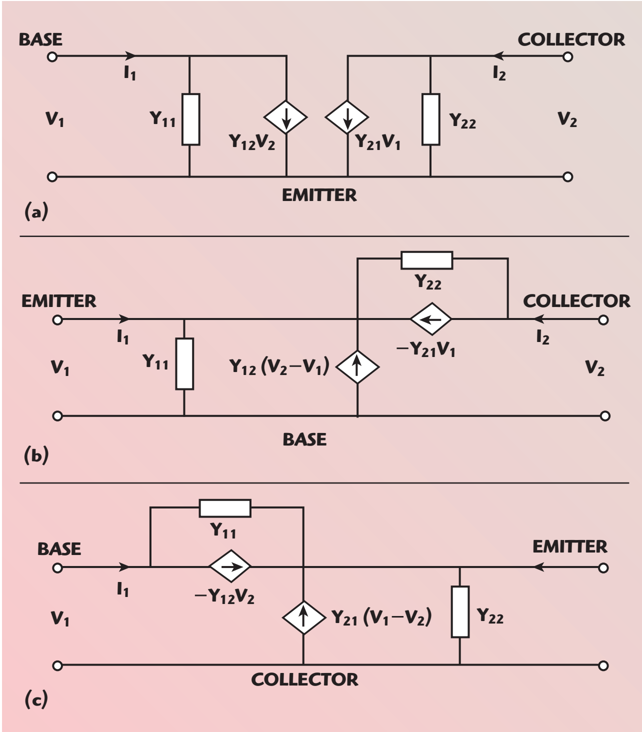
The short circuit Y-parameters for the intrinsic part of the small-signal equivalent circuit in the CE configuration can be expressed as:

$$Y_{11} = Y_{EX} + \frac{Y_{BC} + (1-\alpha)Y_{BE}}{A} \quad (1)$$

$$Y_{21} = -Y_{EX} + \frac{-Y_{BC} + \alpha Y_{BE}}{A} \quad (2)$$

$$Y_{12} = -Y_{EX} + \frac{-Y_{BC}}{A} \quad (3)$$

$$Y_{22} = Y_{EX} + \frac{Y_{BC}(1 + Y_{BE}R_{bi})}{A} \quad (4)$$



▲ *Fig. 2 CS (a), CG (b) and CD (c) HBT configurations.*

with

$$A = 1 + R_{bi}\left[Y_{BC} + (1-\alpha)Y_{BE}\right]$$

$$Y_{BE} = \frac{1}{R_{be}} + j\omega C_{be}$$

$$Y_{BC} = j\omega C_{bc}$$

$$Y_{EX} = j\omega C_{ex}$$

Assuming a single-pole appoximation, the transport factor can be written:

$$\alpha = \frac{\alpha_o}{1 + j\omega/\omega_\alpha} e^{-j\omega\tau} \quad (5)$$

α_0 denotes the intrinsic current gain at low frequency, ω_α is the 3 dB roll-off frequency and τ is the transit time delay.

The CB configuration for the HBT devices considered in the studies can be obtained from exchanging the base and emitter in the CE configuration, and the CC configuration can be obtained by exchanging the collector and emitter in the CE configuration. Because the pad capacitances are the same for the three configurations, all the transformation formulas in this article will not include the effect of pad capacitances. The measured S-parameters and noise parameters without pad capacitances are obtained after de-embedding the pad capacitances.

Signal Parameter Relationships

The equivalent two-port short circuit Y-parameters networks of the CE, CB and CC configurations for the HBT devices are shown in ***Figure 2***. Comparing the Z-parameters of the CE, CB and CC configurations, the Y-parameter relationships can be obtained as follows:

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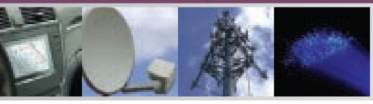

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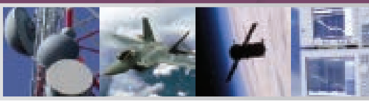

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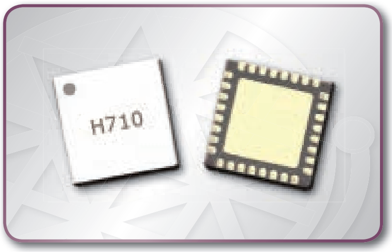

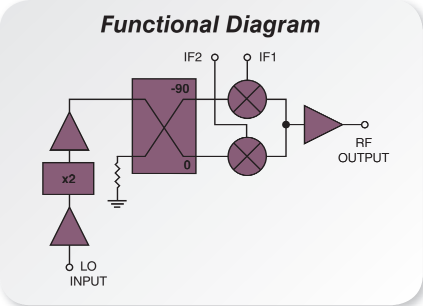

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- LO to RF Isolation: 10 dB
- High Output IP3: +30 dBm
- RoHS 5x5 mm SMT Package

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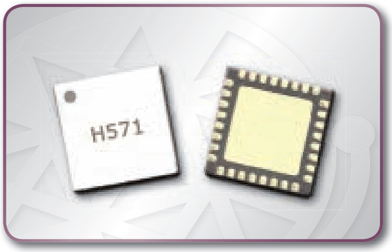
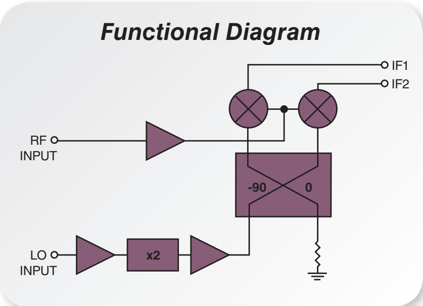
NEW!	11 - 17	I/Q Upconverter / Transmitter	DC - 1.5	13	-20	26	LC5	HMC709LC5
NEW!	16 - 21	I/Q Upconverter / Transmitter	DC - 3.5	12	-20	30	LC5	HMC710LC5

HMC571LC5 I/Q Downconverter / Receiver IC, 21 - 25 GHz





- Conversion Gain: 10 dB
- Noise Figure: 3 dB
- Image Rejection: 18 dB
- Input IP3: +2 dBm
- Available in Die or RoHS 5x5 mm SMT Package

Integrated LO Doubler & RF LNA

IN-STOCK I/Q DOWNCONVERTER / RECEIVER ICs

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7 - 9	I/Q Downconverter / Receiver	DC - 3.5	10	35	1.5	LC5	HMC567LC5
9 - 12	I/Q Downconverter / Receiver	DC - 3.5	14	33	-1	LC5	HMC568LC5
12 - 16	I/Q Downconverter / Receiver	DC - 3.5	14	32	-0.5	LC5	HMC569LC5
17 - 21	I/Q Downconverter / Receiver	DC - 3.5	10	18	2	LC5	HMC570LC5
21 - 25	I/Q Downconverter / Receiver	DC - 3.5	9	18	2	LC5	HMC571LC5
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$$Y_{11}^{CB} = Y_{11}^{CE} + Y_{12}^{CE} + Y_{21}^{CE} + Y_{22}^{CE} \quad (6)$$

$$Y_{12}^{CB} = -(Y_{12}^{CE} + Y_{22}^{CE}) \quad (7)$$

$$Y_{21}^{CB} = -(Y_{21}^{CE} + Y_{22}^{CE}) \quad (8)$$

$$Y_{22}^{CB} = Y_{22}^{CE} \quad (9)$$

$$Y_{11}^{CC} = Y_{11}^{CE} \quad (10)$$

$$Y_{12}^{CC} = -(Y_{12}^{CE} + Y_{11}^{CE}) \quad (11)$$

$$Y_{21}^{CC} = -(Y_{21}^{CE} + Y_{11}^{CE}) \quad (12)$$

$$Y_{22}^{CC} = Y_{11}^{CE} + Y_{12}^{CE} + Y_{21}^{CE} + Y_{22}^{CE} \quad (13)$$

Noise Parameter Relationships

Figure 3 shows the noise equivalent circuits of the CE, CB and CC configurations for HBT devices. $\overline{\upsilon_{Ci}^2}$ and $\overline{i_{Ci}^2}$ (i=E,B,C) are the two noise sources at the input of the noiseless HBT device for different configurations. The chain noise correlation matrix is easier to obtain from the noise measurement because there is a direct relation between the measured noise parameters (F_{min} is the minimum noise figure, R_n the noise resistance, G_{opt} the optimum source conductance and B_{opt} the optimum source susceptance). The relationship of the noise parameters between the CE, CB and CC configurations can be obtained by using the noise source transformation matrix technique.[6-8]

The relationships between the CE and CB configuration are as follows:

$$R_n^{CB} = \frac{R_n^{CE}\left|Y_{21}^{CE}\right|^2}{\left|Y_{21}^{CE} + Y_{22}^{CE}\right|^2} \quad (14)$$

$$B_{opt}^{CB} = \mathrm{Im}\left(\frac{\Delta Y^{CE}}{Y_{21}^{CE}}\right) + B_{opt}^{CE}\,\mathrm{Re}\left(\frac{Y_{22}^{CE} + Y_{21}^{CE}}{Y_{21}^{CE}}\right) - \mathrm{Re}(k_3)\,\mathrm{Im}\left(\frac{Y_{22}^{CE} + Y_{21}^{CE}}{Y_{21}^{CE}}\right) \quad (15)$$

$$G_{opt}^{CB} = \sqrt{\left|\frac{\Delta Y^{CE}}{Y_{21}^{CE}}\right|^2 + \left|Y_{opt}^{CE}\right|^2\left|\frac{Y_{22}^{CE} + Y_{21}^{CE}}{Y_{21}^{CE}}\right|^2 - 2k_1 - (B_{opt}^{CB})^2} \quad (16)$$

$$F_{min}^{CB} = 1 + 2\,\mathrm{Re}(G_{opt}^{CB}R_n^{CB} + k_2) \quad (17)$$

where

$$k_1 = \mathrm{Re}\left[\frac{\Delta Y^{CE}}{Y_{21}^{CE}}\left(\frac{Y_{22}^{CE} + Y_{21}^{CE}}{Y_{21}^{CE}}\right)^* k_3\right]$$

$$k_2 = -R_n^{CB}\left(\frac{\Delta Y^{CE}}{Y_{21}^{CE}}\right)^* + \frac{k_3 R_n^{CE} Y_{21}^{CE}}{Y_{22}^{CE} + Y_{21}^{CE}}$$

$$k_3 = \frac{F_{min}^{CE} - 1}{2R_n^{CE}} - (Y_{opt}^{CE})^*$$

$$\Delta Y^{CE} = Y_{11}^{CE}Y_{22}^{CE} - Y_{12}^{CE}Y_{21}^{CE}$$

The relationships between the CE and CC configuration are as follows:

$$R_n^{CC} = R_n^{CE}\left[1 + \left|\frac{1}{Y_{11}^{CE} + Y_{21}^{CE}}\right|^2 \left|Y_{opt}^{CS}\right|^2\right] + 2k_4 \quad (18)$$

$$B_{opt}^{CC} = \frac{\mathrm{Im}\left[k_3 R_n^{CE}\left(\frac{Y_{21}^{CE}}{Y_{11}^{CE} + Y_{21}^{CE}}\right)^*\right]}{R_n^{CC}} - \frac{R_n^{CE}\left|Y_{opt}^{CE}\right|^2 \mathrm{Im}\left(\frac{1}{Y_{21}^{CE}}\right)\left|Y_{21}^{CE}\right|^2}{R_n^{CC}\left|Y_{11}^{CE} + Y_{21}^{CE}\right|^2} \quad (19)$$

$$G_{opt}^{CC} = \sqrt{\frac{R_n^{CE}\left|Y_{opt}^{CE}\right|^2\left|Y_{21}^{CE}\right|^2}{R_n^{CC}\left|Y_{21}^{CE} + Y_{11}^{CE}\right|^2} - (B_{opt}^{CC})^2} \quad (20)$$

$$F_{min}^{CC} = 1 + 2\,\mathrm{Re}(G_{opt}^{CC}R_n^{CC} + k_5) \quad (21)$$

where

$$k_4 = -\mathrm{Re}\left[\left(\frac{1}{Y_{11}^{CE} + Y_{21}^{CE}}\right)^* k_3 R_n^{CE}\right]$$

$$k_5 = \frac{k_3 R_n^{CE}}{\left(\frac{Y_{11}^{CE} + Y_{21}^{CE}}{Y_{21}^{CE}}\right)^*} - \frac{\left|Y_{opt}^{CE}\right|^2 (Y_{21}^{CE})^* R_n^{CE}}{\left|Y_{21}^{CE} + Y_{11}^{CE}\right|^2}$$

At the low frequency ranges (typically f < 6 GHz), the noise parameter relationships between the CE, CB and CC configurations for the intrinsic HBT device can be simplified by neglecting the influence of the parasitics:

$$R_n^{CB} \approx R_n^{CE}\left(1 + \frac{\omega^2 R_{bi} C_{ex}}{\omega_\alpha}\right)^2 \quad (22)$$

$$F_{min}^{CB} \approx F_{min}^{CE} \quad (23)$$

$$B_{opt}^{CB} \approx -\frac{\omega^2 R_{bi} C_{ex} / \omega_\alpha}{1 + \omega^2 R_{bi} C_{ex} / \omega_\alpha} B_{opt}^{CE} \quad (24)$$

$$G_{opt}^{CB} \approx G_{opt}^{CC} \approx G_{opt}^{CE} \quad (25)$$

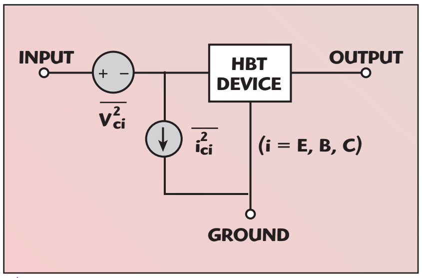
$$R_n^{CC} \approx R_n^{CE}\left(1 + R_{be}^2\left|Y_{opt}^{CE}\right|^2 - 2R_{be}\left(\frac{F_{min}^{CE} - 1}{2} - G_{opt}^{CE}R_n^{CE}\right)\right) \quad (26)$$

$$B_{opt}^{CC} \approx B_{opt}^{CE} \quad (27)$$

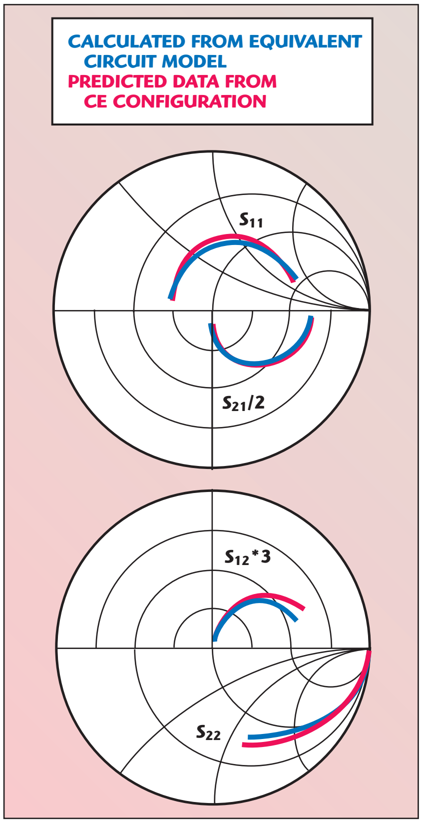
$$F_{min}^{CC} \approx F_{min}^{CE} - 2B_{opt}^{CE}R_n^{CE}\omega(\tau + 1/\omega_\alpha) \quad (28)$$

EXPERIMENTAL VERIFICATION

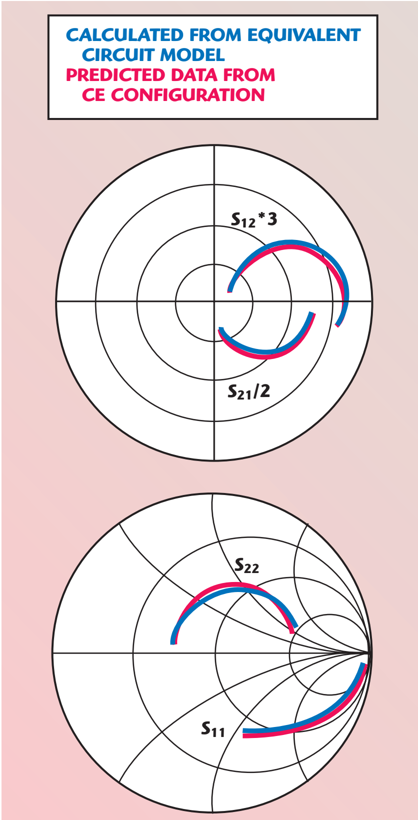
In order to verify the equations derived in the theoretical analysis for the signal and noise parameters, InP/InGaAs DHBTs with a 5 x 5 μm² emitter area have been characterized. The S-parameter measurements for model extraction and verification were made using an Agilent 8510C network analyzer. The DC bias was supplied by an Agilent 4156A. The microwave



▲ *Fig. 3 HBT noise equivalent circuit models for CE, CB and CC configurations.*



▲ *Fig. 4 Comparison of modeled and predicted S-parameters for the HBT in CB configuration.*



▲ *Fig. 5 Comparison of modeled and predicted S-parameters for the InP HBT in CC configuration.*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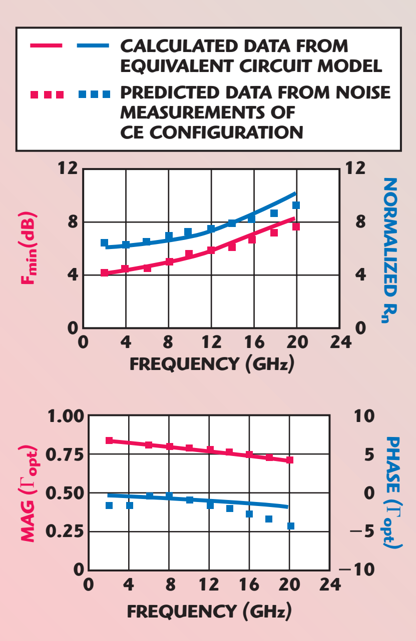
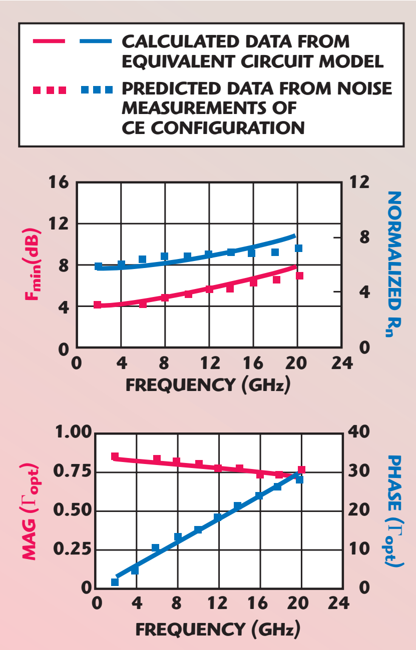
noise parameter measurements were carried out on the wafer over the frequency range from 1 to 20 GHz, using an ATN microwave noise measurement system NP5.

The extracted values of the extrinsic and intrinsic small-signal elements can be easily determined by using the direct extraction technique[9,10] and are summarized in ***Appendix A***. The bias condition is V_{ce}=2.0 V and I_b= 50 µA (I_c=1.84 mA). An excellent agreement over the whole frequency range is obtained for the CE configuration.[10] To illustrate the efficiency of the Y-parameter transformation formulas, the measured and predicted S-parameters for the CB and CC configurations are compared in ***Figures 4*** and ***5***. Good agreement can be observed between the data calculated from the equivalent circuit model and the data predicted by the transformation formulas up to 40 GHz at a bias I_b=50 µA, V_{CE}=2.0 V.



▲ *Fig. 6 Comparison of modeled and predicted noise parameters for the InP HBT in CB configuration.*



▲ *Fig. 7 Comparison of modeled and predicted noise parameters for the InP HBT in CC configuration.*

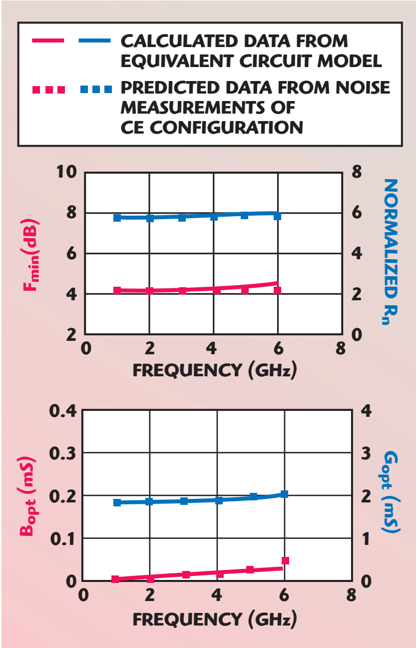
To illustrate the efficiency of the transformation formulas for noise parameters, the predicted and modeled results for InP HBT in the CB and CC configurations are compared in ***Figures 6*** and ***7***. The predicted data for the CB and CC configurations are obtained from measured data of the CE configuration by using Equations 14 to 17. Good agreement is obtained

between measured and predicted data, which verifies the proposed approach for the noise parameters.

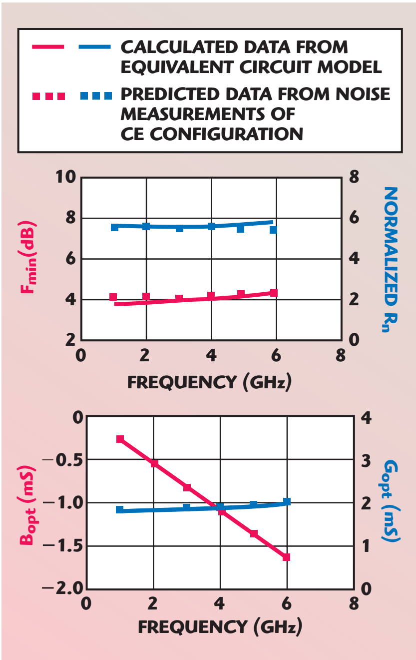
In ***Figures 8*** and ***9***, the calculated noise parameters in the low frequency ranges (Equations 21 to 28) are compared with the predicted data versus frequency for the intrinsic InP HBT device under the same bias condition. Good agreement is obtained between measured and predicted data in the CB and CC configurations, which verifies the proposed approach for the noise parameters.

CONCLUSION

In this article, a set of new analytical expressions for the relationship between common emitter, common base and common collector microwave HBTs is proposed. All the relationships provide a bi-directional bridge for the transformation between CE, CB and CC devices. This technique is



▲ *Fig. 8 Comparison of modeled and predicted noise parameters for the InP HBT in CB configuration at low frequency range.*



▲ *Fig. 9 Comparison of modeled and predicted noise parameters at the low frequency ranges for the InP HBT in CC configuration.*

based on the combination of an equivalent circuit model and a conventional two-port network signal/noise correlation matrix technique. The validity of the new approach is proved by comparison with measured S- and noise-parameters up to 20 GHz. A good agreement has been obtained for InP/InGaAs DHBTs with a 5 × 5 μm² emitter area. ■

APPENDIX A

EXTRINSIC AND INTRINSIC PHEMT PARAMETERS

Extrinsic Parameters	C_{pi}(fF)	C_{po}(fF)	C_{pio}(fF)	L_b(pH)	L_c(pH)	L_e(pH)	$R_{bx}(\Omega)$	$R_c(\Omega)$	$R_e(\Omega)$
Values	14.5	13.5	1.7	44.5	42.5	7.5	3.5	18	3.5
Intrinsic Parameters	α	f_α(GHz)	τ(ps)	C_{ex}(fF)	C_{bc}(fF)	$R_{bi}(\Omega)$	C_{be}(pF)	$R_{be}(\Omega)$	
Values	0.98	75	0.6	38	8	220	0.11	20	

ACKNOWLEDGMENT

This work was supported by the National Natural Science Foundation of China under grant No. 60671054 and New Century Excellent Talent from the Ministry of Education in China.

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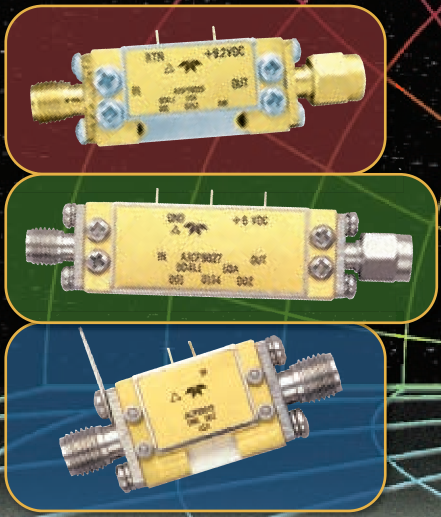

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A3CP7029	**3.0-8.0**	27.5	3.6	**27.5**	33.5/51	12	425
A3CP8027	**3.0-8.0**	23.0	4.0	**21.5**	32/48	12	225
A2CP11039	**5.0-11.0**	12.0	4.0	**33.0**	42/57	15	1500
ACP12019	**6.0-12.0**	9.5	4.0	**28.0**	39/52	10	210
A2CP14639	**6.0-14.0**	11.0	4.0	**33.0**	42/57	15	1500
ACP16025	**8.0-16.0**	7.5	4.3	**28.0**	42/65	12	253
ACP18015	**8.0-18.0**	9.0	4.0	**15.5**	23/31	5	63
A2CP18225	**10.0-18.0**	15.0	4.5	**25.5**	35/44	12	325
ACP20015	**2.0-20.0**	10.0	4.5	**16.0**	26/29	5	76
ACP20215	**2.0-20.0**	20.0	4.8	**18.0**	28/45	5	156

Typical and guaranteed specifications vary versus frequency; see detailed data sheets for specification variations.

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AN ANALOG LINEARIZER BASED ON AMPLITUDE MODULATION WITH EVEN HARMONIC SIGNALS

This article proposes a novel amplifier linearization technique to achieve independent control of third- and fifth-order intermodulation products using amplitude modulation with even harmonic signals. A vector modulator modulates a fundamental signal with both second- and fourth-order harmonic components generated by harmonic generator circuits. It also generates predistortion third- and fifth-order intermodulation signals and controls their amplitude and phase. As a result, this predistorter effectively suppresses individual intermodulation distortion signals of the power amplifier.

Nowadays, it may be inconvenient to live without mobile communication systems. In the past, voice quality in communications was the only essential requirement. Now, however, most people regard the transmission of a large amount of data to be necessary in communications. As a result, more complex modulation and demodulation methods and broad channel bandwidth are required for mobile communication systems. When these signals are amplified in the power amplifier, in addition to the amplified signals, unwanted harmonic and intermodulation (IM) distortion signals are generated simultaneously. These generated IM signals increase the data bit error rate and interfere with adjacent channel signals, decreasing the power amplifier efficiency.

In mobile radio standards, a highly linear transmitter, which can support high crest factor signals, is required. Consequently, the design of a power amplifier with high linearity and high efficiency is a critical issue. However, as the power amplifier operates close to the saturation region where both high efficiency and high output power are achieved, the linearity degradation becomes significant. A compromise between power efficiency and linearity can be a solution, but the use of a linearization technique to compensate for the power amplifier nonlinearity is a better solution.[1-12]

This article introduces a novel amplifier linearization technique to achieve independent control of the third- and fifth-order intermodulation products using an amplitude mod-

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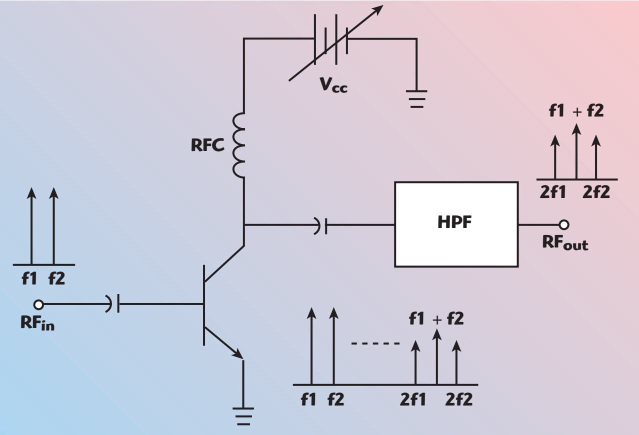
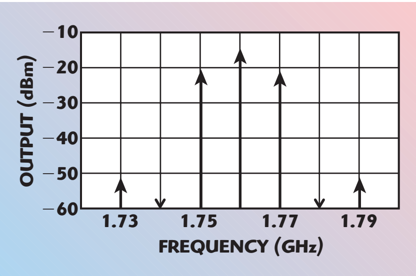


▲ *Fig. 1 Harmonic generator circuit.*



▲ *Fig. 2 Simulated output spectrum of the harmonic generator.*

ulation with even harmonic signals. The proposed linearizer consists of two parts. First, the second harmonic signals are obtained with a harmonic generator that consists of a small-signal amplifier with abnormal bias; fourth harmonic signals are also generated that suppress the second harmonic signals ($2\omega_1$, $2\omega_2$). An AM modulator then modulates the fundamental signals with the extracted even harmonic signals. Second, a vector modulator combines in-phase and quadrature-phase AM signals and the vector modulator output signals are the generated intermodulation signals. The generated IM signals are then controlled individually so that the drawbacks of a conventional linearizer, such as narrow bandwidth and small improvements of IMs, are overcome and a wide dynamic range is guaranteed.[13-15] It simply involves the creation of individual order distortions that are precisely complementary to the distortion characteristics of the power amplifier in order to ensure that the resulting system has little or no input to output distortion.

OPERATING THEORY OF THE PREDISTORTER

The harmonic generator of the proposed linearizer consists of a small amplifier with abnormal bias. The nonlinear transfer characteristics of a harmonic generator are described using a Taylor series expansion.[16] For example, the nonlinear drain and gate currents of a MESFET may be expressed as

$$i_{dsn}(t) = g_1 v_{gs}(t) + g_2 v_{gs}^2(t) + g_3 v_{gs}^3(t) \qquad (1)$$

$$i_{gsn}(t) = \frac{d}{dt}\left[C_1 v_{gs}(t) + C_2 v_{gs}^2(t) + C_3 v_{gs}^3(t)\right] \qquad (2)$$

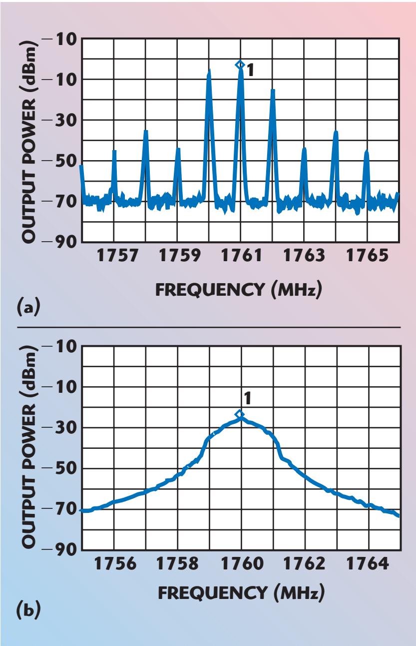
where g_n and C_n (n=1, 2, 3) are bias-dependent coefficients.

The desired signals obtained from the harmonic generator are the even harmonic signals only. Using a Volterra series representation, the second-order mixing products may be as represented as follows:

$$\begin{aligned} v_{out}(2\omega_1, 2\omega_2, \omega_1+\omega_2) = {} & \frac{1}{2} H_2(\omega_1,\omega_1)\cdot v_s^2(\omega_1) \\ & + \frac{1}{2} H_2(\omega_2,\omega_2)\cdot v_s^2(\omega_2) \qquad (3) \\ & + H_2(\omega_1,\omega_2)\cdot v_s(\omega_1)\cdot v_s(\omega_2) \end{aligned}$$

Figure 1 shows the proposed harmonic generator circuit. The harmonic generator has a voltage controller (V_{cc}) that adjusts randomly the bias of the transistor to generate only the desired second-order intermodulation products.

Figure 2 shows the simulated output of the harmonic generator after the transistor bias voltage was adjusted for two-tone signals. The simulation was performed with the ADS2003 software of Agilent Technologies. ***Figure 3*** shows the second harmonic signal measurement results in the case of CW two-tone and CDMA 1FA signals. When the two figures are compared for the two-tone case, the simulation and measured results are practically similar, proving the validity of the harmonic generator.

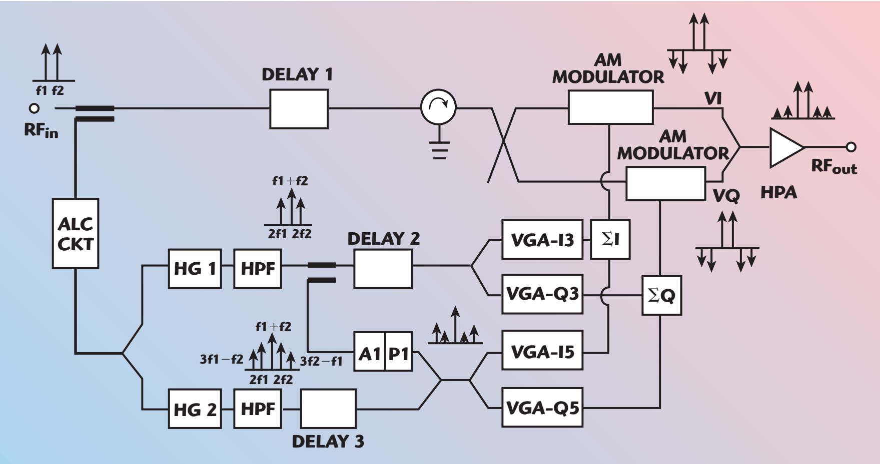


▲ *Fig. 3 Measured output spectrum of the harmonic generator (a) two-tone signal and (b) CDMA IFA signal.*

The level of the second harmonic signals ($2\omega_1$, $2\omega_2$, $\omega_1+\omega_2$) generated from the harmonic generator must be large enough to modulate the fundamental signal in the AM modulator. Variable gain amplifiers (VGA) are used to control the modulation factor.

Figure 4 shows the schematic of the proposed linearized power amplifier. The predistortion IM generator uses vector modulators (VGA) to generate the in-phase and quadrature-phase components of the AM signals. VGA-3I, VGA-3Q and VGA-5I and VGA-5Q are controlling the in-phase and quadrature-phase components of the second and fourth harmonic signals. These signals modulate the fundamental signals. Finally, the vector modulator output generates the predistortion signals. This predistorter controls simultaneously the amplitude and phase of predistortion components using VGA amplitude variation. It provides faster adjustment of phase and amplitude than is provided by a conventional controller consisting of a variable phase shifter and a variable attenuator. The automatic level control (ALC) circuit at the input port stabilizes the device by maintaining a constant IM signal, in spite of variations in the incoming power level.

The fourth-order intermodulation signals ($3\omega_1-\omega_2$, $3\omega_2-\omega_1$) can be generated by subtracting the second harmonic signals ($2\omega_1$, $2\omega_2$), obtained from HG1, from the harmonic signals of HG2. To achieve independent control of the IM products of the power amplifier, the four VGAs control the second and fourth harmonic signals. The signals ($2\omega_1$, $2\omega_2$, $\omega_1+\omega_2$) generated by HG1 under proper bias condition and the signals ($3\omega_1-\omega_2$, $3\omega_2-\omega_1$) generated by adjusting variable attenuator A_1 and phase shifter P_1, modulate the fundamental signal in the AM modulator and the vector modulator output generates the predistortion signals. Then the four VGAs are used to control the amplitude and phase of the predistorted third and fifth IM signal independently.



▲ *Fig. 4 Schematic of the proposed linearized power amplifier.*

The in-phase (I) and quadrature-phase (Q) components of the IM signals generated in the vector modulator are expressed as follows:

In-phase signals

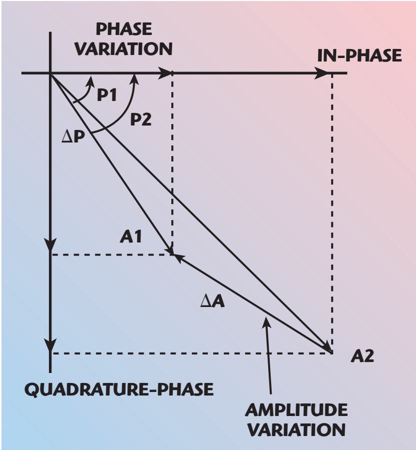
$$\begin{aligned}
V_I &= A\left[1+\alpha\cos(2\omega_1 t)+\beta\cos(2\omega_2 t)+\gamma\cos(\omega_1+\omega_2)t+\right.\\
&\left.\chi\cos(3\omega_1-\omega_2)t+\kappa\cos(3\omega_2-\omega_1)t\right]\cdot(\cos\omega_1 t+\cos\omega_2 t)=\\
&(A+0.5A\alpha+0.5A\gamma)\cos\omega_1 t+(A+0.5A\beta+0.5A\gamma)\cos\omega_2 t+\\
&0.5A(\alpha+\chi)\cos(2\omega_1-\omega_2)t+0.5A\chi\cos(3\omega_1-2\omega_2)t+\\
&0.5A(\beta+\kappa)\cos(2\omega_2-\omega_1)t+0.5\kappa\cos(3\omega_2-2\omega_1)t+\\
&(0.5A\alpha+0.5A\gamma)\cos(2\omega_1+\omega_2)t+\\
&(0.5A\beta+0.5A\gamma)\cos(2\omega_2+\omega_1)t+\\
&0.5A(\alpha+\chi)\cos 3\omega_1 t+0.5A(\beta+\kappa)\cos 3\omega_2 t+\\
&0.5A\chi\cos(4\omega_1-\omega_2)t+0.5\kappa\cos(4\omega_2-\omega_1)t \qquad (4)
\end{aligned}$$

Quadrature-phase signals

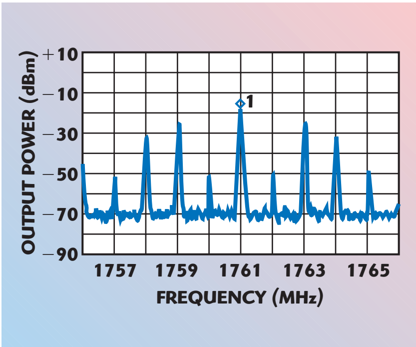
$$\begin{aligned}
V_Q &= A\left[1+\alpha\cos(2\omega_1 t)+\beta\cos(2\omega_2 t)+\gamma\cos(\omega_1+\omega_2)t+\right.\\
&\left.\chi\cos(3\omega_i-\omega_2)t+\kappa\cos(3\omega_2-\omega_1)t\right]\cdot(\sin\omega_1 t+\sin\omega_2 t)=\\
&(A-0.5A\alpha-0.5A\gamma)\sin\omega_1 t+(A-0.5A\beta-0.5A\gamma)\sin\omega_2 t-\\
&0.5A(\alpha+\chi)\sin(2\omega_1-\omega_2)t-0.5A\chi\sin(3\omega_1-2\omega_2)t-\\
&0.5A(\beta+\kappa)\sin(2\omega_2-\omega_1)t-0.5A\kappa\sin(3\omega_2-2\omega_1)t+\\
&(0.5A\alpha+0.5A\gamma)\sin(2\omega_1+\omega_2)t+\\
&(0.5A\beta+0.5A\gamma)\sin(2\omega_2+\omega_1)t+\\
&0.5A(\alpha+\chi)\sin 3\omega_1 t+0.5A(\beta+\kappa)\sin 3\omega_2 t+\\
&0.5A\chi\sin(4\omega_1-\omega_2)t+0.5A\kappa\sin(4\omega_2-\omega_1)t \qquad (5)
\end{aligned}$$

where A = amplitude of CW two-tone
α = amplitude of $2\omega_1$ signal among second harmonic signals
β = amplitude of $2\omega_2$ signal among second harmonic signals
γ = amplitude of ($\omega_1+\omega_2$) signal among second harmonic signals
χ = amplitude of ($3\omega_1-\omega_2$) signal among fourth harmonic signals
κ = amplitude of ($3\omega_2-\omega_1$) signal among fourth harmonic signals

The second- and fourth-order harmonic signals generated in the proposed harmonic generator are transferred to the predistortion IM3 and IM5 signals of the power amplifier to modulate the fundamental signals. By only changing the amplitude of the even harmonic signals, the phase and amplitude of the predistortion IM3 and IM5 components are controlled. ***Figure 5*** shows that when the even harmonic signals are changed in amplitude by the modulation factor, the predistortion signals are changed in amplitude and phase simultaneously.



▲ *Fig. 5 Amplitude and phase variations of the modulated signals.*



▲ *Fig. 6 Extraction of the 4th harmonic signals.*

EXPERIMENTAL RESULTS

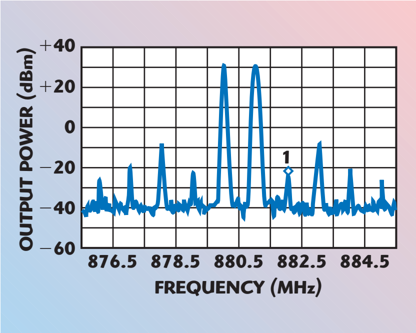
The linearizer was evaluated with a HPA made of a series connection of a Watkins Johnson AH1 and a Motorola MHL 9838 amplifier, for which the gain and P1dB are 43 dB and 37 dBm, respectively.

The signal components at $2\omega_1$, $2\omega_2$ and $3\omega_1-\omega_2$, $3\omega_2-\omega_1$ can be independently adjusted. Due to the fact that they are closely spaced to each other, they cannot be separated using a filtering technique. As a result, the sig-

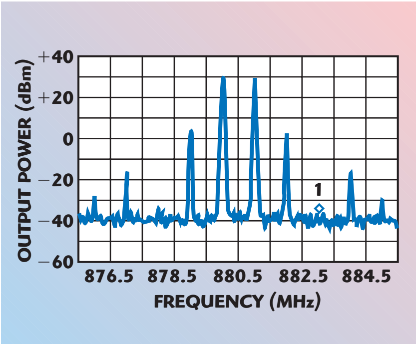
nal components can be separated using an arithmetic operation. For optimal operation, HG1 is biased at 1.2 V and HG2 at 1.9 V. By adjusting the variable attenuator A_1 and the phase shifter P_1, the frequency components at $3\omega_1-\omega_2$ and $3\omega_2-\omega_1$ are extracted at the output of the combiner. The corresponding spectrum is shown in ***Figure 6***. The input frequencies are 880 and 881 MHz with a frequency spacing of 1 MHz. The delay circuits are made of coaxial delay lines that are approximately 14.7 ns for Delay 1, 4.8 ns for Delay 2 and 2.2 ns for Delay 3.

Figure 7 shows the measured IMD performance obtained by setting VGA-5I and VGA-5Q to minimum gain. In this case, it is observed that only the third-order IMD components are suppressed. The input frequencies are 880 and 881 MHz with a frequency spacing of 1 MHz and the output power is 30.7 dBm per tone. It shows that IMD3 is cancelled out by 27 dB.

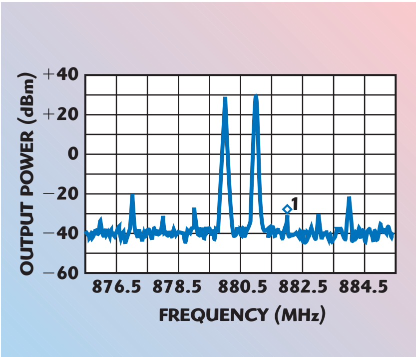
As shown in ***Figure 8***, the IMD5 components can be perfectly reduced while IMD3 is unchanged by setting VGA-3I and VGA-3Q to minimum gain and adjusting VGA-5I and VGA-5Q correctly. It shows that IMD5 is cancelled by 29 dB. Simultaneous suppression of IMD3 and IMD5 is shown in ***Figure 9***. It can be seen that both IMD3 and IMD5 are cancelled by 25 dB. ***Figure 10*** shows the IS-95 CDMA 4FA results. The test frequencies are 876.25, 878.75, 881.25, 883.75 MHz and the fre-



▲ *Fig. 7 Two-tone test with cancellation of IMD3 only.*



▲ *Fig. 8 Two-tone test with cancellation of IMD5 only.*



▲ *Fig. 9 Two-tone test with simultaneous cancellation of IMD3 and IMD5.*

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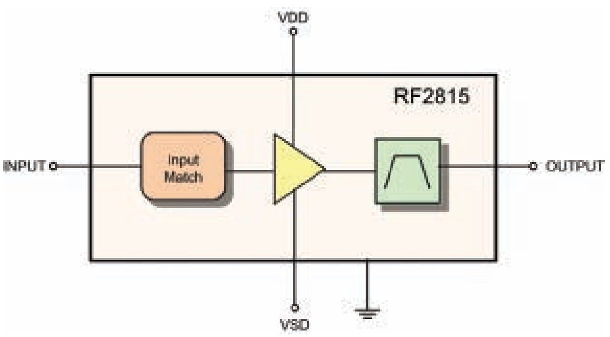
SPECIFICATIONS

Parameter	*High Current Mode*	*Low Current Mode*	*Low Operating Voltages* V_{DD} = 2 V	V_{DD} = 1.5 V	V_{DD} = 1 V	Unit
Gain (G)	13.5	12.5	14	13.5	11.5	dB
Noise Figure (NF)*	0.85	0.95	0.85	0.95	1.1	dB
Input P1 dB Compressed Power (IP1 dB)	-3	-3	-2	-4	-6	dBm
Input 3rd Order Intercept Point (2-tone at fc+/- 2.5 MHz)	8	6	10	7.5	3	dBm
Input Return Loss (S11)	-8	-7	-9	-8	-7	dB
Output Return Loss (S22)	-13	-11	-13.5	-12.5	-11	dB
Reverse Isolation (S12)	-24	-24	-24	-24	-22	dB
Cell Band Rejection (Relative to 1575 MHz at 827.5 MHz)	54	55	52	52	52	dBc
PCS Band Rejection (Relative to 1575 MHz at 1885 MHz)	45	44	45	45	45	dBc
R2	3 K	3 K	1.5 K	1.5 K	1.5 K	ohms
VSD	2.6 V	1.67 V	2 V	1.5 V	1 V	V
DC Supply Current at Shutdown (SD) Voltage VSD = 2.85 V (IDD)	8	4.5	10.5	7.3	4	mA
ISH (Shutdown Current)	0.1	0.1	0.1	0.1	0.1	uA

*Noise Figure Data has not been de-embedded



FEATURES

- Low noise figure: 0.85 dB (Typ)
- High gain: 13.5 dB (Typ)
- High IIP3: +8 dBm (Typ)
- Operable over wide supply voltage range: 1 V to 3.6 V
- CMOS compatible shutdown function (<0.1 uA)
- Current tunable via single resistor
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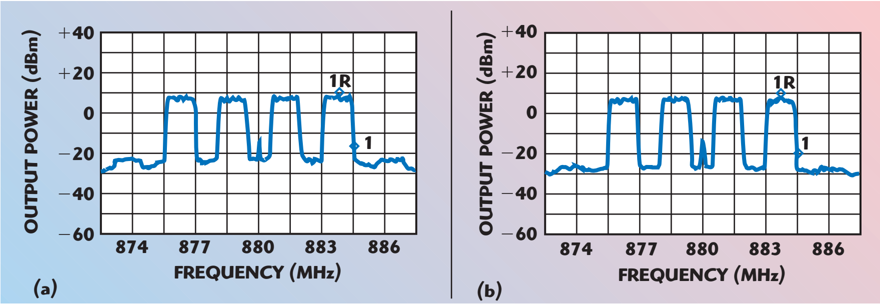
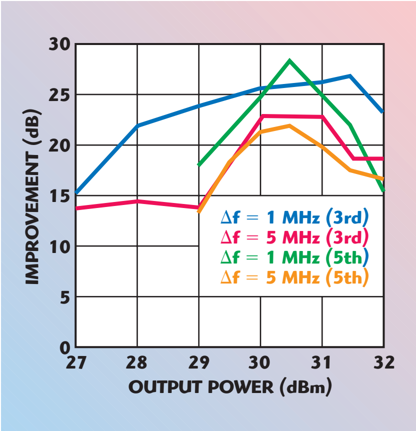


▲ *Fig. 10 Output spectrum of the HPA at 24 dBm/FA (a) without linearizer and (b) with linearizer for IS-95 CDMA 4FA signals.*



▲ *Fig. 11 Improvements of IMD3 and IMD5 vs. output power for a two-tone signal.*

quency bandwidth is 8.75 MHz. The test signal generator used is the ESG4433B from Agilent Technologies. Something like carrier leakage was observed for this equipment at the center frequency. ***Figure 11*** shows the IMD3 and IMD5 improvements for an output power range from 27 to 32 dBm in the case of two-tone signals.

CONCLUSION

A novel amplifier linearization scheme, based on the even-order harmonic signals, has been proposed. The harmonic generator extracts the second and fourth harmonic signals and modulates the fundamental signal with the extracted harmonic signals with an AM modulator. Hence, the amplitude and phase of the predistortion signals are easily controlled simultaneously because the vector modulator consists of in-phase and quadrature-phase components, and its performance reduces the effort of retuning the attenuators and the phase shifters. In the experiments, simultaneous cancellation of IMD3 and IMD5 has been demonstrated with a reduction factor of more than 25 dB. Also, good IM cancellation characteristics are obtained for a wide dynamic range and different kinds of signals. If an adaptive controller is attached in the proposed linearizer, it is expected that the proposed predistortion method may be applied to many kinds of power amplifiers. ■

ACKNOWLEDGMENT

This paper was supported by the Research Fund, Kumoh National In-

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UNDERSTANDING NOISE PARAMETER MEASUREMENT

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This application note reviews noise parameter measurements used to characterize transistors and amplifiers at Modelithics Inc. Noise figure and noise parameter theory is reviewed briefly following with a description of the basic test instrumentation setup and calibration procedures used for noise parameter measurements along with an example.

DEFINITIONS AND THEORY

The formulations in this note were derived from multiple sources.[1-3] The noise figure F of a device or component is described by the following relations:

$$F = \frac{S_{in}/N_{in}}{S_{out}/N_{out}} \text{(always > 1)}$$

$$= 1 + \frac{N_a}{GN_{in}} \text{ with } N_{in} = kT_0B \; (T_0 = 290^\circ K) \quad (1)$$

$$\text{Noise Figure (dB)} = NF(dB) = 10\log(F) \quad (2)$$

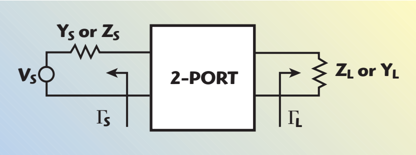
where S_{in} (N_{in}) and S_{out} (N_{out}) are the signal (noise) levels at the input and output of the device, respectively, and N_a is the noise added by the device itself, G is the gain of the device, B is the system bandwidth and k is Boltzman's constant (1.38 x 10^{-23}). Noise figure is of particular interest to receiver designers as the degradation in the minimum detectable signal can be estimated as:

$$MDS(dBm) = -174 + 10Log(B) + NF(dB) + \text{Required } SNR_{dB} \quad (3)$$

This approximation assumes the background or ambient (= kTB) noise is that due to a passive device held at T=290°K, and the required SNR_{dB} represents the minimum signal to noise ratio for acceptable system performance.

The noise parameters describe how the noise figure varies with the source impedance Z_s, the source admittance Y_s, or the source reflection coefficient Γ_s. Consider ***Figure 1***. There are various formulations for noise fig-

LAWRENCE P. DUNLEAVY
Modelithics Inc., Tampa, FL



▲ *Fig. 1 Basic two-port device configuration.*

ure in terms of noise parameters. Some of the popular forms are summarized in Equations 4 through 7.

$$F = F_{min} + \frac{R_n}{G_s}\left[(G_s - G_{on})^2 + (B_s - B_{on})^2\right]$$

4 Noise Parameters:
R_n: Equivalent Noise Reduction
F_{min}: Minimum Noise Figure
G_{on}: Optimum Noise Susceptance
B_{on}: Optimum Noise Susceptance

$$Y_{sopt} = G_{on} + jB_{on} \quad (4)$$

$$F = F_{min} + \frac{G_n}{R_s}\left[\left|(Z_s - Z_{sopt})\right|^2\right]$$

4 Noise Parameters:
G_n: Equivalent Noise Conductance
F_{min}: Minimum Noise Figure
R_{on}: Optimum Noise Resistance
X_{on}: Optimum Noise Reactance

$$Z_{sopt} = R_{on} + jX_{on} \quad (5)$$

$$F = F_{min} + \frac{4R_n}{Z_0}\,\frac{\left[\left|(\Gamma_s - \Gamma_{sopt})\right|^2\right]}{(1 - |\Gamma_s|^2)\left|1 + \Gamma_{sopt}\right|^2}$$

4 Noise Parameters:
R_n: Equivalent Noise Resistance
F_{min}: Minimum Noise Figure
$|\Gamma_{sopt}|$: Magnitude of Optimum Noise Reflection
$\angle\Gamma_{sopt}$: Phase of Optimum Noise Reflection

$$\Gamma_{sopt} = |\Gamma_{sopt}|\angle\Gamma_{sopt} \quad (6)$$

$$F = F_{min} + \frac{N}{\mathrm{Re}(Y_{sopt})}\,\frac{\left[\left|(Y_s - Y_{sopt})\right|^2\right]}{\mathrm{Re}(Y_s)}$$

4 Noise Parameters:
N: Terminal Invariant Constant
F_{min}: Minimum Noise Figure
G_{on}: Optimum Conductance
B_{on}: Optimum Noise Susceptance

$$Y_{sopt} = G_{on} + jB_{on}$$

$$N = \left[F(Y_0) - F_{min}\right]\frac{1 - |\Gamma_{sopt}|^2}{4|\Gamma_{sopt}|^2} \quad (7)$$

All of the above forms provide a description of noise figure in terms of four (4) noise parameters and the source impedance, admittance or reflection coefficient, depending on the form used. One common parameter is the minimum noise figure F_{min}, which will be achieved at some specific optimum (complex) impedance (Z_{opt}), admittance (Y_{opt}) or reflection coefficient (Γ_{opt}). Therefore, in addition to F_{min}, two of the other parameters are either the real and imaginary (or magnitude and angle) of Z_{opt}, Y_{opt}, or Γ_{opt}, with the fourth parameter being the equivalent noise resistance R_n, noise conductance G_n or the terminal invariant parameter N depending on the formulation. The term terminal invariant implies that N is invariant to a transformation through a lossless passive network, that is a reference plane change. It should also be noted that there are other noise parameter formulations in addition to those listed in Equations 4 through 7.

One of the common applications of noise parameters is for low noise amplifier (LNA) design. Typically an LNA is used at the front-end of a receiver to improve the noise figure of the receiver or essentially boost the signal, while adding a low amount of noise to the signal. In addition to its noise figure, the gain of the LNA (and correspondingly the transistors used to make up the LNA) is also important. To better understand this, the following equation can be used to calculate the total noise figure of a cascade connection of three different two-port devices with gains G_i and noise figure F_i (I = 1, 2, 3).

$$F_{TOT} = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2} \quad (8)$$

If an LNA, with high gain G_1 and low noise figure F_1, is the first device, then the system noise figure F_{TOT} can remain low even if the second and third devices have a much higher noise figure.

The gain used in most noise calculations, including the cascade noise figure (Equation 8), is the available gain, which can be expressed in terms of S-parameters as follows:

$$G_A = \frac{|S_{21}|^2(1 - |\Gamma_s|^2)}{|1 - S_{11}\Gamma_s|^2(1 - |S_{22}|^2)} \quad (9)$$

The available gain assumes that the load port is terminated in a conjugate match for a given source reflection coefficient Γ_s. The associated gain is often tabulated along with noise parameters and is simply the available gain from Equation 9 for the particular case of $\Gamma_s = \Gamma_{sopt}$.

$$G_{ASSOC} = \frac{|S_{21}|^2(1 - |\Gamma_{sopt}|^2)}{|1 - S_{11}\Gamma_{sopt}|^2(1 - |S_{22}|^2)} \quad (10)$$

Another set of parameters often plotted are the maximum stable gain, MSG, and maximum available gain, MAG. Often, amplifiers or transistors are unconditionally stable over a certain frequency range and conditionally stable at other frequencies. For frequencies where the device is potentially unstable (with stability factor K<1), the maximum stable gain is defined as the highest realizable gain with passive terminations, after the device is stabilized with cascaded resistance to border line stability; that is to bring about the condition K=1. MSG is given by:

$$MSG = \frac{|S_{21}|}{|S_{12}|} \quad (11)$$

The maximum available gain at frequencies where K>1 (unconditionally stable) is given by:

$$MAG = \frac{|S_{21}|}{|S_{12}|}\left(K - \sqrt{(K^2 - 1)}\right) \quad (12)$$

Hence, MSG and MAG numbers in decibels give the amplifier designer a measure of the maximum gain realizable through impedance matching of the amplifier or transistor. Of course the conditions for matching the input for maximum gain and minimum noise figure may be conflicting and a trade-off between these two may be required. While outside the scope of this note, the plotting of noise figure circles and available gain circles can often be used to aid the designer in choosing the best compro-

mise in matching impedance taking noise and gain into consideration.[2]

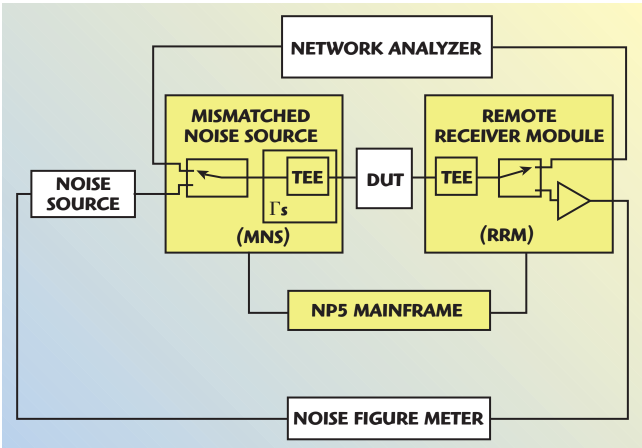
TEST CONFIGURATION AND CALIBRATION

A basic test configuration, used to perform combined noise parameter and S-parameter testing, is shown in ***Figure 2***. The network analyzer is needed to perform S-parameters of the DUT, which are required for design analysis along with the noise parameters. The network analyzer is also needed to make measurements that are required for calibration of the noise parameter test system.

This test system is referred to as an "NP5" system from Maury Microwave[4] and uses a hardware setup and measurement method originally developed by Adamian[5] and commercialized by ATN Microwave. The system consists of a noise figure measurement system (such as HP 8971C/HP8970B combination or alternative), a network analyzer (such as HP8510C or alternative), a mismatched noise source (MNS) and a remote receiver module (RRM). The MNS and RRM each contain a switch that is used to select either the S-parameter measurement mode or the noise parameter measurement mode. They each also contain a bias tee for applying bias to the input and output of the device under test (DUT). The MNS is generally a solid-state tuner capable of presenting multiple different values of Γ_s to the DUT, along with the ability to have a "50 Ω" thru state that allows the noise source to be connected to the DUT through essentially a transmission line. With the RRM switch in the noise measurement position, the RRM includes a low noise amplifier in the path to the noise receiver to improve the measurement receiver noise figure.

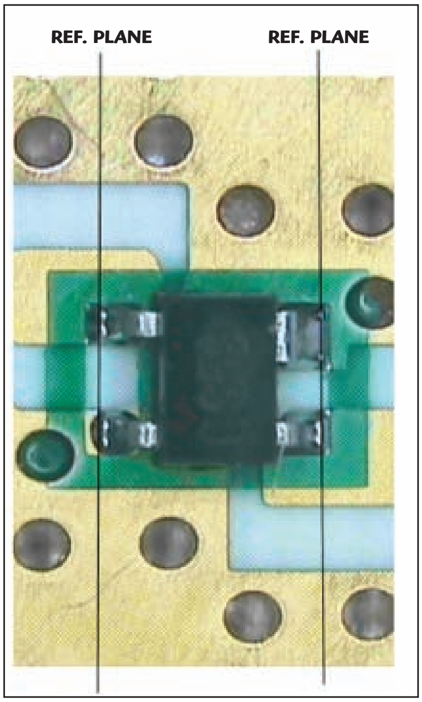
In the S-parameter measurement mode the system is calibrated using thru-reflect-line (TRL) or alternative high accuracy calibration approaches.[6,7] To calibrate and operate the noise parameter measurement system, the Maury ATS software[4] is used to perform a series of steps that may be summarized as follows:

1. Perform a two-port S-parameter calibration to establish measurement reference planes at the input and output of the DUT. Store these calibration coefficients in a selected calibration kit file.
2. Perform a one-port short-open-load S-parameter calibration at the position of the noise source, with a thru device connected in place of the DUT. Store these calibration coefficients in a second selected calibration kit file.
3. Calculate the S-parameters of the MNS thru path from the noise source to the DUT. The Maury ATS software does this automatically using the calibration information from steps 1 and 2; it also measures the noise source reflection coefficient in the hot/biased on state and the cold/biased off state.
4. Perform a tuner characterization. The software uses the calibration information from step 1 to measure and store hundreds of different Γ_s values that can be presented at each frequency to the DUT by the MNS during subsequent measurements.
5. Perform a noise calibration. With a thru connected in place of the DUT and the system switches set to noise measurement position, the ATS software controls the instruments to record the received noise power for the MNS thru state with the noise source diode biased on and off, and for



▲ *Fig. 2 Maury Microwave "NPS" noise and S-parameter test systems.[4]*

several different Γ_s values achieved with the MNS for the case of the diode biased off.

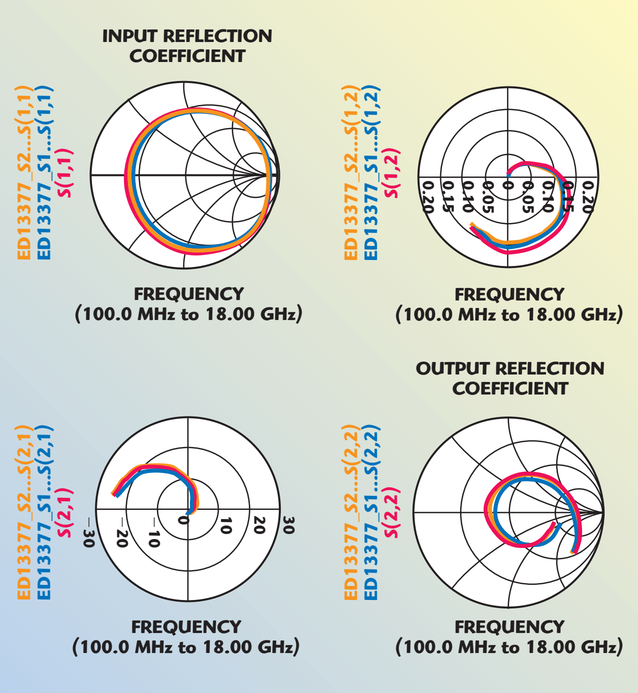


▲ *Fig. 3 Photograph of a mounted SAV series device showing reference planes.*

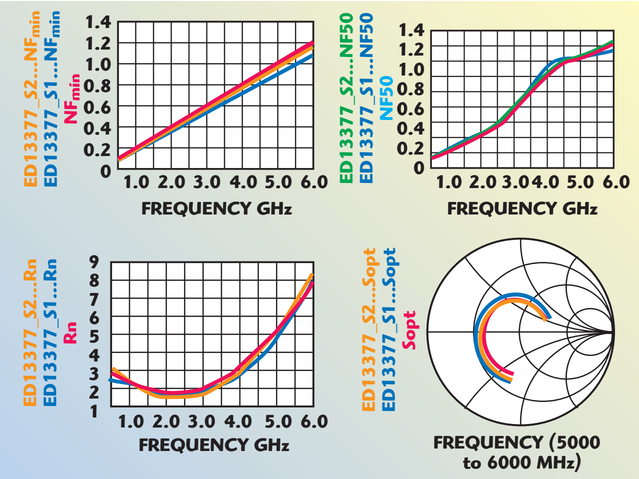
6. The ATS software utilizes the information from the previous steps along with the algorithm developed by Adamian[5] to calculate and store the noise parameters of the receiver along with other system information.
7. Once calibration is complete, the DUT is connected and the S-parameters and noise parameters of the DUT are measured in sequence (usually S-parameters, then noise parameters). Post processing and noise parameter data smoothing is sometimes needed and is provided for in the Maury ATS software.

EXAMPLE RESULTS

In the following, the data taken on samples from the Mini-Circuits SAV amplifier series will be used. ***Figure 3***



▲ *Fig. 4 S-parameters for three samples SAV-581+ from 0.1 to 18 GHz with V_{ds} = 2 V and I_d = 4D mA.*



▲ *Fig. 5 Noise parameters measured on SAV-581+ devices from 0.5 to 6 GHz, with V_d = 2 V and I_d = 40 mA.*

shows the picture of a device sample as mounted in a coplanar waveguide test fixture setup for RF wafer probe testing. TRL standards, fabricated with the same ground-signal-ground test interface, were used along with the NIST Multical method[6] to establish the measurement reference planes at the locations indicated. These same reference planes were established for noise parameter measurements using Maury ATS software. ***Figure 4*** shows examples of S-parameter measurement results, made on three test samples SAV-581+, using HP8510B with a TRL calibration, from 0.1 to 18 GHz. ***Figure 5*** shows the noise parameters measured on SAV-581+ devices from 0.5 to 6 GHz. Clockwise, from upper left, are the minimum noise figure, F_{min} (dB), the 50 Ω noise figure F_{50} (dB), Γ_{sopt} and equivalent noise resistance R_n. ■

ACKNOWLEDGMENTS

This note was assembled under collaboration and encouragement from Mini-Circuits with information and assistance provided by Maury Microwave. Modelithics engineers Rick Connick, Bryan Lee and Hugo Morales assisted with the measurement examples provided here.

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COMPANIES IN TRANSITION

THIS MONTH ONLINE, WE TALK INDIVIDUALLY TO PRESIDENT DESIGNATE JEREMY WENSINGER OF COBHAM DEFENSE ELECTRONIC SYSTEMS AND PRESIDENT JOE THOMAS OF M/A-COM TECHNOLOGY SOLUTIONS TO LEARN WHAT'S NEXT FOR THESE TWO COMPANIES.

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In this article we offer a brief look into the past of two companies whose long history in developing microwave technology and defense systems eventually brought them together. From humble beginnings, Cobham plc and M/A-COM grew, achieved industry leadership status and weathered decades of economic change through their innovations and strategic acquisitions. This past year, Cobham acquired M/A-COM's component businesses (from Tyco Electronics) to further its position as a premier supplier of defense subsystems. The commercial segment, now called M/A-COM Technology Solutions, will be spun-off as an independent company. The *Journal* has covered M/A-COM at critical stages in its history with guest editorials by president Dana Atchley appearing in our first issue (July/August 1958), co-founder and vice-president Richard Walker writing about the company's shifted focus to MIC technology (January 1968), president Frank Brand writing about the company's embrace of MMIC and GaAs technologies (February 1978) and CEO Thomas Vanderslice writing on the re-structuring of the company to apply its core strengths toward both the defense and commercial markets (March 1990). M/A-COM's dedication to R&D will serve both companies well.

Cobham began as an aerospace job shop in the UK and has grown to become a vital link in many of the world's most advanced military and civil aerospace programs. In 1927, Alan Cobham, a well-known aeronautical adventurer and collaborator with aircraft manufacturer Geoffrey de Havilland, formed his own company—Alan Cobham Aviation Ltd. The company soon merged with others in the interest of developing intercontinental "flying boat" service. The focus on long-haul flight led to their developing and purveying in-flight refueling technology, eventually working with the British government during World War II. At that time, the company was called the (Flight Refueling) FR Group. After the war, the US government expressed interest in using aerial refueling to extend the range of its B-29 bombers, and FR Group landed the contract.

DAVID VYE
Editor, Microwave Journal

In the summer of 1950, engineers Vessarios Chigas, Louis Roberts, Hugh Wainwright and Richard M. Walker founded Microwave Associates in 2800 square feet of rented floor space in Boston, MA. Leveraging their experience working at the MIT Radiation Laboratory during World War II, their plan was to provide microwave consulting, R&D and to establish a line of millimeter-wave components. In the first year, the company did R&D work for the US Army Signal Corps, including circular waveguide elements and shortly entered the electron tube field, winning a contract for two magnetron types from the Signal Corps. In its first year of business, the company did $80,000 worth of business according to the company profile that appeared in the third issue of *Microwave Journal* (January 1959). When the article was published, the company had surpassed the $5 M per year mark.

In the 1960s, as defense work was drying up in the UK, Cobham (FR Group) diversified and began marketing a switch from its fueling systems and thus entered the electronics field. As the aerospace industry heated up again and several R&D projects came to fruition in the mid to late 1970s, the company geared up for rapid growth among its three divisions: nuclear and industrial business; military systems; and aerospace components. However, the company's electronics operation struggled among the commercial electronics industry's fast pace growth. Nuclear plant components also suffered due to inconsistent government policies and so the company shifted its efforts toward defense. By 1980, the flight operations division expanded its range of services beyond aerial towing and achieved profits of £3 M on turnover of £19 M despite defense cut-backs. Aerospace components accounted for 40 percent of turnover; military systems, approximately 30 percent.

Meanwhile in the US, Microwave Associates, through heavy investment in research and development throughout the 1960s and 1970s, established itself as a leader in developing and manufacturing RF, microwave and millimeter-wave semiconductors, components and technologies. The advanced R&D allowed M/A-COM to be among the first microwave companies to make the jump from waveguide-based components to MIC and MMIC technology. By 1978, the company changed its name to M/A-COM Inc. to represent its move into the communications market. By 1980 through its various operating companies, M/A-COM was among the world's leading producers of microwave components for the defense and commercial telecommunications markets.

By the early 1980s, Cobham (still known as the FR Group) entered the US components market with the purchase of Stanley Aviation and Chelton, a leading maker of aircraft antennas, in 1989. Its aerial target offerings proliferated, culminating in the Advanced Subsonic Aerial Target (ASAT) system. It also pushed its military products abroad while searching for new opportunities and the group continued to buy businesses that would help this growth. The company's presence in the US grew through these acquisitions and by teaming up with key US defense contractors. Successful equipment deployments in both the Falkland and Gulf Wars helped secure Cobham's status among defense prime contractors and those responsible for military procurement. The trend in


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the aircraft industry was for prime contractors to outsource ever larger assemblies to vendors and so the FR Group directed much of its efforts towards upgrades and upgradeable products, winning significant defense contracts in the mid to late 1990s. With its operations expanded far beyond its flight refueling core, FR Group renamed itself Cobham plc in November 1994.

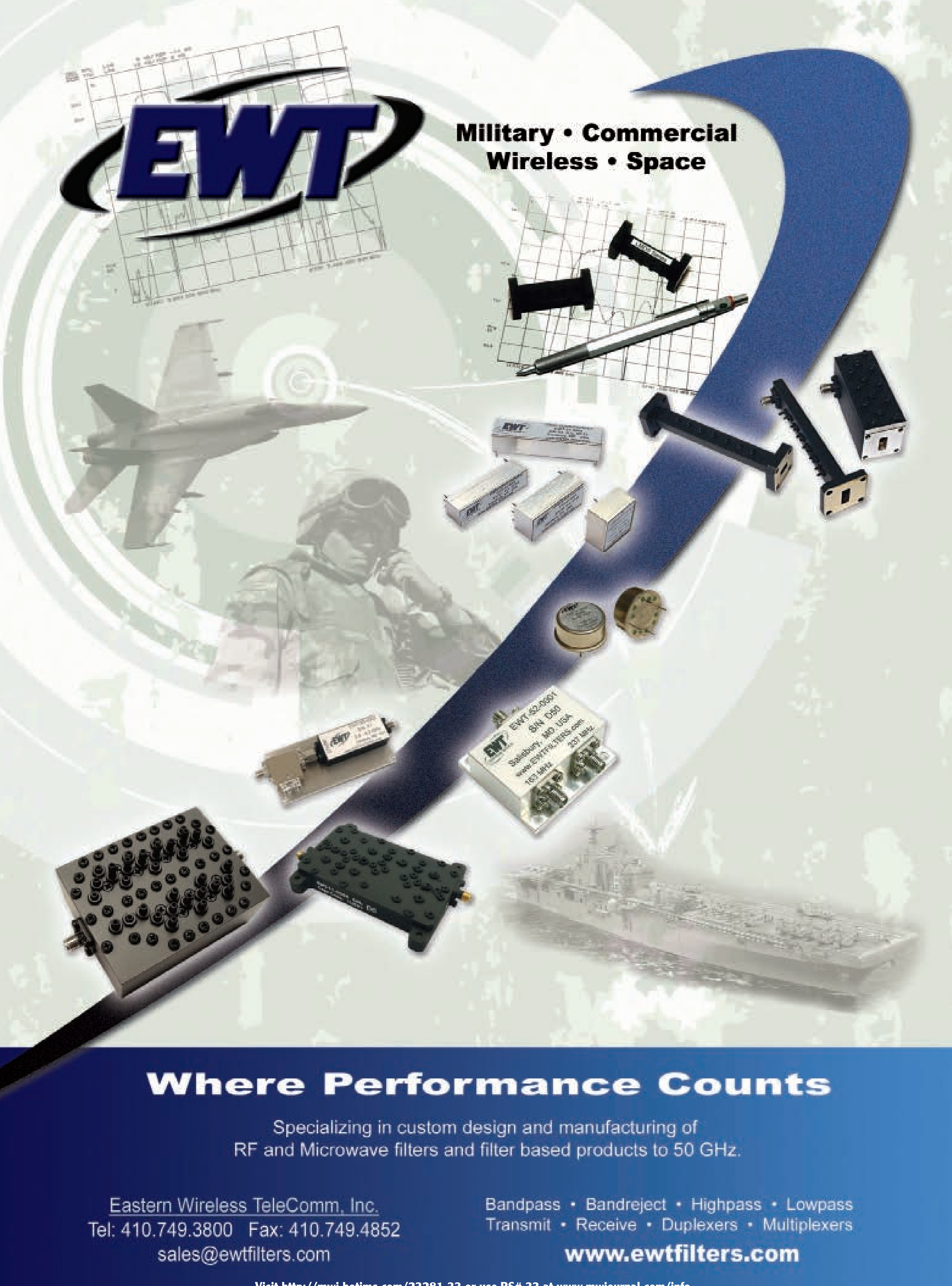
In 1995, M/A-COM was acquired by AMP Inc., a leader in electrical and electronic connection devices and interconnection systems, as part of that company's move into the wireless interconnection components market and to strengthen its subsystems development capabilities. Then in 1999, AMP merged with Tyco International Ltd. As a unit of Tyco Electronics, M/A-COM would continue to serve the wireless telecommunications, aerospace, defense and automotive markets.

Meanwhile, Cobham continued its growth through acquisition, buying Pressure Technologies, Conax, Hyper Technologies and certain product lines from Avionics Controls, while the Chelton division bought several radio product lines from Allied Signal and Cobham bought two other English firms: Credowan Limited, a small microwave components supplier, and the larger European Antennas Limited.

In this decade, the size of Cobham's acquisitions has grown impressively large. In 2004, Cobham purchased REMEC Defense & Space to double the revenues from its radar business and boost its Chelton business. In 2007, the company purchased the Surveillance and Attack business unit of BAE Systems, which it renamed Sensor and Antenna Systems, Lansdale Inc. (after the unit's Lansdale, PA location). Lansdale is now a world leading developer of Electronic Warfare (EW) technology and supplier of EW subsystems for military aircraft.

Last May, Cobham Defense Electronics Systems (CDES) announced that it was buying Tyco Electronics' Aerospace & Defense and Commercial products businesses. Combining M/A-COM's technology with Cobham's REMEC business would give the company the additional microwave technical expertise, enhanced subsystem capability and strong customer relationships required to accelerate development of its advanced products for microwave front-ends for missiles, electronic warfare, and space and ground-based communication systems. The commercial part of the business, M/A-COM Technology Solutions, is currently being run outside of the operating divisions of Cobham and will be resold. The acquired commercial business is operating on a standalone basis with shared facilities and functions separated to allow for the divestment of M/A-COM Technology Solutions (Tyco Electronics retained the M/A-COM land mobile radio group and sold the automotive sensors group to Autoliv of Sweden). ■

Please see pg. 108 to read "DC to 6 GHz 50 W T/R Switch for High Linearity Applications," a Product Feature from M/A-COM Technology Solutions Inc.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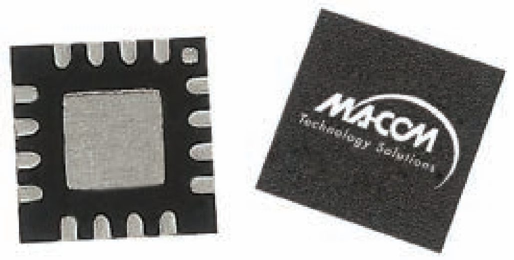

DC TO 6 GHZ 50 W T/R SWITCH FOR HIGH LINEARITY APPLICATIONS

EXECUTIVE INTERVIEW SERIES

MWJ SPEAKS WITH JOE THOMAS, M/A-COM TECHNOLOGY SOLUTIONS INC.

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RF performance and thermal reliability are the two important parameters when selecting an RF Tx/Rx switch at the front end of a high power linear base station, CPE, or femtocell. As always, the RF performance is very critical. Parameters such as insertion loss, isolation, P1dB, IP3, switching speed, bandwidth and VSWR are important to the system designer. These linear systems exceed power levels beyond 10 W of average power, which pushes the designer to consider the switch's thermal properties early in the decision making process. For example, a 10 W signal incident on a switch with 1 dB of insertion loss at 3.5 GHz will require the switch to handle 2 W of power dissipation. The maximum junction temperature of the device could be violated and the lifetime reliability of the component could be compromised if this isn't taken into consideration. The fundamental limitation of power handling at any frequency is ultimately thermal. This is true for both long-term reliability and short-term catastrophic failures.

Linear TDMA systems such as WiMAX and TD-SCDMA use modulation schemes that create very high peak-to-average ratios on the RF power signal. This ratio can be as high as 12 dB specifically for WiMAX systems. This needs to be considered for both the linear performance of the switch as well as the thermal reliability. The 1 dB compression point (P1dB) of a switch only provides a rough guideline as to the true linearity of the switch in this type of linear system. The delta between the switch's P1dB and its Error Vector Magnitude (EVM) at 1 percent can be anywhere between 8 and 12 dB depending on the topology of the switch.

Critical parameters for a higher power Tx/Rx switch include lower insertion loss, especially on the Tx path in order to minimize the requirements of the power amplifier. High isolation in the switch is just as critical since excess leakage from Tx to Rx will saturate the LNA. M/A-COM Technology Solutions has developed a monolithic PIN diode-based SPDT, the MASW-000834-13560T, on its Heterolithic Microwave Integrated Circuit (HMIC) technology to address both the RF and thermal needs of these linear systems. HMIC is the ultimate form of SOI, which has a unique thermal design that provides the ability to both handle > 1000 W of pulsed peak and up to 50 W of CW RF incident transmit power, while simultaneously providing very low RF distortion, excellent linearity and high receive isolation. This results in high

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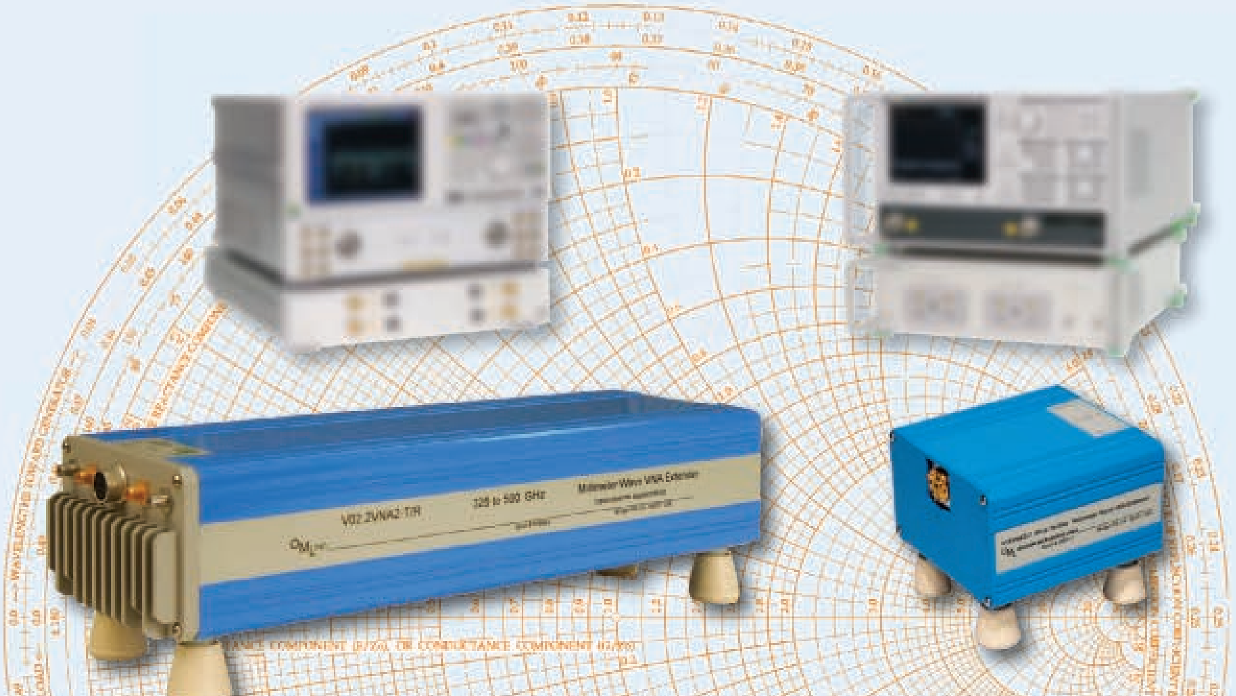

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HMIC is a unique process that combines glass and silicon that enables the high frequency and high power handling properties of the two materials to be optimized plus provides true surface-mount device structures to be produced using standard semiconductor processing equipment and techniques. It also allows for the integration of high Q (or low loss) passives as well as low Rs (series resistance) active elements in order to create more complex components. This allows for smaller size components like the MASW-000834-13560T with low loss and high power handling. In addition, the monolithic insertion of various diode-based active components such as PIN diodes and Schottky diodes in the HMIC circuit topology allows a number of more complex monolithic integrated circuits to be realized.

A cross-section for both passive and diode-based HMIC devices is shown in ***Figure 1***, which shows the elements needed for HMIC circuit design. Silicon vias to achieve vertical connections (i.e. front to back) are a natural consequence of the HMIC fabrication process. The top surface of these vias typically serves as the "active" layer for the formation of the required diode-based active devices and as possible interconnection paths for the requisite passive elements. The various circuit elements, either active or passive, are then laterally linked using standard photolithography and metallization techniques.

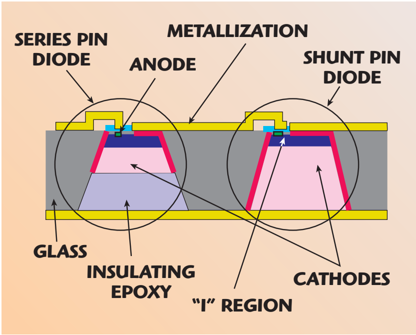
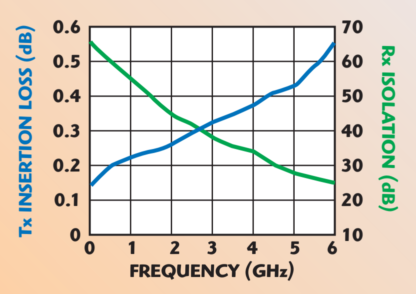


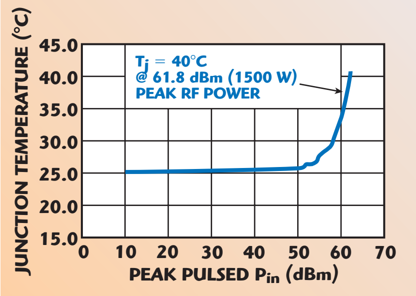
Fig. 1 Cross-section of the HMIC device.

The shunt diode has the highest power handling since it has a very high thermal conductivity from the surface to ground. The series diode, by contrast, is always the weaker thermal link in the design since it has the lowest thermal conductivity. The thermal analysis needs to focus on improving the thermal properties of the series diode in order to increase its power handling capacity. Although the series diode is electrically in series, it needs to focus on its thermal shunt cross-section. One area specifically focused on is the insulating epoxy under the series diode. Optimizing the thickness of the boron filled, electrically insulating thermal epoxy between the cathode and bottom metallization offers the best compromise between electrical insulator, thermal conductivity and manufacturability, which M/A-COM Technology Solutions has optimized over many years of experience.

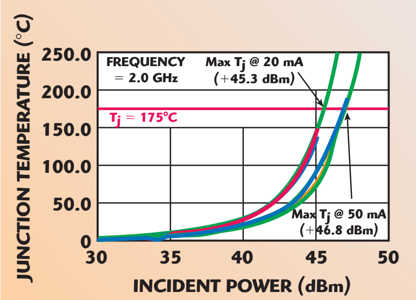
HMIC allows for broader band operating frequency and lower parasitics while operating at high power levels than traditional devices, as shown in ***Figure 2***. For instance, the MASW-000834-13560T achieves 0.3 dB insertion loss and over 40 dB of Rx isolation at 2.5 GHz while handling power levels up to 50 W of CW power without degradation of the basic PIN diode junction parametric characteristics.



▲ *Fig. 2 MASW-000834-13560T broadband performance.*



▲ *Fig. 3 MASW-000834-13560T junction temperature vs. peak pulsed input power (50 µsec pulse width, 1% duty cycle).*



▲ *Fig. 4 MASW-000834-13560T junction temperature vs. CW input power.*

In terms of the pulsed Tx power handling, the use of the boron filled epoxy, larger vertically etched silicon pedestals, and optimized anode topology design allows for significant power handling, as shown in ***Figure 3***, which is a plot of measured junction temperature versus pulsed input power at 50 µsec pulse widths and at a 1 percent duty cycle. A peak incident power level of +61.8 dBm, approximately 1500 W, in the Tx mode results in a junction temperature of 40°C, which is a 15°C rise over ambient, and well below a safe maximum operating temperature of 175°C.

When the Tx arm of the MASW-000834-13560T SPDT is operated in CW mode, ***Figure 4*** shows that a maximum safe junction temperature of 175°C is reached at an incident drive level of +46.8 dBm or 47.8 W at an ambient heat sink temperature of 25°C. This HMIC design out performs other traditional designs by a wide margin and can be used in commercial and military applications.

CONCLUSION

M/A-COM Technology Solutions has developed a high power PIN diode-based Tx/Rx switch, the MASW-000834-13560T, capable of simultaneously delivering broadband performance (DC to 6 GHz) while reliably handling high power levels utilizing the patented HMIC integration technology. This technology has the ability to produce low loss series PIN diodes that have both high electrical isolation from the ground plane and a low thermal impedance to maintain reliable peak junction temperatures that out performs traditional devices currently available in the market.

M/A-COM Technology Solutions Inc., Lowell, MA (978) 442-5000, www.macom.com.

RS No. 301

DIGITAL RADIO TEST SET ADDRESSES LTE TEST CHALLENGES

Although standardization work is currently on-going, the 3GPP evolved UTRAN LTE specifications are close to providing a workable description for the implementation of complete devices. With the introduction of next-generation mobile network technology, new challenges will face device developers, including how to confirm that their new design functions correctly, meets the standards under all conditions and without over-heating or draining the battery too quickly. The Aeroflex 7100 Digital Radio Test Set is a test solution that has been developed to enable R&D engineers working on LTE terminal design to meet these challenges.

WHY IS IT A CHALLENGE?

High performance, wide bandwidths, high data rates, fast response times (reducing latency), more complex antenna configurations—and that's just the LTE part—all combine to present greater challenges to the development of next generation devices. In order to support roaming onto other network technologies, multiple radio standards will need to be supported, especially with the lack of voice support in early LTE networks.

For much of the world, LTE devices will need to be backed up with GSM/GPRS, WCDMA/HSPA and/or CDMA2000/1xEVDO support in a range of frequency bands, with downlink frequencies potentially ranging from 746 MHz to 2.69 GHz (Ref: 3GPP TS 36.101). Initial certification of LTE devices is expected to be in bands 1 (2100 MHz), 3 (1700 MHz), 7 (2.6 GHz) and 8 (900 MHz) for FDD mode and bands 38 (2.6 GHz) and 40 (2.4 GHz) for TDD mode. The WRC-07 conference allocated further spectrum for mobile use, meaning both lower (down to 450 MHz) and higher frequencies (up to 3.6 GHz) are likely to be seen as LTE rolls out over the next five years.

In addition, emphasis is being placed by major network operators on support for both FDD mode and TDD mode. There are two reasons for this: LTE TDD mode is the accepted upgrade path for Chinese 3G networks and is being championed by China Mobile, a major network operator. Secondly, many network operators already have unused spectrum

AEROFLEX TEST SOLUTIONS
Stevenage, UK

that is allocated for non-paired operation, so this could be used for LTE deployment. Spectrum (or lack of it) is one of the major issues facing LTE operators, with the need for up to 20 MHz blocks to achieve the 100 Mbps headline data rate.

Another challenge for LTE devices is to maintain data throughput rates at the cell edges, where the SNR is usually worst, and also in crowded cell conditions. For these situations it is essential that the receiver performance is optimized, making the best use of the available signal in a noisy environment.

The typical form factors for LTE devices are likely to be USB sticks, dongles and PC cards in addition to the internal chipsets that will be integrated into lap-tops and high-end PDAs and smartphones. Thermal management will be important in these compact devices when so much functionality needs to be incorporated.

MEETING THE CHALLENGE

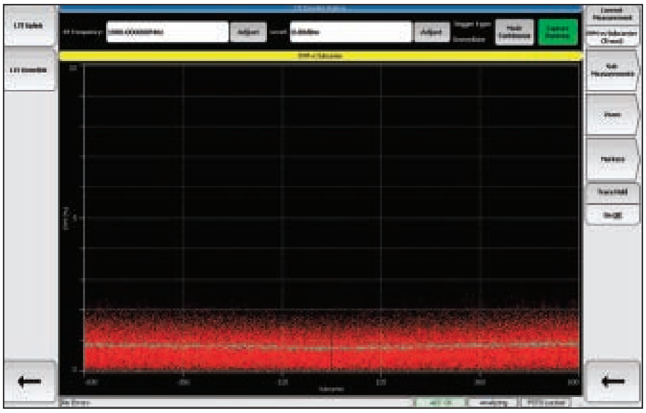
The 7100 integrates all the major functions needed in a bench-top instrument to enable comprehensive testing during the R&D stages of new devices. It simulates the radio and core networks and provides all the key measurements for characterizing the performance of LTE mobile devices, both at the radio interface and throughout the protocol stack, including the PCDP and IMS layers. End-to-end performance can be accurately assessed, along with correct idle mode and connected mode behavior.

MEASUREMENT NEEDS

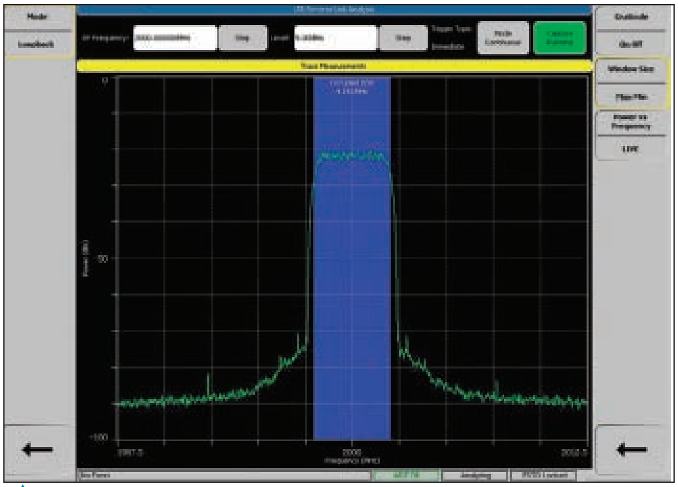
There are a number of key performance measurements that need to be made. Some of these are familiar from previous technologies, including maximum output power, power control and receiver sensitivity, but due to the transmission schemes used, OFDMA in the downlink, SC-FDMA in the uplink, new measurement equipment will be needed to support these tests.

Other measurements are specific to LTE, with its OFDMA transmission scheme; for example, EVM per sub-carrier becomes an essential test of modulator performance. As the modulation bandwidth becomes a higher percentage of the centre frequency, this can pose a challenge with some modulator architectures. As a result, the EVM can be seen to rise at the band edges, as shown in ***Figure 1***. With the availability of the 700 MHz analogue TV spectrum, the likelihood is that LTE will be deployed at lower frequencies than GSM or WCDMA, resulting in 20/700 MHz = 2.8% bandwidth compared to 5/2100 MHz = 0.24% for typical WCDMA devices.

There are six channel bandwidth allocations specified for LTE operation (1.4, 3, 5, 10, 15 and 20 MHz) and it is necessary to measure the occupied bandwidth to ensure that the transmitter output remains within the channel bandwidth for all channel allocations (see ***Figure 2***). The same applies to measurement of ACLR to ensure the interference between devices using adjacent frequency allocations is kept within specification.



▲ *Fig. 1 EVM per sub-carrier.*



▲ *Fig. 2 Measuring occupied bandwidth.*

Due to the dynamic nature of some of the tests, including power control, the measurement conditions need to be established using the signaling protocol, making it essential that the test equipment includes the protocol stack, simulating the evolved Node B (eNB) base station. The 7100 provides this, allowing standard and user-definable test conditions to be established. For the RF measurements, the signaling protocol operates automatically, using user-definable parameters such as channel number, allowing the engineer to focus on the measurement being made.

Although the LTE physical layer uses a cyclic prefix to add resistance to multipath effects, this needs to be tested to ensure correct operation. The 7100 incorporates a baseband fading option, enabling the impact of multipath fading on the end-to-end throughput to be assessed. This allows a real-world view of the behavior of the device in the field to be seen in the lab, before field trials are conducted.

The digital radio test set also incorporates a 3GPP Rel-8 compliant protocol stack and physical layer to emulate an eNB and the Evolved Packet Core (EPC) network (see ***Figure 3***). A comprehensive range of RF tests is featured, including some based on the 3GPP TS 36.521 RF test specification, covering the key transmitter, receiver and transceiver measurements. An integrated IMS server allows complete functional testing to be performed, allowing end-to-end throughput and latency to be measured in a controlled environment.

ADVANCED PROTOCOL TESTING

One of the challenges for the protocol stack developer will be to ensure that the state change response requirements are met. Although the LTE specifications have reduced the number of states that a terminal can be in to RRC_IDLE and RRC_CONNECTED, the time it takes to change from one to the other will be a major part of the delay budget when data needs to be sent for the messaging sequence involved (see ***Figure 4***). In RRC_IDLE mode, as much of the device as possible will be in a low power consumption state to ensure good battery life, with only the receiver activated periodically to check for paging messages. When data transmission is

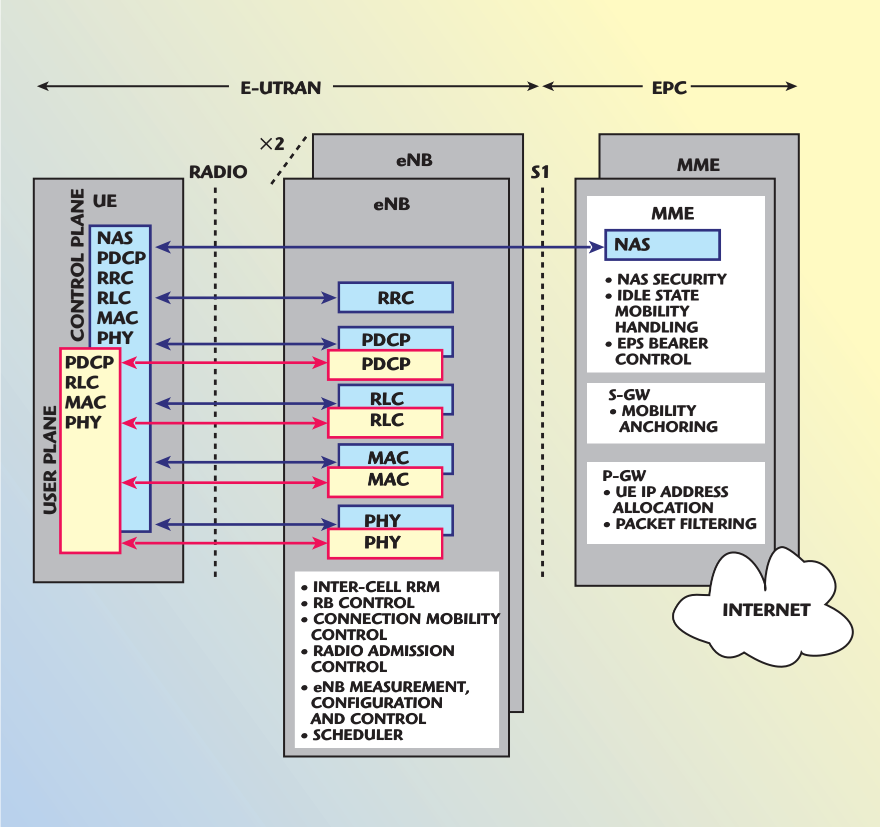


Fig. 3 LTE/SAE protocol partitioning.

to be scheduled, the device must wake up and rapidly synchronize its uplink.

Protocol testing with the 7100 is based on the Aeroflex Script Editor environment and uses a C++ API to construct signaling sequences. A message editor allows programmers to build customized messages for use in protocol test scripts, useful for both positive and negative testing. Although this can be accessed from the front panel, a VGA monitor and USB mouse and keyboard can also be connected for longer test script development and analysis sessions.

All radio interface protocol layers can be tested:

- MAC: scheduling and hybrid ARQ, logical channel multiplexing
- RLC: in-sequence delivery of SDUs, segmentation/concatenation of IP packets, retransmission of erroneous packets and duplication removal
- PDCP: IP header compression, ciphering and integrity protection

In addition, the control plane signaling layers can also be tested:

- RRC: handling of idle and connected state activity, system information, mobility management and connection control
- AS: control of cell selection/re-selection, location registration and de-registration
- IMS: SIP/SDP IP real-time service and connectivity handling

Protocol test diagnostic features include time-stamped message logging and decoding, providing the ability to trace through signaling message flows in detail, ensuring timing requirements are met.

VERSATILITY

The range of features included in the 7100 make it suitable for a broad range of test duties in the R&D stages of LTE device development, with the integrated RF, baseband and protocol stack allowing the entire device to be tested. This combination of features makes the digital radio test set appeal

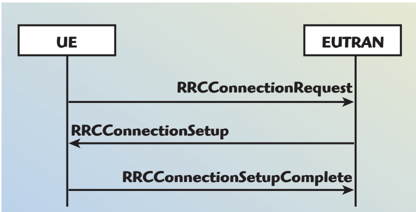


Fig. 4 RRC connection establishment (from 3GPP TS 36.331).

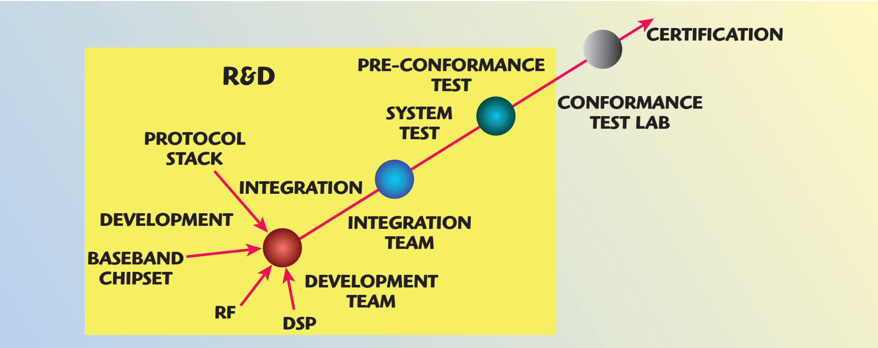


Fig. 5 R&D test stages.

to hardware engineers and software engineers as well as system test and integration engineers, right through to the pre-conformance test stage as illustrated in ***Figure 5***.

As with all new technologies, there will be a period of time before the specifications are fully stable, so it is essential that the test equipment can be easily upgraded to track the changes. The 7100 is based on a software-defined radio architecture enabling it to be updated in the field as the standards evolve and as new tests emerge. Internally, the RF section is capable of 90 MHz bandwidth, well beyond the 20 MHz likely to be seen on first generation LTE devices. The modular nature of the 7100's architecture allows future enhancements to the standards to be readily adopted.

Beyond the technical features of the 7100, its touch screen control and large (12.1 inch) LCD screen provides an elegant and intuitive user interface that enables engineers to easily navigate the extensive range of test functionality while providing clear results.

CONCLUSION

The next generation of mobile technology is rapidly emerging from the standardization process and is bringing with it a new generation of technical problems that need to be solved. Aeroflex is continuing to introduce new test solutions to help engineers working in this challenging new area, in both the RF and protocol domains. The 7100 Digital Radio Test Set is part of the company's range of LTE test solutions, which also includes the TM500 LTE Test Mobile, the 3410 Signal Generator and the PXI modular system.

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CBL-3FT-SMSM+	SMA	3	1.5	27	72.95
CBL-4FT-SMSM+	SMA	4	1.6	27	75.95
CBL-5FT-SMSM+	SMA	5	2.5	27	77.95
CBL-6FT-SMSM+	SMA	6	3.0	27	79.95
CBL-10FT-SMSM+	SMA	10	4.8	27	87.95
CBL-12FT-SMSM+	SMA	12	5.9	27	91.95
CBL-15FT-SMSM+	SMA	15	7.3	27	100.95
CBL-25FT-SMSM+	SMA	25	11.7	27	139.95
CBL-2FT-SMNM+	SMA to N-Type	2	1.1	27	99.95
CBL-3FT-SMNM+	SMA to N-Type	3	1.5	27	104.95
CBL-4FT-SMNM+	SMA to N-Type	4	1.6	27	112.95
CBL-6FT-SMNM+	SMA to N-Type	6	3.0	27	114.95
CBL-15FT-SMNM+	SMA to N-Type	15	7.3	27	156.95
CBL-2FT-NMNM+	N-Type	2	1.1	27	102.95
CBL-3FT-NMNM+	N-Type	3	1.5	27	105.95
CBL-6FT-NMNM+	N-Type	6	3.0	27	112.95
CBL-10FT-NMNM+	N-Type	10	4.7	27	156.95
CBL-15FT-NMNM+	N-Type	15	7.3	27	164.95
CBL-20FT-NMNM+	N-Type	20	9.4	27	178.95
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CBL-3FT-SFNM+	SMA-F to N-M	3	1.5	27	124.95
CBL-6FT-SFNM+	SMA-F to N-M	6	3.0	27	146.95
ARMORED CABLES		Male to Male			
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SOFTWARE FOR COMPLIANT TESTING

AR's SW1006 software is a standalone program that combines conducted immunity test software, radiated susceptibility test software and pre-compliance conducted and radiated emissions test software into one user-friendly package suitable for corporate to professional test lab users. The software automatically performs both calibration and immunity testing in full compliance with IEC 61000-4-3, 4-6; MIL STD 461/462 RS103, CS114 and RTCA/DO160 Section 20 specifications. In addition, the program supplies the user with selectable test parameters and a "thresholding" mode for pre-compliance investigation of equipment susceptibility.

AR RF/Microwave Instrumentation,
Souderton, PA (215) 723-8181, www.ar-worldwide.com.
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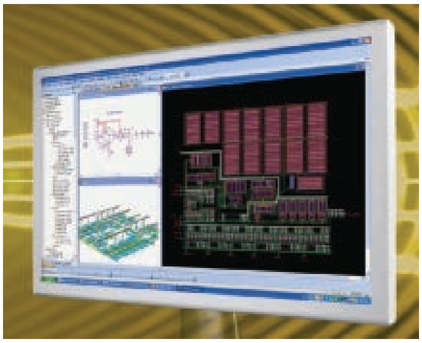

ANALOG OFFICE DESIGN ENVIRONMENT

AWR's recently released Version 2008 Analog Office Design Environment is targeted for RFIC design. Version 2008 includes hundreds of enhancements to the user interface and design flow that dramatically increase user flexibility and productivity. The user interface of AWR tools is widely recognized as extremely easy to use, and the enhancements within Version 2008 place it even further ahead of its competitors. For example, features such as project, elements, layout tabs, and the status window are now dockable and floatable, providing a design environment that is fully configurable to suit personal preferences. This new flexibility streamlines design tasks to save time, maximize useable screen space, provide greater insight into the design, and allow more complex designs to be handled more quickly.

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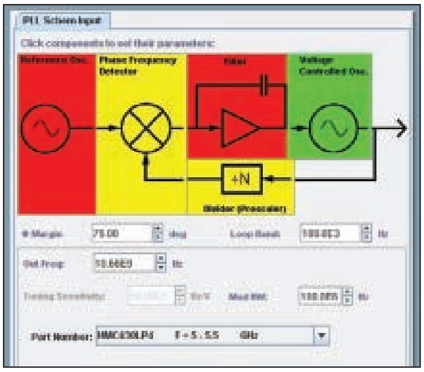

PLL PHASE NOISE SOFTWARE

The widely popular PLL Phase Noise Calculator tool on Hittite's web site was specifically designed to help synthesizer designers select the best Hittite divider, phase frequency detector and VCO for their PLL circuit needs. The interrelation of these building blocks is critical to achieving optimal PLL phase noise, and each component in the PLL circuit will impact overall performance. A graphical interface guides the user through the component selection process, and the calculator uploads the key performance attributes for each Hittite component selected. The PLL Phase Noise Calculator quickly provides the phase noise contribution of each PLL element, as well as the total for the entire loop.

Hittite Microwave Corp.,
Chelmsford, MA (978) 250-3343, www.hittite.com.
RS No. 312

CABLE ASSEMBLY BUILDING ONLINE

The new web-based product RF Cable Assembly Configurator offers an intelligent, fast and easy way to design, specify and request a coaxial RF cable assembly online. It enables users to create, save and print a HUBER + SUHNER datasheet based on the input. The configurator sends a request for quotation and delivery information online, with confirmation sent via e-mail including a datasheet per configuration. It is simple to use and the easy way to build cable assemblies.

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Herisau, Switzerland, http://rfwebpcf.hubersuhner.com.
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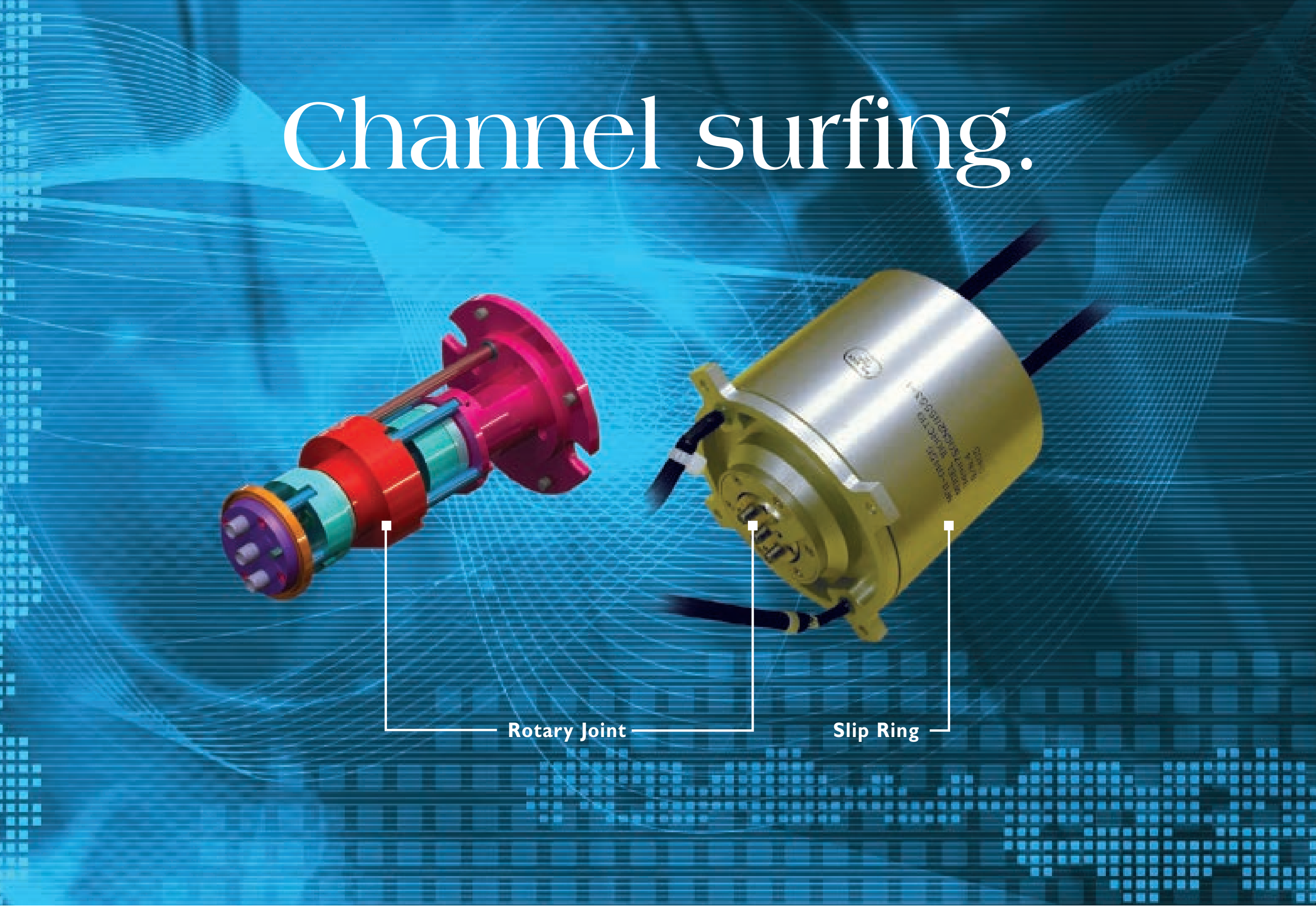

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SOFTWARE UPDATE

RF COMMUNICATIONS TOOLKIT SOFTWARE

Keithley has expanded its SignalMeister™ software platform to now include RF signal analysis along with RF signal generation. First introduced in 2007, SignalMeister software is now the only software package on the market that integrates signal generation and analysis into one package for unmatched speed and simplicity. Furthermore, SignalMeister now has the capability of generating and analyzing both single-input single-output (SISO) and multiple-input multiple-output (MIMO) signals in the same environment. With SignalMeister software, research, design and test engineers can quickly and easily create and analyze signals with a powerful, yet easy to use, block diagram-based, graphical user interface. In addition, the SignalMeister RF Communications Toolkit now supports the latest wireless, MIMO protocol standards, WiMAX Wave 2 and 802.11n WLAN.

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Cleveland, OH (800) 688-9951, www.keithley.com.
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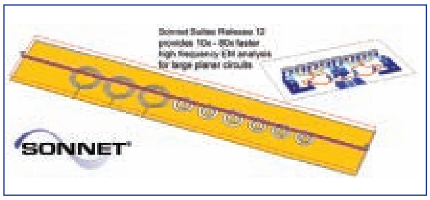

HIGH FREQUENCY EM SIMULATION SOFTWARE

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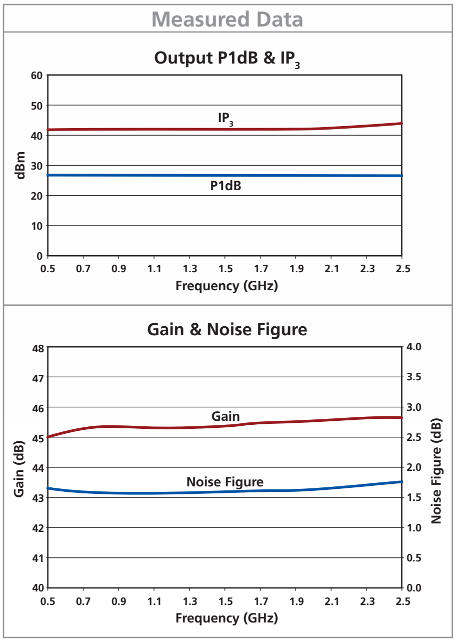
Sonnet Software Inc.,
Syracuse, NY (315) 453-3096, www.sonnetsoftware.com.
RS No. 316

High Linearity LNAs



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Model	Frequency Range GHz	Gain dB Min	Gain Flatness +/- dB Max	Noise Figure dB Max	Output P1dB dBm Min	OIP_3 dBm Min	VSWR In & Out Max	DC Current @ +12 to +15VDC mA Typ	Package Type
JCA02-4000	0.5 to 2.0	40	1.00	1.8	24	40	1.8:1	450	K4
JCA24-4001	2.0 to 4.0	35	1.25	2.0	24	40	1.8:1	450	K4
JCA48-4000	4.0 to 8.0	35	1.50	2.2	24	40	1.8:1	450	K4

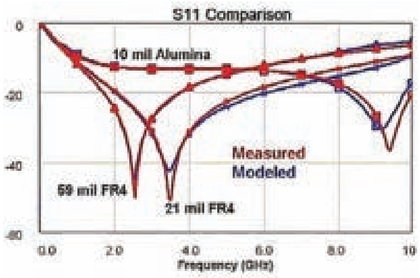
OPTIONS

Variable Gain Control	TTL Switching	Temperature Compensation
Input/Output Isolators	Waveguide Interface	Detector Output
Input Limiters	Phase Tracking	Gain Matching
Limiting Amplifiers	Low Phase Noise	Hermetic Packages
Environmental Screening	K-Connectors	Bias-T Output

endwave®

www.endwave.com

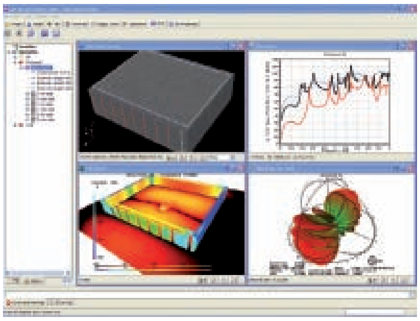
Software Update



NON-LINEAR TRANSISTOR LIBRARY

Modelithics Inc. has released an enhanced version of its powerful and feature-rich Non-Linear Transistor (NLT) Model Library for AWR Microwave Office. The Modelithics NLT Library™ consists of high accuracy non-linear and noise models from leading semiconductor manufacturers. The NLT Library addresses noise, substrate-scalability, temperature dependence, broad-bandwidth and high power, among other stringent requirements of state-of-the-art RF and microwave design.

Modelithics Inc.,
Tampa, FL (888) 359-6359, www.modelithics.com.
RS No. 315



CST MICROSTRIPES VERSION 2009

CST MICROSTRIPES™ (CST MS) is a powerful 3D electromagnetic simulation tool, used extensively for solving the most challenging radiation problems including complex antenna structures, installed performance, EMC/EMI/E3 issues and more. Its solver technology is based on a multi-grid formulation of the time-domain Transmission-Line Matrix (TLM), and users benefit from Octree-based meshing, which helps keep computer requirements to an absolute minimum. CST MS is widely used to design antenna and microwave structures and assess their installed performance, to optimize RFID systems, to analyze radar cross-section (RCS), EMI/EMP and lightning effects on vehicles, ships and aircraft, and to predict absorption of EM fields in human tissue.

CST of America® Inc.,
Framingham, MA (508) 665-4400, www.cst.com.
RS No. 317

i²S® INTELLIGENT INTERACTIVE SYNTHESIZERS

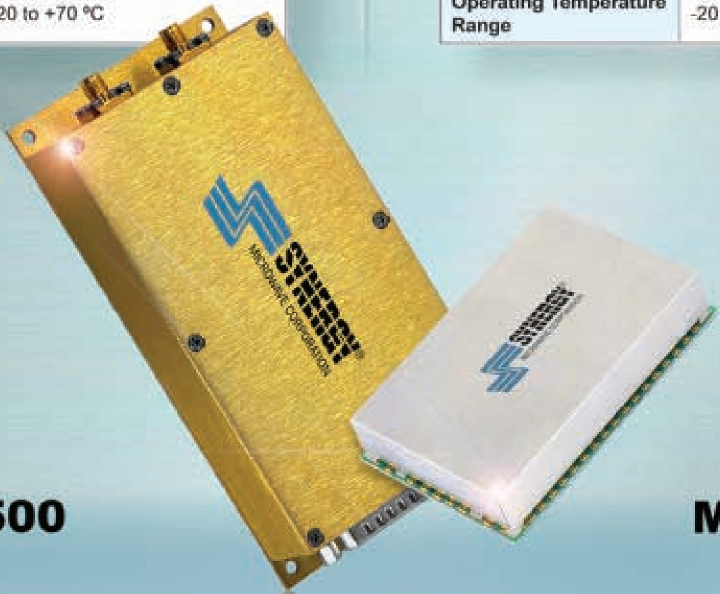
FEATURES: Over an octave bandwidth tuning, Small step size resolution, Outstanding spectral purity, High spurious rejection, Fast lock settling time

KMTS2500

Output Frequency*	1100 - 2500 MHz
Bandwidth	1400 MHz
External Reference	10 MHz
Step Size	Programmable to 1 Hz
Suppply Voltage	+10 to +16 VDC
Output Power	+10 dBm (Typ.)
Spurious Suppression	60 dBc (Typ.)
Harmonic Suppression	10 dBc (Typ)
Typical Phase Noise	Offset: 1 kHz → -95 dBc/Hz.; 10 kHz → -100 dBc/Hz.; 100 kHz → -118 dBc/Hz.
Settling Time	Per Adjacent Step: <1 mSec; End-To-End Jump: <16 mSec
Operating Temperature Range	-20 to +70 °C

MTS2500

Output Frequency*	1100 - 2500 MHz
Bandwidth	1400 MHz
External Reference	10 MHz
Step Size	Programmable to 1 Hz
Bias Voltage	+5 / +3.3 V
Output Power	+10 dBm (Typ.)
Spurious Suppression	60 dBc (Typ.)
Harmonic Suppression	10 dBc (Typ)
Typical Phase Noise	Offset: 1 kHz → -91 dBc/Hz.; 10 kHz → -92 dBc/Hz.; 100 kHz → -110 dBc/Hz.
Settling Time	Per Adjacent Step: <1 mSec; End-To-End Jump: <16 mSec
Operating Temperature Range	-20 to +70 °C



KMTS2500 MTS2500

Programming Interface: 3.3V SPI, RS232

**Available frequencies ranging up to 6000 MHz*

SYNERGY® MICROWAVE CORPORATION

For additional information, contact Synergy's sales and application team.
201 McLean Boulevard, Paterson, NJ 07504 | Phone: (973) 881-8800
Fax: (973) 881-8361 | E-mail: sales@synergymwave.com

Visit http://mwj.hotims.com/23281-114 or use RS# 114 at www.mwjournal.com/info

Visit Our Website At WWW.SYNERGYMWAVE.COM

Multi-position Switch

The QK series of coaxial multi-position switches feature K type connectors that operate in a frequency range from DC to 40 GHz. Available actuator options include normally open and TTL circuitry with integrated indicator circuits. Terminated models are also available with the 2.4 mm connector. Features include: an RF impedance of 50 ohms nominal; operating temperature of -35° to +85°C ambient; operating life of 1,000,000+ cycles; switching time of 15 mSec maximum; a switching sequence of Break Before Make; and is designed to meet MIL-E-5400 and Mil-S-3928.

Ducommun Technologies Inc., Carson, CA (310) 513-7214, www.dt-usa.com.

RS No. 216

Fixed Chip Attenuator

EMC Technology introduces a new high frequency, wire bondable chip attenuator, KFA. Designed with the KTVA footprint in mind, this component offers a flat attenuation from 16 to 36 GHz. The KFA chip attenuator can handle 200 mW and is available in 1 to 10 dB with an operating temperature from -55° to +150°C. The KFA is also available for high-reliability applications under the HRKFA part number with Group A, B and C life testing according to Mil-PRF-55342. This new attenuator is available with gold wire bondable terminals and a platinum silver, solder attachable ground plane in an ultra miniature chip size of 0.065" × 0.120". The KFA ultra broadband attenuator is available for immediate delivery.

EMC Technology,
Stuart, FL (800) 544-5594,
www.emct.com.

RS No. 217

Pseudo Elliptic Bandpass Filter

KR Electronics introduces a 550 MHz pseudo elliptic bandpass filter. The filter offers a typical insertion loss of 3.5 dB, a 3 dB bandwidth of 55 MHz and a 60 dB bandwidth of 100 MHz. The use of pseudo elliptic type filters at bandwidths as low as 10 percent allows performance not easily attainable with all-pole filter types. The filter is supplied in an SMA package measuring 0.6" × 0.6" × 2.25" and can also be supplied in a surface-mount package. The filter can be customized for other center frequencies and bandwidths.

KR Electronics Inc.,
Avenel, NJ (732) 636-1900,
www.krfilters.com.

RS No. 218

PCS Combiner Diplexer

The WP-E026-O is a combiner diplexer that covers the lower 700 MHz band and PCS frequencies. The combiner diplexer exhibits less than 0.3 dB of insertion loss across the passbands of 698 to 746 MHz and 1850 to 1990 MHz while providing greater than 80 dB of isolation. The unit measures 8" × 5" × 3", meets IP67 weatherproofness and is available from stock.

Lorch Commercial and Wireless,
Salisbury, MD (410) 860-5100,
www.lorchwireless.com.

RS No. 220

Fixed Attenuators

The 615 series attenuators feature attenuation values to 90 dB in a single package. These RoHS compliant, fixed attenuators are available in N-male/female configuration covering all commercial wireless bands from DC to 2 GHz. Indoor/outdoor use with 2 W average (1 kW peak) power handling. Standard attenuation values of 40, 50, 60, 70, 80 and 90 dB available from stock to four weeks ARO. These attenuators are made in the USA and offer a 36-month warranty.

MECA Electronics,
Denville, NJ (973) 625-0661,
www.e-meca.com.

RS No. 221

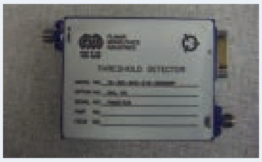
Power Connectors

With a 40 amp max current rating, Phoenix's Power Connectors are designed to meet the increasing system power requirements that are driving the need for improved current density. Contacts are screw-machined for precision, high-reliability and high-current applications. Features include: single power connector accommodates a maximum of 40 amps based on a 20°C temperature-rise with zero airflow; secure, push-on snap facet for easy and quick mating; available in board-to-board and cable-to-board configurations; SMT, Cable and thru-hole designs; pick-and-place and tape-and-reel versions; and custom cable assemblies are also available.

The Phoenix Co. of Chicago,
Wood Dale, IL (800) 323-9562,
www.phoenixofchicago.com.

RS No. 223

Threshold Detector

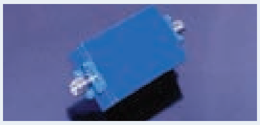


Model TD-30T-SHS-218-30DB-AMP Options DAC, DS, is an ultra-high speed, high sensitivity threshold detector designed for broadband applications in the 2 to 18 GHz frequency range. This model offers an eight-bit digital control to adjust the threshold level and has TTL output. Size: 2.5" × 2.0" × 0.5" and the power supply is ±12 V.

Planar Monolithics Industries,
Frederick, MD (301) 631-1579,
www.planarmonolithics.com.

RS No. 224

Wideband Bandpass Filter



The 11AS-6/18.16G-11 is a wideband bandpass filter that offers a passband of 6 to 18.16 GHz. Featuring loss of 1 dB and rejection in excess of 60 dB, this unit is perfect for portable or "hi-rel" applications.

Reactel Inc.,
Gaithersburg, MD (301) 519-3660,
www.reactel.com.

RS No. 225

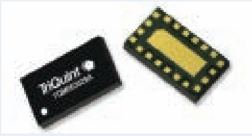
High Power Directional Couplers

These high power directional couplers offer accurate coupling, low insertion loss and high directivity in a compact package. The standard units are optimized for 2 octave bandwidths and are available with a choice of coupling values. These units are ideal for sampling forward and reflected power with a negligible effect on the transmission line and very low intermodulation products.

RLC Electronics Inc.,
Mount Kisco, NY (914) 241-1334,
www.rlcelectronics.com.

RS No. 226

PA Duplexers



The TRITIUM II PA-Duplexer Module™ family includes the TQM663029A, (PCS band), the TQM613029 (cellular band) and the TQM653029 (AWS band). Together with TriQuint's SP3T antenna switch, GPS LNA/filter module and RF filters, the TRITIUM II PA-Duplexers™ provide customers a complete front-end solution for multi-band CDMA handsets. Utilizing in-house technology enables TriQuint to offer a solution that is more cost-effective, more efficient and half the size of solutions comprised of discrete components.

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

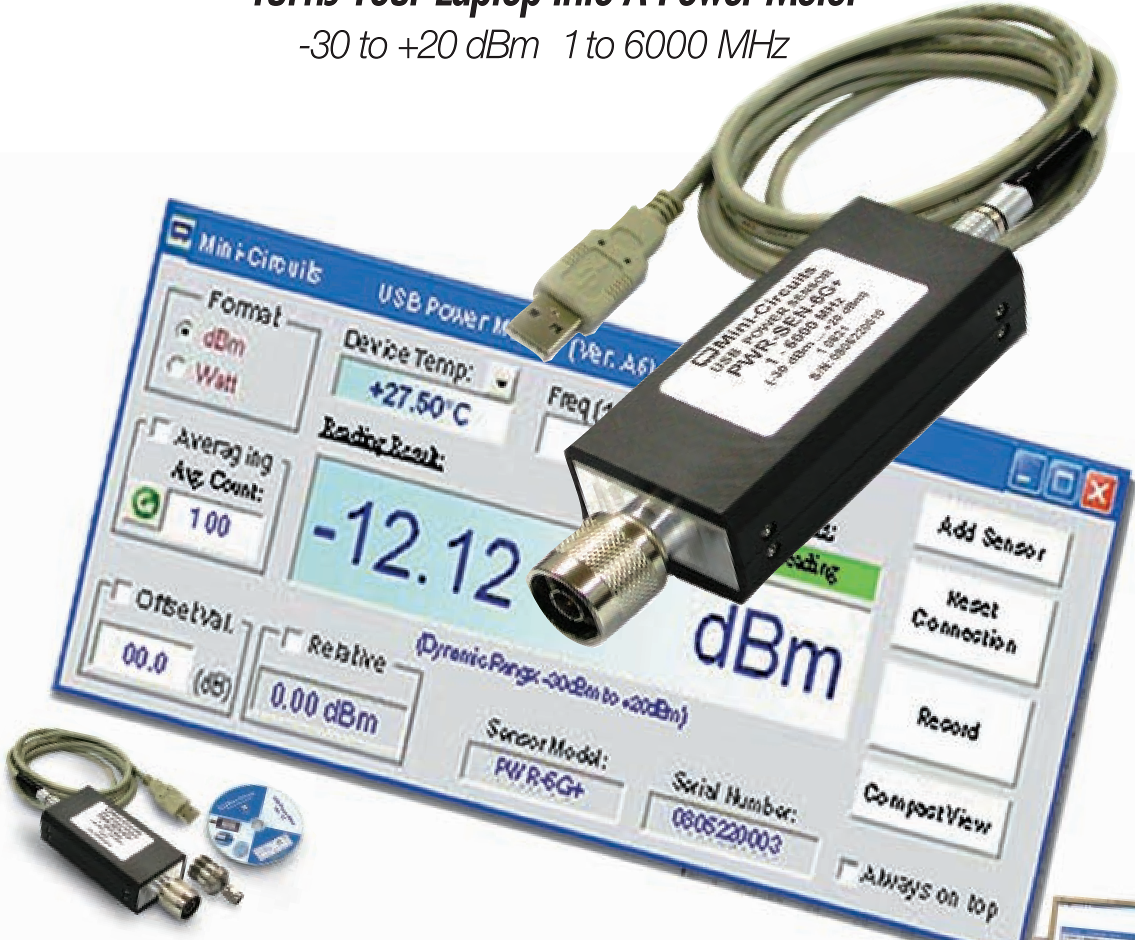
RS No. 227

MINI-CIRCUITS

USB POWER SENSOR

Turns Your Laptop Into A Power Meter

-30 to +20 dBm 1 to 6000 MHz



POWER SENSOR PWR-6G+ Package

only $695 ea. (qty.1-4)

Includes:
PWR-SEN-6G+ Power Sensor Unit
Power Data Analysis Software
SMA Adaptor, USB Cable

Fully loaded software features

- *Power data analysis*
- *Power level offset*
- *Scheduled data recording*
- *Averaging of measurements*
- *Interface with test software*
- *Multi sensor support software* (up to 16 sensors support software)
- *Compatible with LabVIEW™, Delphi, C++ and Visual Basic software*

LabVIEW is a registered trademark of National Instruments Corp. Delphi and C++ are registered trademarks of Codegear LLC. Visual Basic is a registered trademark of Microsoft Corporation. The Mini-Circuits USB Power Sensor is not affiliated with any of the programming software referenced above.

Now, Mini-Circuits offers a USB Power Sensor and software that will reduce your equipment costs and provide new application features that will simplify your power measurements.

All you need is a personal computer (PC) or laptop computer and a Mini-Circuits PWR-6G+ USB Power Sensor. It turns any computer into a powerful power meter having a measurement range of -30 to +20 dBm at frequencies from 1 to 6000 MHz. The PWR-6G+ is supplied with easy-to-use, Windows-compatible measurement software to speed and simplify your power measurements, allowing you to set as many as 999 averages and to record results for further analysis. The PWR-6G+ USB Power Sensor provides 0.01-dB measurement resolution and impressive accuracy over temperature. Visit the Mini-Circuits' web site at www.minicircuits.com to learn more.

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IF/RF MICROWAVE COMPONENTS

457 rev B

Amplifiers

GaN RF Amplifier

Model SSPA 0.1-0.8-125 is a high power, broadband, Gallium Nitride (GaN) RF amplifier that operates from 100 to 800 MHz. This PA is ideal for broadband military platforms as well as commercial applications because it is robust and offers high power over a multi-octave bandwidth with excellent power added efficiency. This amplifier was designed for high efficiency applications. The amplifier operates with a base plate temperature of 85°C with no degradation in the MTBF for the GaN devices inside. It is packaged in a modular housing that is approximately 2.5" (width) by 6.4" (long) by 1.06" (height). This amplifier has a typical P3dB of 125 W at room temperature.

Aethercomm Inc.,
Carlsbad, CA (760) 598-4340,
www.aethercomm.com.

RS No. 228

20 W Solid-state Amplifier

AR's model 20S6G18, a 20 W solid-state amplifier covering 6 to 18 GHz, provides high gain, low noise, good linearity and excellent mismatch capability. The amplifier also delivers superior error vector magnitude (EVM) performance. With a minimum of 43 dB gain and a typical noise figure of 6 dB, the 20S6G18 offers significant advantages over traveling wave tube amplifiers in this frequency range.

AR RF/Microwave Instrumentation,
Souderton, PA (215) 723-8181,
www.ar-worldwide.com.

RS No. 229

Gain Block Amplifier

The Hittite HMC599ST89E is a GaAs PHEMT-based, wide dynamic range gain block MMIC amplifier that is rated from 50 to 960 MHz and delivers 14 dB gain, +39 dBm output IP3, and noise figure as low as 2 dB. Input and output return losses are excellent at 15 dB or better. The HMC599ST89E can be used as a cascadable 75 ohm RF or IF gain stage as well as a PA or LO driver with up to +19 dBm output P1dB compression. This versatile MMIC amplifier exhibits excellent gain and output power stability over temperature, and requires a minimal number of external bias components. The HMC599ST89E is housed in an industry standard RoHS compliant SOT89 package, and can be powered directly from either a +3 or +5 V supply.

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

RS No. 230

Linear Power Amplifier

The XP1050-QJ is a QFN packaged GaAs MMIC linear power amplifier with 49 dBm OIP3 and 14.5 dB small-signal gain. This power amplifier operates in a frequency range from 7.1 to 8.5 GHz and includes an integrated temperature compensated on-chip power detector. The amplifier comes in an RoHS compliant, industry standard, fully molded 6×6 mm QFN package and includes on-chip ESD protection structures and DC bypass capacitors to ease implementation and volume assembly. The XP1050-QJ is well suited for wireless communications applications such as point-to-point radio, LMDS, SATCOM and VSAT applications.

Mimix Broadband Inc.,
Houston, TX (281) 988-4600,
www.mimixbroadband.com.

RS No. 231

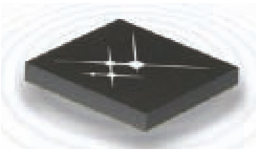
Ultra-low Noise Amplifier

Mini-Circuits ultra-low noise ZX60-0916LN+ boasts a noise figure of only 0.55 dB, while delivering 18 dB gain and a high output power of up to 16.5 dBm, making it a very desirable amplifier in today's market. Ultra reliable and packaged in a rugged patented unibody housing, using SMA connectors, these amplifiers provide for a broad range of applications from 824 MHz to 960 MHz, including: CDMA: 824 to 894 MHz, GSM Rx: 880 to 915 MHz and GSM Tx: 925 to 960 MHz. Mini-Circuits 5 V amplifiers ZX60-0916LN+ are available from stock at the low price of $39.95 (1-9).

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

RS No. 232

Multi-band, Multi-mode Power Amplifier



The SKY77441 is a fully matched 16-pin surface-mount module developed for LTE FDD (Band 7) and TDD (Bands 38 and 40) applications and covers the 2.3 to 2.7 GHz range. It delivers over 26 dBm of linear power output with full LTE resource block allocation under either quadrature phase-shift keying (QPSK), or 16 quadrature amplitude modulations (QAM), and over 28 dBm of linear output power under wideband code division multiple access (WCDMA) modulation. Small and efficient, the LTE FEM integrates the input and output matching networks, the power amplification stages, and the power detection in a single 4 × 4 × 0.85 mm package.

Skyworks Solutions Inc.,
Woburn, MA (781) 376-3000,
www.skyworksinc.com.

RS No. 233

PIN DIODE SWITCHES

FEATURES:

- Multioctave bands 0.2 to 18 GHz
- Reflective or Absorptive
- Current or TTL control
- Low insertion loss
- High isolation

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

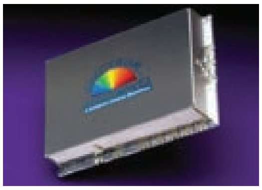
Note: The above models are all reflective switches. Absorptive models are also available, please contact MITEQ.

ISO 9001 Registered · ANAB · RoHS compliant · 3 Year Warranty

For additional information or technical support, please contact our Sales Department at (631) 439-9220 or e-mail components@miteq.com

MITEQ®
100 Davids Drive, Hauppauge, NY 11788
(631) 436-7400 FAX: (631) 436-7430
www.miteq.com

Low Noise Amplifiers



These surface-mount filtered GPS low noise amplifiers (LNA) offer multiple gain stages of 26 to 38 dB with more than 35 dB of out-of-band rejection at 1575.42 MHz. This new small surface-mount design exhibits a low noise figure of 1.8 dB, and operates from a 5 to 32 V supply while only consuming 77 mA. These filtered amplifiers offer a four-pin design for easy mounting and customer selected 26, 32 or 38 dB gain options while still maintaining a low 1.8 dB noise figure from 0° to 70°C. Spectrum also offers these filtered LNAs in connectorized hermetic packages for in-line booster applications or other harsh environments.

Spectrum Microwave,
Delmar, DE (888) 553-1531,
www.spectrummicrowave.com.

RS No. 234

Power Amplifier

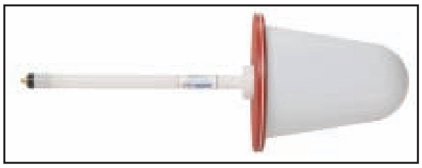
The model SM7177-43 is a COFDM power amplifier designed primarily for the European D-ENG market. The unit operates from 7.1 to 7.7 GHz with a P1dB of +43 dBm. Gain is 55 dB with a flatness of ±0.5 dB across the band. Standard features include forward and reflected power detection, TTL on/off, gain control and an RF sample port. In module form, the unit measures 7.5" × 3.97"× 0.79".

Stealth Microwave Inc.,
Trenton, NJ (609) 538-8586,
www.stealthmicrowave.com.

RS No. 235

Antennas

Omnidirectional Antennas

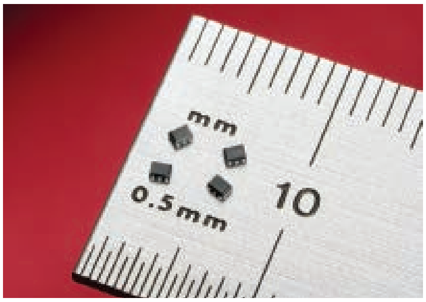


This new series of omnidirectional biconical antennas, models 3180, 3181 and 3182, are designed for broadband spectrum monitoring. The omnidirectional radiation pattern means the antenna can receive signals from every direction around its axis. In addition, for models 3180 and 3182, the elements have been optimized to avoid any splitting of the main radiation beam in the elevation cut. Models 3180 and 3182 are designed to cover the traditional frequency range of EMC measurements, from 30 MHz to 1 GHz. The antennas also cover all of the VHF and part of the UHF bands, making them ideal for spectrum monitoring of FM, TV and some cellular phones.

ETS-Lindgren,
Cedar Park, TX (512) 531-6400,
www.ets-lindgren.com.

RS No. 236

Devices



The UPA828TD twin transistor combines two closely matched silicon NPN chips in a miniature 1.2 × 1.0 × 0.5 mm 6 pin leadless RoHS-compliant package. Ideal for VCO applications, the UPA828TD enables oscillator and buffer amplifier functions to be combined in one miniature device. Its small size and extremely low power consumption make it a great choice for portable, battery-powered products. Typical specifications at 1 V, 3 mA, 2 GHz include: noise figure of 1.3 dB, insertion power gain $|S_{21e}|^2$ of 7.5 dB and frequency f_T of 9 GHz. Price: $0.68 (10K).

California Eastern Laboratories,
Santa Clara, CA, www.cel.com.

RS No. 237

High Voltage Vertical Field Effect Transistor

This High Voltage Vertical Field Effect Transistor (HVVFET™) architecture is designed for radar applications in the UHF band. This HVVFET operates in a frequency range from the 420 to 470 MHz band. The HVV0405-175 offers UHF system designers a fully qualified 175 W RF power transistor with unsurpassed gain and ruggedness specifications. HVVi also recently announced the HVV0912-150, a new addition to the company's growing family of power transistors for Distance Measuring Equipment (DME) applications. Operating across the 960 to 1215 MHz band, the HVV0912-150 is designed for ground-based DME systems that require a wider bandwidth than the company's earlier announced parts for airborne DME applications.

HVVi Semiconductors Inc.,
Phoenix, AZ (480) 776-3800,
www.hvvi.com.

RS No. 238

Processing Equipment

Electric CNC Coax Bender

Winton Machine introduces its newest bench top all electric CNC coax bender. The model CX6 coax bending machine is built to bend semi-rigid coax cable. This production ready bender is microprocessor controlled with a standard keypad and display to allow the operator to easily program the

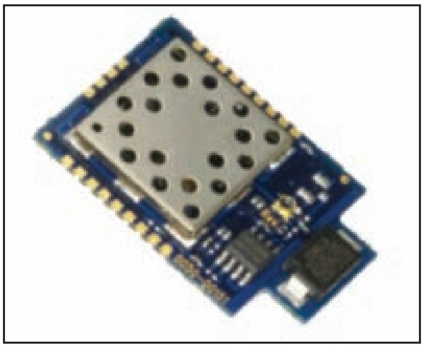
cable. The design of the carriage spindle allows it to position the end of the coax cable to get right up next to the bend tooling on the very last bend. This often translates into avoiding a trimming operation after bending.

Winton Machine Co.,
Suwanee, GA (770) 831-1917,
www.wintonmachine.com.

RS No. 239

Sources

RF Modules



Laird Technologies' LT2510 is a fifth generation 2.4 GHz FHSS module that sets the standard for industrial RF communication. Based on its established proprietary FlexRF™ technology and operating in the globally available 2.4 GHz spectrum, the LT2510 is optimized to outperform conventional wireless standards. Embedded with Laird Technologies' robust server-client protocol, the LT2510 permits each module to communicate with any other in-range module for true peer-to-peer operation. "Out of range" modules can be reached via a meshing topology. The configuration and test software enables OEMs to structure and optimize networks to suit their application.

Laird Technologies Inc.,
St. Louis, MO (800) 492-2320,
www.lairdtech.com/wireless.

RS No. 219

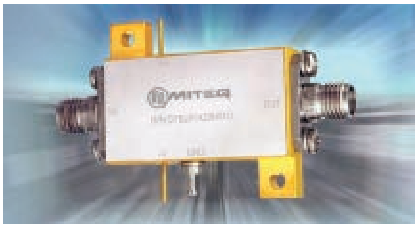
Frequency Synthesizers

The HFS-1540 and HFS-2150 frequency synthesizers are designed for dual-channel telemetry receivers utilizing auto-tracking antenna systems. The HFS-1540 operates from 1435 to 1540 MHz and the HFS-2150 operates from 1850 to 2150 MHz, both units in a step size of 100 kHz. The HFS units feature excellent phase noise (<-95 dBc/Hz at 10 kHz), +13 dBm power output, from a +5 VDC at 165 mA power source. HFS units are housed in small, surface-mount packages, 1.25" × 1.00" × 0.24", and are designed for high-vibration tolerance.

EM Research Inc.,
Reno, NV (775) 345-2411,
www.emresearch.com.

RS No. 242

Frequency Doubler

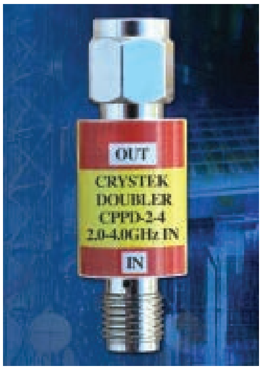


MITEQ introduces its new frequency doubler, model SYS2X1428N01U, which produces a doubled output of +29 dBm from 27,500 to 28,500 MHz with an input harmonic rejection of -20 dBc typical. This doubler requires an input level of 10 dBm typical, +15 VDC at 740 mA and -15 VDC at 10 mA. It is supplied with type "K" female connectors. Model SYS-2X1428N01U measures 1.29" × 1.20" × 0.27" without connectors.

MITEQ Inc.,
Hauppauge, NY (631) 436-7400,
www.miteq.com.

RS No. 243

Frequency Multipliers



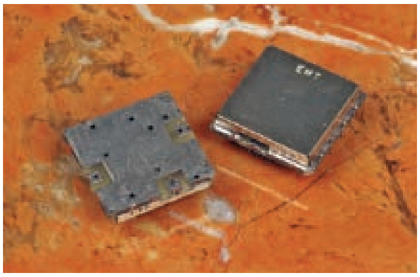
The Crystek Pocket Passive Doubler (CPPD) series of frequency multipliers is designed in a rugged SMA housing for easy in-line assembly and operation in test equipment and general lab use. The CPPD-0.85-2 will accept an input frequency from 0.85 to 2.0 GHz and multiply by a factor of two to achieve output frequencies from 1.7 to 4 GHz. Likewise, the input for the CPPD-2-4 is 2 to 4 GHz with an output of 4 to 8 GHz. The CPPD frequency multipliers feature an input drive level of +10 to +20 dBm with a typical conversion loss of 15 dB for the CPPD-0.85-2.0 and 13 dB for the CPPD-2-4.

Crystek Corp.,
Fort Myers, FL (239) 561-3311,
www.crystek.com.

RS No. 240

Voltage-controlled Oscillators

This series of surface-mount voltage-controlled oscillators (VCO) offers excellent performance for wireless communications and instrumentation



applications. The special design enables the customer to cover frequency ranges from 5 MHz to 7 GHz and provides linear monotonic tuning over the entire tuning range. Operating voltages of +5, +12 and +15 VDC, and tuning voltages ranging from 0 to +20 VDC are available.

Emhiser Micro-Tech,
Verdi, NV (775) 345-0461,
www.emhiser.com.

RS No. 241

Voltage-controlled Oscillator

Model ZRO0833A1LF is a compliant voltage-controlled oscillator (VCO) in the UHF band. The ZRO0833A1LF operates from 826 to 841 MHz with a tuning voltage range of 0.3 to 4.7 VDC. This VCO features a typical phase noise of -122 dBc/Hz at 10 kHz offset and a typical tuning sensitivity of 5 MHz/V. The ZRO0833A1LF is designed to deliver a typical output power of -4 dBm at 5 VDC supply while drawing 13 mA (typical) over the temperature range of -40° to 85°C.

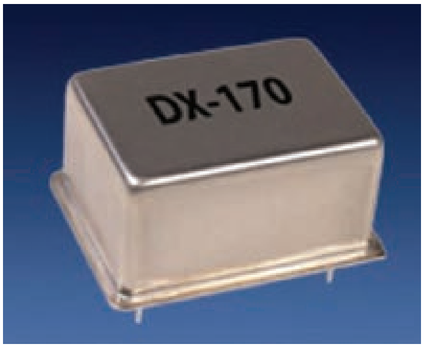
This VCO features typical 2nd harmonic suppression of -15 dBc and comes in Z-Comm's industry standard MINI-16-SM package measuring 0.5" × 0.5" × 0.22". It is available in tape and reel packaging for production requirements. The ZRO0833A1LF is also ideal for automated surface-mount assembly and reflow.

Z-Communications Inc.,
San Diego, CA (858) 621-2700,
www.zcomm.com.

RS No. 245

Double Oven Controlled Crystal Oscillator

This latest version of the DX-170 double oven controlled crystal oscillator (DOCXO) is available in a 28 × 36 × 19 mm package, half the size of its predecessor, requiring less power while offering the same high stability required for telecom, measurement and military applications. With temperature stability as tight as 0.2 ppb and aging of 0.2 ppb, the DX-170 offers excellent holdover stability. The reduced



package size saves space in base stations and expands the variety of applications possible for measurement and military.

Vectron International,
Hudson, NH (603) 598-0070,
www.vectron.com.

RS No. 244

Test Equipment

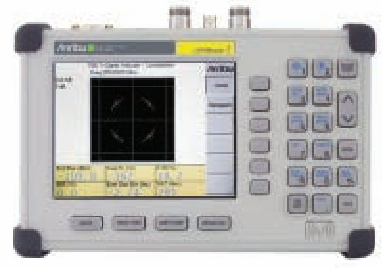
Signal Generator

The Merlin product line of handheld signal generators is designed for CATV installation testing. The standard cable modem receiver signal strength must be between -15 dBmV, and +15 dBmV for proper HDTV picture quality. To test system components for either egress, or ingress susceptibility, Merlin, used with selective frequency receivers, must overcome natural cable system losses; hence the relatively high output power level of +20 dBmV at 75 ohms of impedance (up to +40 dBmV possible on request). Frequencies are available from 100 to 160 MHz.

Noisecom,
Parsippany, NJ (973) 386-9696,
www.noisecom.com.

RS No. 247

Handheld Test Instrument



The S412D LMR Master is a handheld test instrument exclusively for the installation, verification and service of the new US government-mandated P25 Public Safety communications systems. A lightweight, easy-to-use battery-op-

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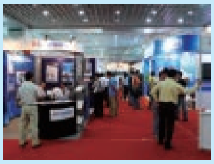




New Products

erated instrument, the LMR Master combines the functionality of a cable and antenna analyzer, spectrum analyzer, interference analyzer, and power meter, significantly reducing the number of tools field technicians and engineers must use, thereby saving time and money while ensuring accuracy. The S412D provides the full suite of measurements offered by Anritsu's Site Master analyzers, plus P25 transmitter measurements and P25 coverage mapping.

Anritsu Co.,
Morgan Hill, CA (800) 267-4878,
www.us.anritsu.com.

RS No. 246

Test Cables

The ZMA series precision coaxial connectors reduce annual cable replacement rates from six per year to practically none by using bayonet coupling connectors instead of threaded connectors. MegaPhase's ZMA bayonet coupling connectors offer many critical advantages over standard threaded connectors. Since the connectors can easily be mated and de-mated by hand with a quarter turn, no torque wrenches are needed, making it ideal for applications where space is tight. The connectors are "keyed" with lugs in two-, three- or four-lug styles. Since the MegaPhase ZMA connectors provide a high coupling force, they are ideal for extreme vibration applications where insufficient room is available for spring loaded blindmate panels.

MegaPhase LLC,
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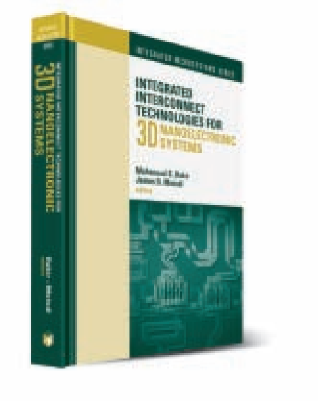

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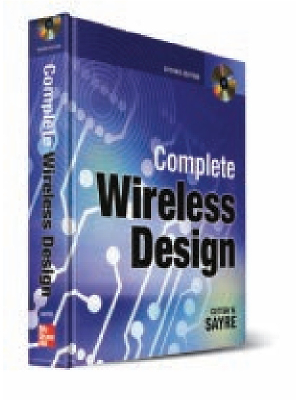

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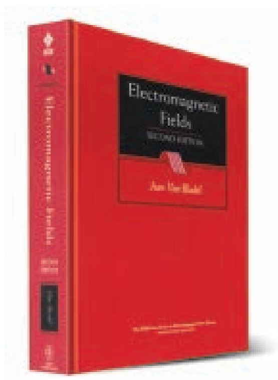

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CONFERENCE / EXHIBITION DATE: May 23-26, 2009

CONFERENCE / EXHIBITION VENUE: Xi'an Qujiang International Conference and Exhibition Center, P. R. China

BACKGROUND OF MICROWAVE INDUSTRY EXHIBITION IN CHINA

The Microwave Industry Exhibition has already been held over 10 years. It is held with the National Conference on Microwave and Millimeter Wave in China every odd year, and with the International Conference on Microwave and Millimeter Wave Technology every dual year.

The goal is to provide a platform for enterprises engaged in Microwave Millimeter wave and RF field to publicize your company/ products.

BACKGROUND OF NCMMW

NCMMW is China's largest conference on microwave and millimeter wave technologies. It is organized by Chinese Institute of Electronics (CIE) and held every two years (odd year).

www.mws-cie.org, www.cnmw.org

The proceedings of the conference will be published by Publishing House of Electronics Industry of China.

The year 2009 comes the Microwave Society of Chinese Institute of Electronics 30th anniversary, so more than 500 conferees will participate in this microwave and millimeter wave conference (Specialized visitor will exceed one thousand people), as the conferees are experts、design engineers and scholars in the field of Microwave and Millimeter wave ,they will be the most professional visitor . And this will be another grand exhibition after "2008 Microwave Industry Exhibition in Nanjing China"!

STANDARD BOOTH: 3 m x 3 m,
Will consist of one board with company name, one table, two chairs and so on.

CUSTOMIZED BOOTH: From 36 m^2
Empty area, you can customize the booth to highlight your company / products.

NOTES:
- The exhibitor will have a chromatic page of introduction in the exhibition handbook, which is free.
- Two packs of lunch will be provide for standard booths, four packs of lunch will be provided for customized booths.
- A list of conferees and professional visitor will be provided.

NCMMW 2009 will surely attract a large numbers of scholars and industry companies from China (Mainland), Hong Kong, Macao and Taiwan. It is a great opportunity for publicizing your company / products.

Looking forward to seeing your company taking part in the exhibition!

WHY YOU SHOULD ATTEND?

MIE 2009 is the largest event of microwave field in China, which is organized by Microwave Society of Chinese Institute of Electronics.
MIE 2009 is where to provide a nice opportunity for the scientists and engineers specialized in the field of Microwave and Millimeter wave to present your new ideas and learn from each other.
MIE 2009 is where to provide a platform for enterprises engaged in Microwave Millimeter wave and RF field to publicize your company/ products in China.

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- Fabricator / distributor for RF / microwave / millimeter wave devices / components: solid state device and circuits (including MMIC): amplifiers, mixers, oscillators, etc. and passive components: filters, duplexers, couplers, attenuators, and antennas etc.
- Designer / distributor for RF / microwave / millimeter wave software.
- Fabricator / distributor for RF / microwave / millimeter wave equipments.
- Fabricator / distributor for RF / microwave PCB and connectors.
- Fabricator / distributor for microwave absorber
- Fabricator / distributor for microwave / millimeter inductor, capacitor and high power resistor
- RF / microwave / millimeter related press and media.

Xi'an is the largest hub of research and development of RF / microwave / millimeter wave products in China. There are many famous universities, institutes and factories in this area, including Xidian University, Xi'an Jiaotong University, Northwestern Polytechnical University, Air Force Engineering University, The Second Artillery Engineering College of PLA , 4th Research Institute of Telecom Science and Technology, 20th and 39th Research Institute of China Electronics Technology Group Corporation, 206th Research Institute of China Arms Industries Group Corporation, and 504th Research Institute of China Aerospace Science and Technology Corporation, etc.

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The Sharp (and Painful) Relation between Market and Economy Trends to One's Engineering Field of Expertise and Career Choices

A Real-life Story

In this month's column I have chosen to bring up a real-life story received from one of our readers (name withheld). In summary, it tells the story of an RF engineer who strayed to programming fields and has a hard time coming back.

The Story

Dear Sirs,

I have read with great interest the articles depicting the shortage of EM professionals and the short-sighted government and education policies that do nothing to help rectify the problem.

I have an interesting story for you and perhaps you can offer some advice in return.

I am a systems and software professional with 25 years experience. But it wasn't always that way. I received my BSEE degree in 1984 and my favorite specialty was EM, RF, radar and antenna systems. I studied under Dr. James F. Corum, then at West Virginia University. I liked it so much I believe I took every EM course the university had to offer—even the Master's level courses.

So after graduation I was all set to progress down the path to an EM career. All the places I interviewed with required a security clearance and I had relatives in East Germany at the time. They all said I would have to wait but I couldn't wait as I had a ton of school loan debt to pay off. To bridge the gap I took a programming job. It was easy and well paying and as often happens it shaped my destiny: I never went back to EM.

Fast-forward 25 years and most well paying software development jobs have gone overseas. While the software job migration was taking place I thought about getting back into EM. A year ago I decided to try to re-enter the EM job market. I have had no success whatsoever. If the EM market is so great, why hasn't anyone expressed interest? I have carefully tweaked my resume and crafted cover letters expressing my interest in an EM career and how I believe my software development experience would benefit a transition to a new facet of electrical engineering. Nada. Really though, Maxwell's equations never go out of style so what does it take in this day and age to get an employer to take a look at me? I have a track record of success and one would think that employers, seeing the personality traits behind success might just realize that these traits translate to success in most human endeavors and not just software development. Perhaps employers are partly to blame and not just government education policy? Perhaps there is an age bias as I am now 47?

Please help me understand. Your thoughts are greatly appreciated.

(Name withheld)

Our Humble Advice

Indeed, the demand and hence the "market value" varies for different technology fields of expertise.

RF engineering is among the analog engineering sciences, which exhibit an ongoing shortage for about a decade now. Unlike computer sciences and software engineering, making an RF engineer requires many years of experience and expensive infrastructure and instrumentation. In recent years RF and microwave technologies have diversified to numerous fields of expertise and firms are very intolerant in general to on-the-job training. At the same time, employers' requirements are very stringent and uncompromising about specific skill-sets and experience.

Going back to the story, lack of practical experience is evidently the negative factor. Firms today are not keen for on-the-job training and age might be playing a hidden role in considerations as well. Yet it might be a good idea to steer the career in according to such radical changes in the industry.

My first and intuitive advice would be for you to pursue a position that incorporates programming with RF in a way that enables you to present your forte and utilize the experience that you have acquired. Your knowledge of RF engineering from college as well as your passion for EM engineering should be the factors qualifying you for this interdisciplinary job, interfacing the RF design. From that point, you might have the opportunity to enrich your RF engineering experience and move deeper into the EM world.

Please note that there are many venues for RF engineering today. Different technologies and markets (e.g. wireless communications, Wi-Fi, RFID, medical, SATCOM, defense, etc.) require different EM expertise and projected levels of demand could vary over time and geography. You will need to make your own research. They all require programmers, though.

To summarize: Review and define your professional experience as a programmer. Your immediate goal is to locate positions that utilize your specific systems and programming experience, while being part of EM project teams so that your formal education becomes an advantage as well.

Beyond wishing our fellow engineer the best of luck, we learn from this story. What we have learned is to look forward. In times of rapid technology changes occur in parallel to radical global economy changes your field of expertise is your asset as well as barrier. For the country, RF engineers are an indispensable asset.

Isaac Mendelson
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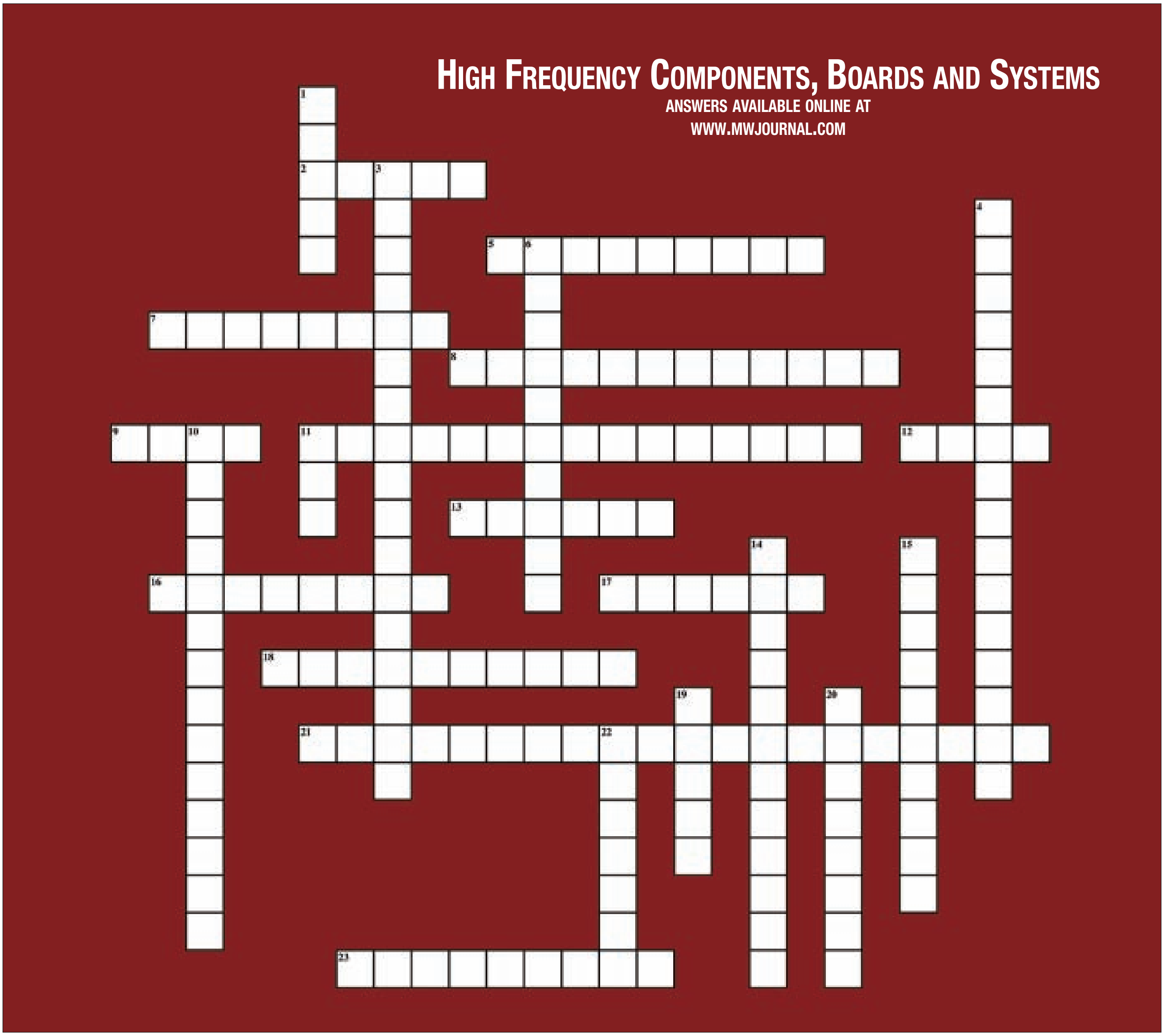

ACROSS

2 Differential quadrature phase shift key modulation

5 A circuit or device whose output signal is a faithful version of the input signal but with increased amplitude, usually specified as voltage or current

7 A solder consisting of two or more metals, all in the appropriate proportions to allow the lowest possible melting point for the given combination

8 A measure of how much better a material is as a path for magnetic flux as compared to free space

9 Digital European Cordless Telephone

11 A reference signal generating circuit that is contained within a receiver or transmitter (2 words)

12 Monolithic Microwave Integrated Circuit

13 A widely used board material used to make microwave printed circuit boards, especially those employing microstrip, stripline and coplanar waveguide transmission line structures

16 A circuit that produces a low frequency output signal, typically DC or video, whose amplitude is dependent upon the RF incident power level

17 One millionth of a meter

18 A two-port circuit or device that reduces the amplitude of an input signal by a desired amount typically expressed in decibels

21 A feedback system that changes the gain or attenuation in response to variations in magnitude of the input signal, thereby maintaining the output signal of the system at a constant magnitude (3 words)

23 One billionth of a meter

DOWN

1 Wideband Code Division Multiple Access

3 Devices that do not amplify or produce a signal (2 words)

4 The amount of electrical power converted to heat by a device (2 words)

6 An unbalanced transmission line structure that consists of a ground plane on the back side of a PCB, the dielectric material of the PCB and a narrow strip on the top side of the circuit board

10 The reduction of signal power as a result of the conversion from the signal frequency to the IF frequency by a down converting mixer (2 words)

11 Long Term Evolution

14 An impedance that does not have a linear relationship with voltage and current

15 The property of a circuit or component that tends to oppose changes in current due to the magnetic field that is a result of the current itself

19 A transformer circuit that couples a balanced transmission line to an unbalanced transmission line

20 A test used to determine the integrity of a wire bond, in which mechanical stress is applied to the wire in the direction that would pull it from the semiconductor bonding area (2 words)

22 A tandem arrangement of two or more components in which the output of one component is connected to the input of the next component

CELEBRATING 2009: THE YEAR OF MMIX

2009 translates in Roman numerals to "MMIX." It only happens once, so Mimix Broadband is celebrating by declaring 2009... **the Year of MMIX**. During the year, we'll highlight key advances in our product portfolio, as well as pay tribute to other engineering feats – specifically the Seven Wonders of the Modern World as chosen by the American Society of Civil Engineers.

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In Production	Power Amplifier (QFN)	XP1035-QH	5.9-9.5	26.0	+/-1.0	+29.0	+39.0	500 @ 6.0	4x4
In Production	Power Amplifier (QFN)	XP1050-QJ	7.1-8.5	14.5	+/-0.5	+34.5 Psat	+49.0	1.2 A @ 8.0	6x6
In Production	Power Amplifier (QFN)	XP1042-QT	12.0-16.0	21.0	+/-1.0	+25.0	+38.0	500 @ 5.0	3x3
In Production	Power Amplifier (QFN)	XP1043-QH	12.0-16.0	21.5	+/-1.0	+30.0	+41.0	700 @ 7.0	4x4
In Production	Power Amplifier	XP1072-BD	34.0-37.0	22.0	+/-2.0	+35.0 Psat	-	2.4 A @ 5.5	DIE
In Production	Power Amplifier	XP1073-BD	34.0-37.0	22.0	+/-2.0	+37.0 Psat	-	4.8 A @ 5.5	DIE
Coming Soon	Power Amplifier	XP1057-BD	13.5-16.0	17.0	+/-1.0	+39.0	+48.0	3.7 A @ 7.5	DIE
Coming Soon	Power Amplifier	XP1058-BD	14.0-16.0	27.0	+/-1.0	+36.0	+45.0	2.2 A @ 8.0	DIE

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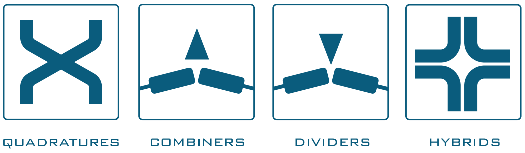

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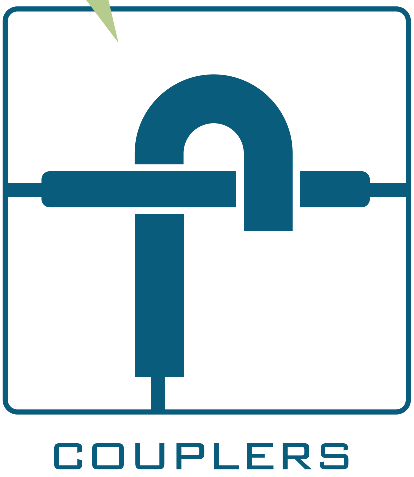

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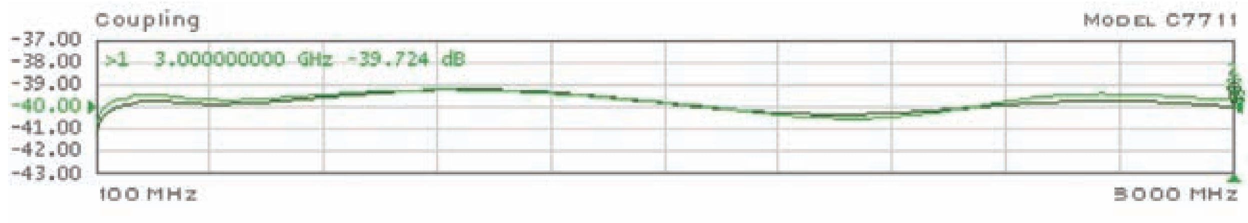

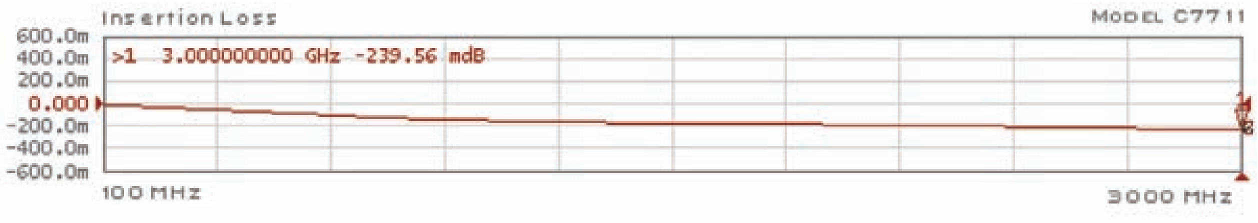

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Model	Coupler Type	Frequency (MHz)	Power CW (Watts)	Coupling (dB)	Flatness (±dB)	Insertion Loss (dB)	VSWR (Mainline)	Directivity (dB)	Size (Inches)
C7734	Dual Directional	30-2500	100	43	±1.5	0.35	1.25:1	18	3.5 x 2.6 x 0.7
C7148	Bi Directional	60-600	200	10	±1.0	0.35	1.20:1	20	6.0 x 4.0 x 0.75
C7711	Dual Directional	100-3000	100	40	±1.0	0.35	1.25:1	18	3.0 x 2.2 x 0.7
C7783	Bi Directional	200-1000	200	20	±0.75	0.2	1.20:1	20	3.0 x 1.5 x 0.53
C6600	Bi Directional	200-2000	200	20	±1.2	0.25	1.25:1	18	4.0 x 2.0 x 0.72
C7152	Bi Directional	300-3000	100	20	±1.0	0.35	1.20:1	15	3.7 x 2.0 x 0.75
C7811	Dual Directional	500-2500	100	40	±0.5	0.2	1.25:1	20	3.0 x 2.0 x 0.6
C7753	Bi Directional	700-4200	100	20	±1.0	0.35	1.25:1	18	1.8 x 1.0 x 0.6