Vol. 54 • No. 2
February 2011

Microwave Journal

in Pursuit of the Highly Functional, Ever-shrinking, Multi-layer Microwave Integrated-circuit

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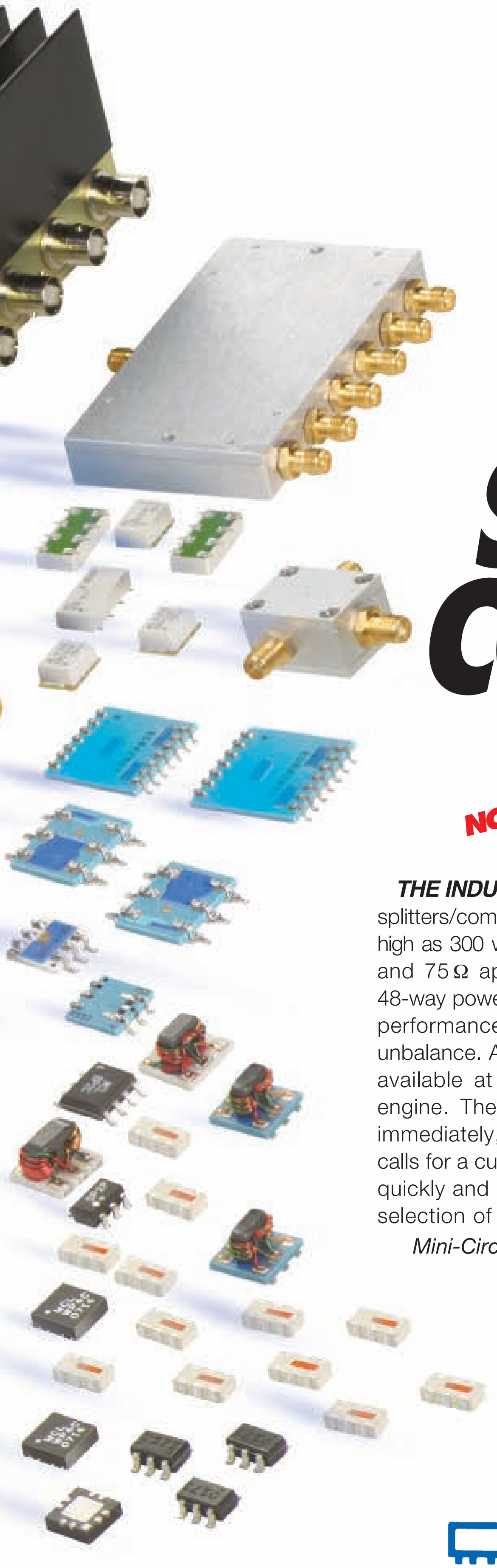

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THE INDUSTRY'S LARGEST SELECTION Mini-Circuits offers thousands of power splitters/combiners for applications from *2 kHz to 18 GHz* and with power handling as high as 300 watts. Choose from coaxial, flat-pack, and surface-mount housings, for 50 Ω and 75 Ω applications. The industry's largest selection includes 2-way through 48-way power splitters/combiners in 0°, 90°, and 180° configurations, with outstanding performance in terms of insertion loss, VSWR, amplitude unbalance, and phase unbalance. All models are characterized with detailed data and performance curves, available at the touch of a button using Mini-Circuits advanced Yoni2 search engine. These ***low-cost, off-the-shelf power splitters/combiners*** are available immediately, and backed by Mini-Circuits 1year guarantee. But if your application calls for a custom unit, our development team will meet or exceed your requirements quickly and cost-effectively. Contact Mini-Circuits today, for the industry's largest selection of power splitters/combiners.

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U.S. patent 7739260

IF/RF MICROWAVE COMPONENTS

448 rev E

PIN DIODE SWITCHES

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- 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.

3 YEAR WARRANTY

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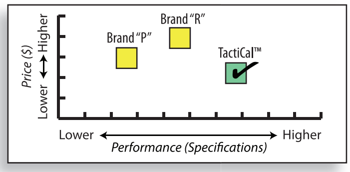

Need Adapters? TactiCal™ Coaxial Adapters Are Available For:

- 1.85mm
- 2.4mm
- 2.92mm
- 3.5mm
- 7mm
- Type N

(Configurations at right)

	7mm	N	3.5mm	2.92mm	2.4mm	1.85mm
7mm		●	●			
N	●	●	●			
3.5mm	●	●	●	●	●	
2.92mm			●	●	●	
2.4mm			●	●	●	
1.85mm						●

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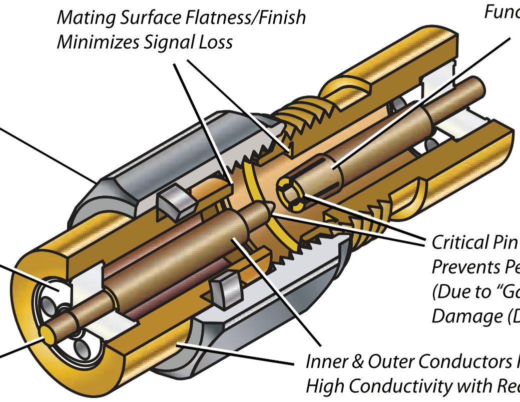
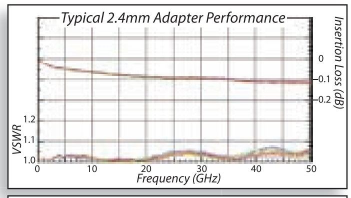
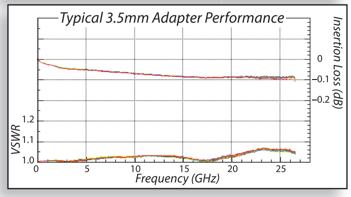


TactiCal™ Adapter Performance





The TactiCal™ Solutions Family

		OPENS	SHORTS	LOADS	VNA CALIBRATION KITS	IN-SERIES ADAPTERS (sold separately)	BETWEEN SERIES ADAPTERS (sold separately)
1.85mm	Female	TC-O-185-F	TC-S-185-F	TC-L-185-F	TC-CK-185 including: • 2 1.85mm Shorts (1 M /1 F) • 2 1.85mm Opens (1 M /1 F) • 2 1.85mm Loads (1 M /1 F) • 1 TC-TW-8 Torque Wrench	TC-A-185-FF 1.85mm Female to 1.85mm Female TC-A-185-MM 1.85mm Male to 1.85mm Male TC-A-185-MF 1.85mm Male to 1.85mm Female	TC-A-2435-FF 2.4mm Female to 3.5mm Female TC-A-2435-FM 2.4mm Female to 3.5mm Male TC-A-2435-MF 2.4mm Male to 3.5mm Female TC-A-2435-MM 2.4mm Male to 3.5mm Male
	Male	TC-O-185-M	TC-S-185-M	TC-L-185-M			
2.4mm	Female	TC-O-24-F	TC-S-24-F	TC-L-24-F	TC-CK-24 Including: • 2 2.4mm Shorts (1 M /1 F) • 2 2.4mm Opens (1 M /1 F) • 2 2.4mm Loads (1 M /1 F) • 1 TC-TW-8 Torque Wrench	TC-A-24-FF 2.4mm Female to 2.4mm Female TC-A-24-MM 2.4mm Male to 2.4mm Male TC-A-24-MF 2.4mm Male to 2.4mm Female	TC-A-2435-FF 2.4mm Female to 3.5mm Female TC-A-2435-FM 2.4mm Female to 3.5mm Male TC-A-2435-MF 2.4mm Male to 3.5mm Female TC-A-2435-MM 2.4mm Male to 3.5mm Male
	Male	TC-O-24-M	TC-S-24-M	TC-L-24-M			
2.92mm	Female	TC-O-29-F	TC-S-29-F	TC-L-185-F	TC-CK-29 Including: • 2 2.92mm Shorts (1 M /1 F) • 2 2.92mm Opens (1 M /1 F) • 2 2.92mm Loads (1 M /1 F) • 1 TC-TW-8 Torque Wrench	TC-A-29-FF 2.92mm Female to 2.92mm Female TC-A-29-MM 2.92mm Male to 2.92mm Male TC-A-29-MF 2.92mm Male to 2.92mm Female	TC-A-2429-FF 2.4mm Female to 2.92mm Female TC-A-2429-FM 2.4mm Female to 2.92mm Male TC-A-2429-MF 2.4mm Male to 2.92mm Female TC-A-2429-MM 2.4mm Male to 2.92mm Male
	Male	TC-O-29-M	TC-S-29-M	TC-L-29-M			
3.5mm	Female	TC-O-35-F	TC-S-35-F	TC-L-35-F	TC-CK-35 Including: • 2 3.5mm Shorts (1 M /1 F) • 2 3.5mm Opens (1 M /1 F) • 2 3.5mm Loads (1 M /1 F) • 1 TC-TW-8 Torque Wrench	TC-A-35-FF 3.5mm Female to 3.5mm Female TC-A-35-MM 3.5mm Male to 3.5mm Male TC-A-35-MF 3.5mm Male to 3.5mm Female	TC-A-357-F 3.5mm Female to 7mm TC-A-357-M 3.5mm Male to 7mm TC-A-35N-FF Female to Type N Female TC-A-35N-MM 3.5mm Male to Type N Male TC-A-35N-FM 3.5mm Female to Type N Male TC-A-35N-MF 3.5mm Male to Type N Female
	Male	TC-O-35-M	TC-S-35-M	TC-L-35-M			
TYPE N	Female	TC-O-N-F	TC-S-N-F	TC-L-N-F18 (High Band) TC-L-N-F2 (Low Band)	TC-CK-N Including: • 2 Type N Shorts (1 M &1 F) • 2 Type N Opens (1 M &1 F) • 2 Type N High Band Loads (1 M /1 F) (Low Band Loads sold separately) • 1 TC-TW-12 Torque Wrench	TC-A-N-FF Type N Female to Type N Female TC-A-N-MM Type N Male to Type N Male TC-A-N-MF Type N Male to Type N Female	TC-A-7N-F Type N Female to 7mm TC-A-7N-M Type N Male to 7mm TC-A-35N-FF 3.5mm Female to Type N Female TC-A-35N-MM 3.5mm Male to Type N Male TC-A-35N-FM 3.5mm Female to Type N Male TC-A-35N-MF 3.5mm Male to Type N Female
	Male	TC-O-N-M	TC-S-N-M	TC-L-N-M18 (High Band) TC-L-N-M2 (Low Band)			

MAURY MICROWAVE CORPORATION

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FEATURES

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PRODUCT FEATURES

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Free Webinars

Innovations in EDA Series Presented by Agilent Technologies Inc.

Memory Effects in RF Circuits: Manifestations and Simulation: This Webcast defines memory effects in RF circuits commonly used in various radio blocks and demonstrates how these effects can adversely impact the accuracy of simulations using traditional behavioral approaches. Finally, new techniques are presented for sufficient simulation speed and accuracy.

Available for on demand viewing after 2/3/11
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RF/Microwave Training Series Presented by Besser Associates

RF Power Amplifiers - Digital Pre-distortion Techniques: This webinar, presented by Dr. John Wood, discusses modern communications signals and the impact of RF power amplifier design on linearity and efficiency. Topics include: linearizer basics, memory effects, digital pre-distortion techniques, system architecture and linearization results.

Live webcast: 2/15/11, 11:00 AM EST
Sponsored by **Scintera Networks Inc.**

Technical Education Series

Presented by AWR and Rohde & Schwarz

LNA design and characterization using modern RF/microwave software together with T&M instruments: In this webcast, Microwave Office is used to develop a prototype of an LNA design, applying the simulator to reveal and quantify sensitive circuit parameters. The ZVA, a R&S Vector Network Analyzer, is used to characterize the LNA design built according to the simulation results. Microwave Office and the ZVA are plugged together to bring the measured and simulated results together for instantaneous comparison and virtual model verification.

Live webcast: 3/8/11, 12:00 AM EST
Sponsored by **AWR** *and* **Rohde & Schwarz**

Executive Interview

Dr. Alexander Chenakin, Vice President of the Signal Sources Group at **Phase Matrix**, talks about the technology behind the company's state-of-the-art frequency synthesizers and the specific market requirements addressed by these high performance products.

Coverage of Upcoming Events

February has its share of important industry events including DesignCon 2011, the International Solid-state Circuits Conference (ISSCC 2011), NATE and Mobile World Congress. MWJ will be reporting exhibitor product news from these events and covering Mobile World Congress live from Barcelona, Spain, with blogs, Twitter and our Microwave Flash newsletter.

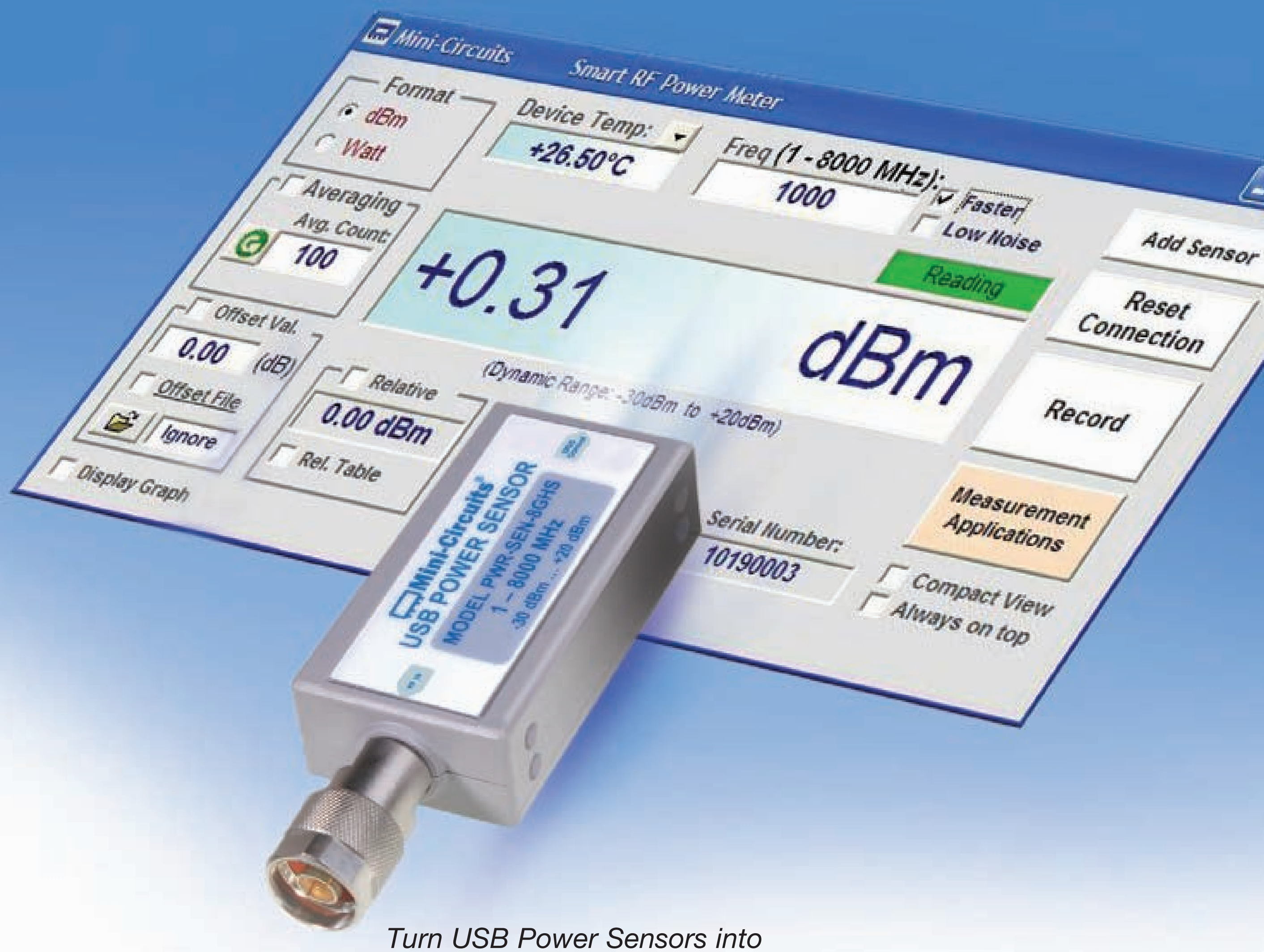
Online Technical Papers

Finite Element Modeling of Electromagnetic Scattering for Microwave Breast Cancer Detection
Reza Firoozabadi, Airvana Network Solutions, and Eric Miller, Tufts University

What is Phase Noise?
Tutorial, Peregrine Semiconductor

Characteristics of E-pHEMT vs. HBTs for PA Applications
White Paper, Avago Technologies

Time Matters: How Power Meters Measure Fast Signals
Wolfgang Damm, Wireless Telecom Group



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PWR-4GHS	9 kHz-4 GHz	30 ms	50	795.00
PWR-2GHS-75	100 kHz-2 GHz	30 ms	75	795.00

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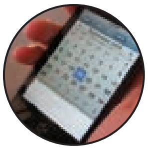
IF/RF MICROWAVE COMPONENTS

MARCH 2011

SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
27	28	1 CST STUDIO SUITE Microwave & Antenna Training Munich, Germany Agilent Technologies Innovations in EDA Webcast	2 ANSOFT HFSS Training Boston, MA	3	4	5
6	7	8 AWR ROHDE&SCHWARZ Webinar on LNA Design and Characterization	9	10 IWCE Las Vegas, NV	11	12
13	14	15 SATELLITE 2011 MWJ Besser Webinar: VCO Design Sponsored by Mini-Circuits	16 Washington, DC	17 ROHDE&SCHWARZ Webinar on Real Time	18	19
20	21	22 RF Microwave Zone The 3rd Annual RF / Microwave Zone Pavilion at CTIA Wireless 2011 - March 22-24, 2011 Orange County Convention Center, Orlando, FL International CTIA WIRELESS 2011	23	24 Understanding MIMO OTA Testing: CTIA Wireless Expert Forum Orlando, FL Organized by Microwave Journal	25	26
27	28	29 ACES 2011 27th International Review of Progress in Applied Computational Electromagnetics Williamsburg, VA	30	31	1	2

Go to: www.mwjournal.com/events



COMING EVENTS

CALL FOR PAPERS

EuMW 2011
Deadline: February 12, 2011
ARMMS Conference
Deadline: February 28, 2011
MILCOM 2011
Deadline: March 18, 2011
RADAR 2011
Deadline: May 1, 2011
IEEE COMCAS 2011
Deadline: June 15, 2011

ONLINE
www.mwjournal.com/events

FEBRUARY

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

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

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

MARCH

SATELLITE 2011
March 14–17, 2011 • Washington, DC
www.satellite2011.com

CTIA with RF/Microwave and M2M Zones
March 22–24, 2011 • Orlando, FL
www.ctiawireless.com

ACES 2011
27th International Review of Progress in Applied Computational Electromagnetics
March 27–31, 2011 • Williamsburg, VA
http://aces.ee.olemiss.edu/conference/

APRIL

ARMMS RF and Microwave Society Conference
April 4–5, 2011 • Oxfordshire, UK
www.armms.org

WAMICON 2011
IEEE Wireless and Microwave Technology Conference
April 18–19, 2011 • Clearwater, FL
www.wamicon.org

MAY

IEEE Sarnoff Symposium
May 2–4, 2011 • Princeton, NJ
http://sarnoff-symposium.ning.com

JUNE

MIE 2011
2011 National Conference on Microwave and Millimeter Wave in China
2011 Microwave Industry Exhibition in China
June 4–7, 2011 • Qingdao, Shandong, China
www.cnmw.org

RFIC 2011
IEEE Radio Frequency Integrated Circuits Symposium
June 5–7, 2011 • Baltimore, MD
www.rfic2011.org

IMS 2011
IEEE MTT-S International Microwave Symposium
June 5–10, 2011 • Baltimore, MD
www.ims2011.org

ARFTG 2011
ARFTG Microwave Measurement Conference
June 10, 2011 • Baltimore, MD
www.arftg.org

AUGUST

EMC 2011
IEEE International Symposium on Electromagnetic Compatibility
August 14–19, 2011 • Long Beach, CA
www.emc2011.org

OCTOBER

EuMW 2011
European Microwave Week
October 9–14, 2011 • Manchester, UK
www.eumweek.com

AMTA 2011
33rd Annual Symposium of the Antenna Measurement Techniques Association
October 16–21, 2011 • Englewood, CO
www.amta.org

RADAR 2011
International Conference on Radar
October 24–27, 2011 • Chengdu, China
www.radar2011.org

NOVEMBER

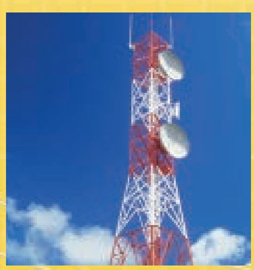
COMCAS 2011
International IEEE Conference on Microwaves, Communications, Antennas and Electronic Systems
November 7–9, 2011 • Tel Aviv, Israel
www.comcas.org

MILCOM 2011
November 7–10, 2011 • Baltimore, MD
www.milcom.org

DECEMBER

Asia Pacific Microwave Conference
December 5–8, 2011 • Melbourne, Australia
www.apmc2011.com

Performance vs. price? At last, resistive parts that make a priority of both.



Our new resistive components are suitable for today's wireless and broadcast applications requiring excellent power-handling in small, cost-competitive packages.

Designed specifically for commercial wireless bands – and priced more competitively than ever before – Anaren's new wireless resistive components are the answer when performance and price must share the top slot on your priority list:

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> Choose from a range of packages including SMD, chip, flanged, and flangeless

> Environmentally friendly, thanks to BeO-free AlN and Alumina designs – and RoHS compliant, lead-free finish

> Accurate characterization of performance so you can spec these parts with confidence

> Extremely cost-competitive – Anaren's unique designs and manufacturing help you hit your aggressive cost targets, while ensuring a quality product. (Every single component is tested before it leaves our plant!)

Got a resistive component priority checklist of your own? Include Anaren on your RFQ list, and we'll show you how we measure up!

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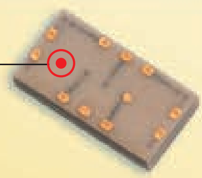

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Multilayer Technology Enables Miniaturization of Integrated Multi-function Modules

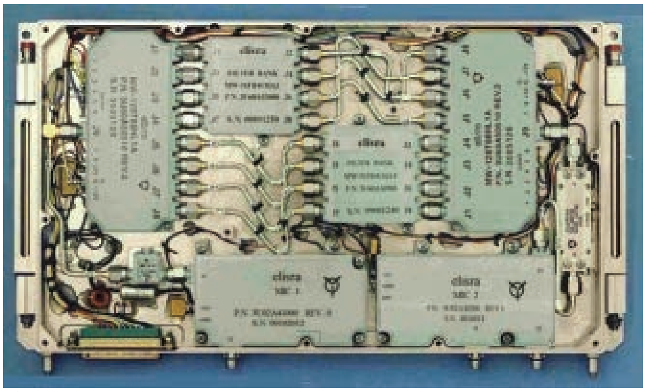
The RF and microwave components market has seen the introduction of many new technologies over the years. In the early days, RF and microwave systems and subsystems were built using discrete single-function components, connected by semi-rigid or flexible cables. Each component was realized by the most suitable process and technology for its function. Filters were realized as metal cavities or by lumped element devices. Amplifiers were realized by biasing and matching discrete transistors and so on. The total system was large and bulky, and mismatch between components was difficult to predict and compensate for. Such a subsystem is shown in ***Figure 1***.

One of the technologies used to realize an RF and microwave function is the microwave integrated circuit (MIC). In this technology, a device in bare die form is used with a combination of soft-board (Teflon-based) or hard-board (ceramics, such as alumina) matching and bias networks. The device is connected to the board with a gold or silver ribbon or bond. This technology is also referred to as chip and wire. Such a MIC amplifier is shown in ***Figure 2***.

Along with improvements in the MIC capabilities, more than a single function was integrated to a single MIC component, thus creating the super-component or integrated multifunction module. These super-components enable a designer to get more functionality into a smaller volume, while keeping the component to component matching under control. Such a super-component is shown in ***Figure 3***.

In the super-component world, miniaturization is limited by several factors. First, the bias and control lines, usually fed from the other side of the mechanical housing, consume a lot of space. In ***Figure 4***, a very small device takes up a much larger area due to the hermetically sealed pins and control lines around it. Another limiting factor is the introduction of filters. Since the MIC is planar in construction, the easiest way to integrate a filter into the design is to print the filter on an alumina substrate. However, planar filters have a lower Q-factor than 3-D filters and thus more filters must be used in a given design. Non-planar filters were also used, paying the price of higher volume.

In highly integrated super-components, there are also some DC and digital functions to



▲ *Fig. 1 Subsystem with semi-rigid cables.*

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Elisra Electronic Systems Ltd.
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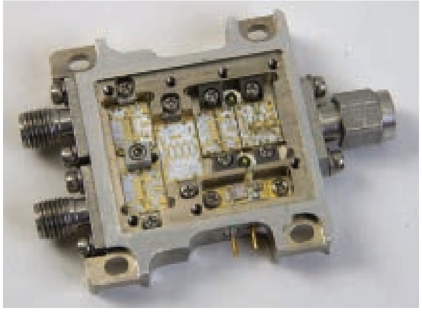


Fig. 2 Chip and wire amplifier.

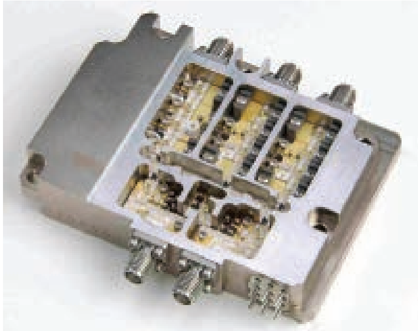


Fig. 3 Super-component, MIC technology.

be integrated. This was usually done by designing a standard PCB, with all components assembled by the automatic surface-mount technology (SMT) process. This DC and control PCB is usually located in the side opposite to the MIC side, with hermetical pins connecting the two sides. This allows the PCB to be located in a non-hermetic space and thus makes it easier for a designer to come up with smaller assemblies.

Along with the introduction of microwave monolithic integrated circuit (MMIC) technology, multifunction devices become available in the form of a single die or SMT device. This enabled reducing the size of super-components even further. By using commercial off-the-shelf (COTS) MMIC devices, several dies may be replaced by one MMIC. For medium and large scale programs, system designers use custom MMIC devices that are designed to meet the exact functionality and size requirements for the specific program. In ***Figure 5***, a custom millimeter-wave tripler with high fundamental signal rejection is shown.

As MMIC and SMT technologies advance, more and more super-components are realized as pure SMT circuits. Currently, this approach supports the low to medium frequency range. High-frequency or high-Q filters are still a challenge in these non-hermetic all SMT circuits.

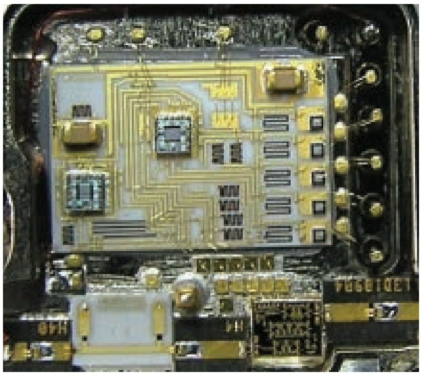


Fig. 4 Phase shifter feeding network.

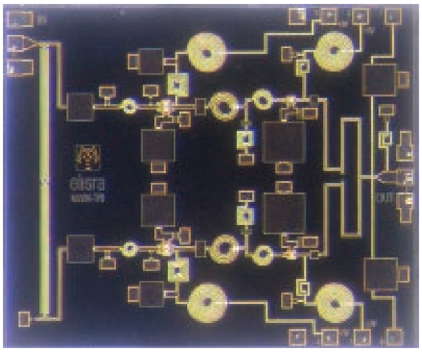


Fig. 5 Millimeter-wave tripler.

In recent years, MIC technology in multilayer RF circuits has emerged as the chosen solution for small form and high functionality integrations. As described below, this technology enables combining bare-die devices, SMT components (including BGA), planar filters, ceramic filters, DC and control functions, and more.

MULTILAYER CONSTRUCTION

This method comprises multilayer RF and microwave circuits based on PCBs with many different layers of different composition and thickness. Usually the top and bottom layers are used for the RF signals, one or more additional internal layers are used for RF bypass lines and embedded circuits, and the other layers are used for DC and control and various analog functions. The top layer has some cavities in it. The cavities extend down to the ground metallization of the RF top layer. Such a cavity is shown in ***Figure 6***.

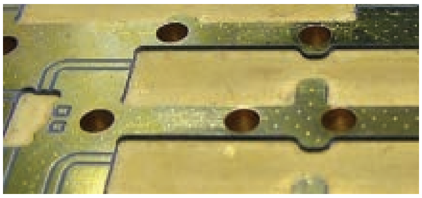
An RF device is placed inside the cavity. This can be a transistor, a MMIC device, an alumina filter, etc. The device has excellent grounding since the grounding is common to both the RF feeding lines and the device. Assuming the cavity depth is carefully chosen, the devices do not protrude from the cavity and bond-

ing wire or ribbon lengths are kept to a minimum. By analyzing only the top layer, this looks like a classic MIC assembly, and all the design roles of MIC assembly apply here.

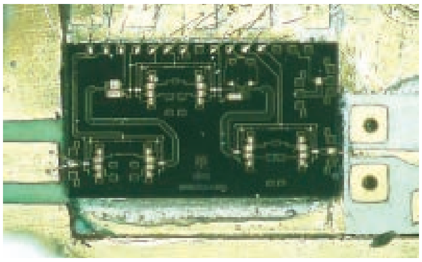
MAIN TECHNOLOGICAL ACHIEVEMENTS

DC and Control Feeds

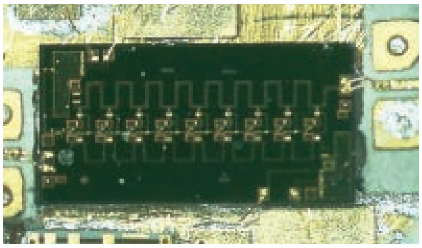
As described above, in MIC technology, the DC and control feeds occupy much of the area around the device. In a multilayer circuit, these lines are routed in the inner layers and pop-out, using a via-hole very close to the device. This reduces the required area significantly. In the top layer, above the DC and control line, the area is used for other functions; various active and passive devices may be assembled without interacting with these internal lines. In ***Figure 7***, a digitally controlled attenuator (DCA) is fed by ten differential command lines, with very modest real estate on the board used for that in particular.



▲ *Fig. 6 Cavity (zoom-in).*



▲ *Fig. 7 Elisra's DCA in multilayer PCB.*



▲ *Fig. 8 Amplifier in a cavity.*

Wideband MIC Device Integration

Since the devices are assembled on a common ground with the RF feeding lines and since the bond wire or ribbon length is kept to a minimum, a very wide band of frequencies is supported. Some products cover a frequency range starting at very low frequencies and reaching millimeter waves. The devices, such as MMICs, alumina matching circuits or discrete chips, are attached directly to the bottom of the cavity. Where the devices are very thin, a metal pedestal may be used in order to align the device with the rest of the circuit. This is a common practice in MIC assembly and works just fine for multilayer circuits as well. The measured performance of devices embedded in the multilayer board is compared to these of standard MIC assemblies. An amplifier in a cavity is shown in ***Figure 8***.

Alumina Passive Devices

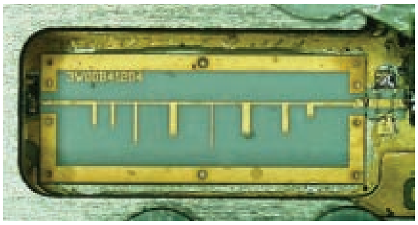
Using the cavities for passive devices that are printed on alumina substrates enables a wide range of applications. An SMT board may now include some alumina filters for high frequencies. Wideband alumina couplers, hybrids and other types of circuits are also easily integrated. Since the alu-

mina substrate is placed directly in the cavity and there is no height difference between the lines printed on the alumina and the lines printed on the multilayer board, excellent frequency response is achieved. A BPF on an alumina substrate integrated on a multilayer PCB is shown in ***Figure 9***.

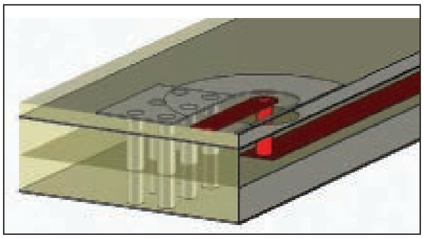
Single-side RF Bypass

As with lower frequencies, it is sometimes necessary to get from one point of the circuit to the other side without interacting with the other components on board. This is done by using a blind via-hole to connect the upper layer transmission line to an inner layer transmission line. For DC and control, only one via-hole will suffice. However, in the RF and microwave world, transmission lines have two parts: the center (or top) line and the ground line (or plane).

Thus, in order to connect a microstrip line on the top to a stripline on an inner layer, the grounding plane must be connected as well. It is therefore required to add more via-holes near the main via-hole in order to maintain grounding continuity. A 3-D model of the transition is shown in ***Figure 10***. The exact dimensions of this transition must be analyzed and optimized, based on the exact dielectric and mechanical properties of the selected layers.



▲ *Fig. 9 BPF in a cavity.*



▲ *Fig. 10 Via-hole microstrip to stripline transition.*

Side-to-side RF Connections

In some multilayer boards, the bottom side is also used for transmission lines, in order to enable more flexibility in signal routing across the board. For that end, a side-to-side connection is used. The design procedures and considerations are similar to that of the single-side RF bypass. However, the resulting dimension after optimization may be different, due to different types and numbers of layers involved. Note that the RF signal is now crossing many layers, each containing different signals. Caution must be used in order to avoid cross-coupling between the RF, DC and control signals. Each layer must be monitored and proximity between RF vias and DC and control lines must be avoided.

Buried Filters

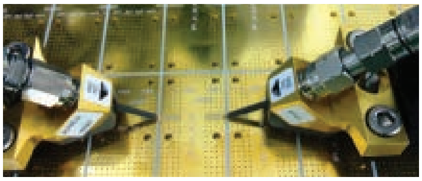
As described above, filters may be constructed on the top layer as lumped elements or as alumina printed circuits. However, in order to save board space, it may be desired to realize the filters in the inner layers. This is done using a standard stripline type of filter. The filters are fed from the top layer and do not take any of the board real estate. More than one fil-

ter may be connected in series in order to improve out-of-band rejection properties. In ***Figure 11***, a coupon of a BPF is shown. Only the input and output transmission lines are visible.

Board Design and Manufacture Challenges

Multilayer board design is not as straightforward as it seems. First of all, the number of layers and their composition must be selected. The top layer, bottom layer and inner RF layer material is chosen. This material must support the highest frequency used within the board with minimum loss.

The thickness of the RF layer must be carefully selected. Thin layers will yield very thin RF lines, which are more difficult to manufacture, have higher loss and are prone to mechanical damage. The thickness of the top layer, where the cavities are realized, must be compatible with the thickness of devices and alumina substrates to be used within the cavities. Once the RF layers have been selected, more DC and control layers are introduced. It is important to keep the board symmetric, so that it does not bend after production and assembly. Sometimes, it is necessary to add an additional layer just to keep the board cross-section symmetric.



▲ *Fig. 11 Stripline filter on a coupon.*

The next step is to decide how many types of via-holes are to be used. The more types of via-holes used, the more production steps are needed. This is a major cost and yield factor. Another limitation is that not all via-hole combinations are possible. For example, take an 11-layer board. A side-to-side via-hole is the 1-11 via-hole.

If an internal RF line is used, the designer may want to use the 1-x via-hole, where x is the inner line index. Once a designer has decided on that, it is not possible to use a y-11 via-hole if y has values between 1 and x. Thus, it is impossible to manufacture such a circuit. What is easily possible with LTCC circuits becomes a limitation in multilayer technology.

Once all the layers are selected and all the via-holes are defined, a survey of manufacturers must be conducted. Not all PCB manufacturers can handle RF cavities. In the standard PCB world, if some adhesive film spills out from inside the board to the cavity, this is not a critical issue. However, for RF assemblies, this may cause the alumina circuits or discrete components to be unleveled and have poor grounding. The cavities must have a perfectly clean metal bottom and perfectly straight walls, as seen in Figure 6.

PRODUCT EXAMPLES

Wideband DIFM

The wideband digital instantaneous frequency measurement (DIFM) module (Elisra Microwave Division) is a wideband receiver. This receiver covers the 2 to 18 GHz instantaneous bandwidth. Any signal, from a short 100 nanoseconds single pulse up to CW within this frequency range, shall be detected and its frequency shall be measured. The frequency measurement has a resolution of 0.9 MHz with an accuracy of

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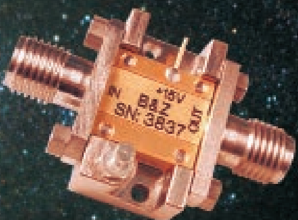

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Model	Frequency Range (GHz) Start	Frequency Range (GHz) Stop	Noise Figure (dB) (dB) Max.	Gain (dB) (dB) Min.	Output P1dB (dBm) Min.	Gain Flatness (± dB) Max.	VSWR In / Out
BZP140A	0.1	40	5.5	26	8	2.5	2.5:1
BZ1840A	18	40	4.7	23	8	2.5	2.5:1
BZ1840B	18	40	4.7	32	8	2.8	2.5:1
BZ2640A	26	40	4.5	24	8	2.5	2.5:1
BZ2640B	26	40	4.5	32	8	2.6	2.5:1
BZP126A	0.1	26	4.5	28	10	2.0	2.5:1
BZ1826A	18	26	2.5	27	8	1.5	2.0:1
BZP118A	0.1	18	2.5	30	8	1.5	2.5:1
BZP118F	0.1	18	5	22	17	2.0	2.5:1
BZ0218A	2	18	2.3	30	8	1.5	2.3:1
BZ0218F	2	18	3.5	28	25	2.0	2.3:1
BZ0618B	6	18	1.8	28	8	1.5	2.3:1
BZ0618A	6	18	2.3	30	8	1.5	2.3:1
BZ0618F	6	18	3	28	25	1.5	2.0:1
BZ0818A	8	18	1.7	28	8	1.5	2.0:1
BZ1218A	12	18	2.3	30	8	1.5	2.3:1
BZ1218F	12	18	3	30	26	1.0	2.0:1
BZP112A	0.1	12	2	24	8	1.5	2.3:1
BZ0412A	4	12	2.3	30	8	1.5	2.3:1
BZ0612A	6	12	2.3	30	8	1.5	2.3:1
BZ0812A	8	12	1.5	28	8	1.0	2.0:1
BZ0812F	8	12	3	28	27	1.0	2.0:1
BZP108A	0.1	8	1.7	24	8	1.4	2.3:1
BZ0208B	2	8	1.5	24	8	1.5	2.0:1
BZ0208A	2	8	2.3	30	10	1.5	2.3:1
BZ0208F	2	8	3	28	27	1.0	2.0:1
BZ0408F	4	8	3	28	27	1.0	2.0:1
BZP106A	0.1	6	1.2	24	8	1.0	2.0:1
BZ0206A	2	6	1.2	24	8	1.0	2.0:1
BZ0206B	2	6	2.3	30	12	1.0	2.0:1
BZP104A	0.1	4	1.3	24	8	1.3	2.3:1
BZP504A	0.5	4	1.2	24	8	1.0	2.0:1
BZ0104A	1	4	1.3	24	8	1.5	2.0:1
BZ0204A	2	4	1.2	24	8	1.0	2.0:1
BZ0204F	2	4	3	28	27	1.0	2.0:1
BZP103A	0.1	3	1.2	24	8	1.3	2.3:1
BZP102A	0.1	2	1.1	24	8	1.3	2.3:1
BZP502A	0.5	2	1.2	24	8	1.0	2.0:1
BZ0102A	1	2	1.2	24	8	1.0	2.0:1

Note: Specifications degrade slightly below 500 MHZ

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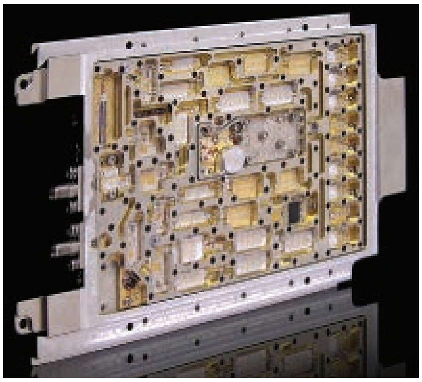
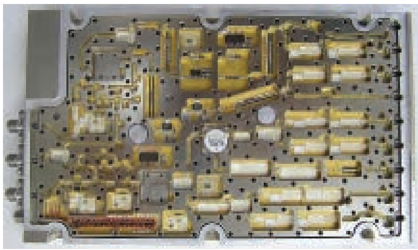
2.5 MHz RMS. The DIFM covers 60 dB of dynamic range, down to signal levels of -55 dBm. The DIFM is capable of accurately measuring the signal's frequency within a SNR of 3 dB. The module is housed in a 152 × 147 × 30 mm package and dissipates 24 W. The RF side of the module is shown in ***Figure 12***.

Narrow Band Receiver

The narrow band receiver (NBR) module is a classical superheterodyne receiver. This receiver covers the 0.5 to 18 GHz band and may zoom in to any required sub-band with various IF bandwidths. The NBR covers 80 dB of dynamic range, down to signal levels of -75 dBm. Once a threat is detected, the NBR jumps to that sub-band within 50 nanoseconds. The signal is converted to a video signal for amplitude measurement and converted to the IF frequency for further analysis. The module is housed in a 152 × 147 × 30 mm package and dissipates 24 W. The module is shown in ***Figure 13***.



▲ *Fig. 12 DIFM unit.*



▲ *Fig. 13 Narrow band receiver.*

FUTURE TRENDS

As MMIC packaging techniques improve, more devices are becoming available in the SMT package for increasing frequencies. This enables multilayer circuits to contain more SMT devices and fewer cavities. This trend reduces the cost of the module. However, the size of the module may be affected, since the SMT device may need more real estate on the board than a die component in a cavity.

One current area of research is substrate integrated waveguide (SIW) components. Using this technique, some of the alumina filters may be replaced by SIW filters. Another trend is that both sides of the PCB are used for RF with cavities. This enables twice as much area on board for die and alumina circuits. However, the cost and the yield of the PCB and the assembly costs become higher.

As system designers push for more functionality in ever decreasing volumes, engineers are going to come up with new and creative ways to accommodate this need. Multilayer is just one more step in this direction. ■

All the photos in this article are courtesy of the Elisra Microwave Division.

Ronen Holtzman *is a Senior Scientist in the CTO Division of Elisra Electronics Systems Ltd. He has more than 20 years experience and is a specialist in RF and microwave super-components and subsystems.*

Boonton
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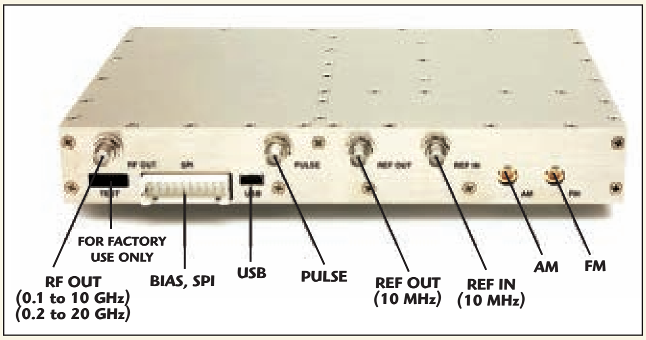
Boonton 4500B Pulse
Measurement
Display
CLEAR
Measure Mode
Pulse
Auto-Setup
START
Exit
MENU
Peak Power Sensor

A Compact Synthesizer Module Offers Instrument-grade Performance and Functionality

Alexander Chenakin,
Vice President of the Signal Sources Group at Phase Matrix.
Visit www.mwjournal.com to read this in-depth interview.

To address today's market requirements for a low-cost, high-performance frequency synthesizer, Phase Matrix has introduced the QuickSyn™ series of microwave frequency synthesizers. The employed patented architecture provides a unique combination of fast-switching speed and low phase noise characteristics. The main idea is to substitute a slow-tuning, bulky and expensive YIG oscillator (normally used in high-end designs) with a tiny VCO that can easily support microsecond tuning. Excessive phase noise (traditionally associated with VCO devices) is suppressed by utilizing an ultra-wideband PLL scheme in conjunction with a low-noise reference source. In contrast to traditional architectures (which tend to minimize the PLL division ratio), this new technology makes a radical step by completely removing the divider from the loop. Moreover, it inverts the PLL division ratio by applying a multiplication within the PLL that drastically improves both phase noise and spurious characteristics. These characteristics are achieved by using low-cost, general-purpose ICs, which are offered as standard "off-the-shelf" parts. Inside any synthesizer, there are always many devices that can potentially carry multiple functions and be reused to increase functionality without a significant cost penalty. This philosophy has resulted in a compact design (see ***Figure 1***), which demonstrates excellent performance and extended functionality.



▲ *Fig. 1 QuickSyn™ synthesizer with module-level size and cost.*

FREQUENCY COVERAGE AND RESOLUTION

The QuickSyn synthesizer is available in two models, the FSW-0010 and FSW-0020, covering

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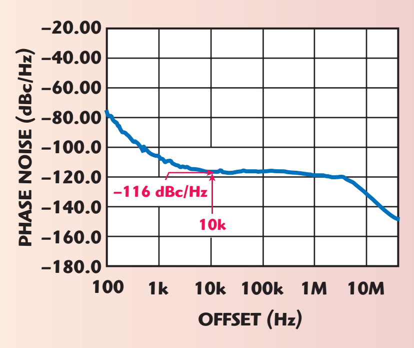
0.1 to 10 GHz and 0.2 to 20 GHz, respectively. Both models utilize broadband solid-state VCOs that offer fundamental output to 10 and 20 GHz, respectively. In contrast to widely used frequency multiplication schemes, this approach eliminates possible spectrum contamination by sub-harmonic products. The VCO coverage is extended down by utilizing a frequency divider that improves phase noise and spurious characteristics at lower frequencies. The use of the advanced direct digital synthesis (DDS) approach (in conjunction with dedicated spur-reduction circuitry) enables a very fine frequency resolution of 0.001 Hz without a common penalty of slower tuning speed or elevated spurs.

The synthesizer includes a highly stable internal OCXO that is factory calibrated to a GPS standard to ensure adequate accuracy of the synthesized signal. The OCXO supplies a 10 MHz reference signal to the outside world. The internal oscillator can be automatically locked to an external reference too. The synthesizer also provides the ability to adjust the internal oscillator frequency (via software) for temperature and aging compensation as desired.

SWITCHING SPEED

The utilized PLL hardware itself needs just a few tens of microseconds to bring the output frequency to a desired value while the output is completely locked and refined within less than a hundred microseconds. Digital signal processing adds extra delays required to receive a tuning command, perform all necessary calculations in accordance with the employed frequency plan, and program individual devices. Hence, the total switching time is specified at 200 μsec in the regular operation mode when new frequency commands are sent one-by-one. Most of these delays, however, can be reduced or completely eliminated in the list mode. The switching speed in the list mode is specified at 100 μsec regardless of the current and destination frequency (i.e., the specification is valid from "any to any" frequency step within the entire operating range). Furthermore, the synthesizer provides a software-selectable blanking function that allows turning-off the RF output while it transitions to the new-programmed frequency. This prevents the output frequency uncertainty



▲ *Fig. 2 Phase noise performance at 20 GHz output.*

that otherwise may result in unexpected behavior of a system where the synthesizer is utilized.

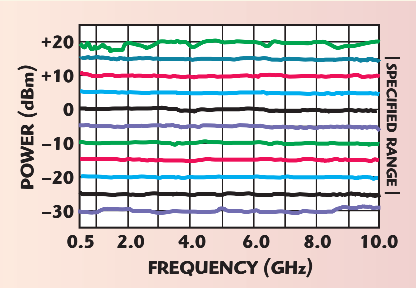
SPECTRAL PURITY

VCO phase noise is controlled by utilizing an ultra low-noise reference OCXO as well as a very wide (a few MHz) loop bandwidth. The employed architecture allows realizing nearly "ideal" frequency translation with minimal added phase noise degradation. Typical phase noise measured at a 20 GHz output and a 10 kHz offset is -116 dBc/Hz, as shown in ***Figure 2***. The phase noise at a 10 GHz output drops down to -122 dBc/Hz, which supersedes the performance of traditional YIG-based synthesizers at the same frequency settings. Phase noise remains flat to a few MHz offset then rolls down sharply showing about -153 dBc/Hz noise floor. At lower output frequencies, phase noise is further improved at 6 dB per octave rate resulting from the employed frequency division scheme.

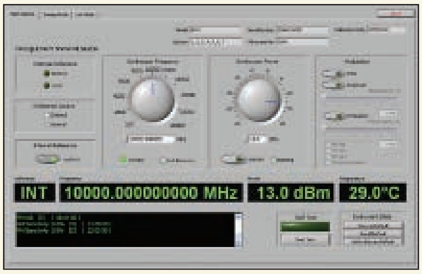
In contrast to conventional designs, the employed technology does not elevate any PLL-induced spurs (since the multiplication factor equals unity or below unity within the loop). As a result, the output is clean of spurious perturbations to typical levels of -80 dBc and even lower. Note that it is quite hard to measure the spurs at these levels since they become comparable to the spurs generated by the test equipment itself. Thus, the spurious emission is specified at -65 dBc to simplify product testing in mass production. A filter bank at the synthesizer output reduces generated harmonics, which typically do not exceed -40 dBc. Another benefit of the utilized approach is reduced microphonics as a result of the use of a low-mass VCO and very wide loop filter bandwidth.

OUTPUT POWER

The synthesizer supplies almost +20 dBm unleveled output power that is calibrated and digitally controlled between -25 and +15 dBm (FSW-0010 model), as shown in ***Figure 3***. The FSW-0020 control range is -10 to +13 dBm. The output power is controlled using an open-loop method that ensures extremely fast output power settling. The design also includes sophisticated temperature compensation resulting in flat and repeatable output power characteristics across operating frequency and temperature ranges. The output power can also be turned off (i.e., muted) by switching off the output power amplifier. Note that the VCO and PLL core remain turned on, which minimizes recovery time when the synthesizer is back to normal operation.



▲ *Fig. 3 The FSW-0010 model supplies –25 to +15 dBm leveled output.*



▲ *Fig. 4 QuickSyn™ GUI emulates traditional bench-top signal generators.*

EXTENDED FUNCTIONALITY

The QuickSyn communicates with the external world via SPI interface, which provides high throughput and flexibility. In addition to the SPI, the complimentary USB connection offers instant deployment of the synthesizer using a personal computer. The QuickSyn comes with a GUI that emulates virtually all functions available in traditional bench-top and rack-mountable signal generator instruments, as illustrated in ***Figure 4***.

The QuickSyn offers both frequency and power sweep functions in two modes. The fast sweep mode ensures very fast switching speed by calculating all necessary parameters prior to initiating a sweep. A disadvantage is a limited number of points (32,000) due to internal memory limitations. Alternatively, in the normal mode, all calculations are made on the fly, thus enabling an unlimited number of points. The list mode offers even better flexibility by storing a list of frequencies and power levels in the synthesizer's memory. The list is executed by sending a proper command or by applying a trigger signal. Once the CPU detects a trigger pulse, it commands the synthesizer to move from one frequency-power state to another according to the programmed list. Alternatively, the synthesizer can go to the next state, stop there, and wait for the next trigger pulse; the process then repeats.

Furthermore, the QuickSyn provides all major modulation capabilities including pulse, amplitude, frequency and phase modulation. For example, when the pulse modulation is enabled, the synthesizer accepts external CMOS pulses that turn on and off the synthesizer's output with a better than 80 dB on/off ratio and 10 nsec rise/fall time. Similarly, the AM and FM functions are realized by applying a modulating signal to a proper input and enabling a desired mode. Both AM and FM input sensitivity is adjustable by software. Note that the inputs are DC coupled, thus the user can change both amplitude and phase of the synthesized signal by varying a DC voltage on a proper input.

The synthesizer is shielded in a small metal box and is biased from a single +12 V DC supply. The nominal power consumption is less than 18 W for the FSW-0010 model and 20 W for the FSW-0020 model. The built-in self test monitors the synthesizer's internal temperature and voltages as required. Overall, the exceptional performance, extended functionality and small footprint make the QuickSyn synthesizer an ideal building block for a variety of instruments and subsystems.

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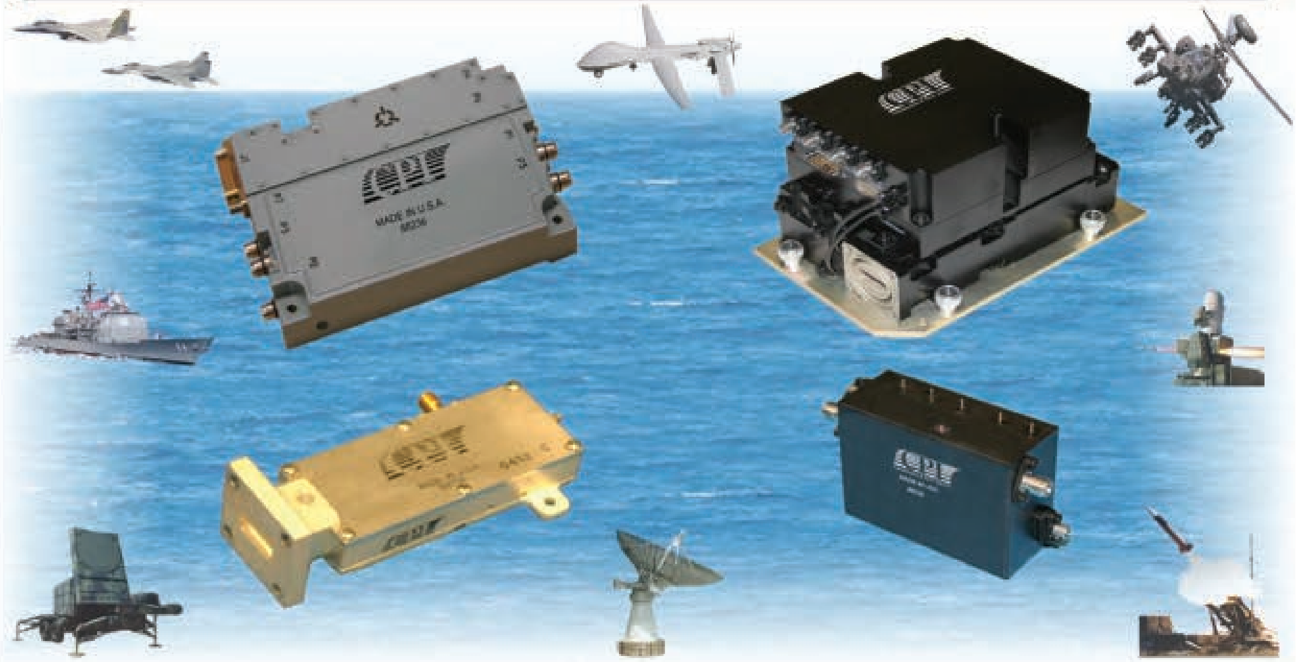

Dan Massé, Associate Technical Editor

Raytheon Awarded Contract for F/A-18 Super Hornet AESA Radars

The US Department of Defense is awarding Raytheon a $52.25 M contract modification for 19 APG-79 active electronically scanned array (AESA) radars to be retrofitted into F/A-18E/F aircraft, Lots 26-29. The APG-79 AESA radar, which will replace the APG-73 radar, will provide increased air-to-air detection and track range, increased air-to-ground targeting capabilities, longer launch range for standoff weapons, enhanced capability against advanced threats, and optimized utilization of the Super Hornet's weapons systems. The contract was awarded to Raytheon Space and Airborne Systems of El Segundo, CA. The work will be performed in Forest, MS (43 percent); Dallas, TX (29 percent); El Segundo, CA (27 percent); and Andover, MA (1 percent), and is expected to be completed in December 2013. Contract funds will not expire at the end of the current fiscal year. The Naval Air Systems Command, Patuxent River, MD, is the contracting activity. This award is a modification to a previously awarded firm-fixed-price contract (N00019-09-C-0003).

ITT Awarded Contract for Band C Counter Radio-control IED Systems

The US Naval Sea Systems Command has awarded ITT Corp. a contract to produce 425 Band C systems and their related spares and equipment for $16.7 M. Band C is an upgrade for the US military's installed base of vehicle-mounted systems that prevent the detonation of radio-controlled improvised explosive devices (RCIED). This award brings the total number of Band C systems on contract to 1,121 for a total contract value of $39 M to date. The initial contract was awarded in April 2010.

The Band C system will work with the currently fielded counter-RCIED electronic warfare (CREW) vehicle receiver jammers (CVRJ) to address a broader frequency range of the evolving spectrum of electronic warfare threats. This upgrade will provide greater capabilities while the longer term development of the next generation of counter-IED systems matures.

This award brings the total number of Band C systems on contract to 1,121 for a total contract value of $39 M to date.

"As threats evolve, our technologies must keep pace," said Chris Bernhardt, President of ITT's electronic systems business. "Our Band C systems are critical technology upgrades designed to respond to more threats and give our forces enhanced capabilities to perform their missions more safely."

The CVRJ and Band C programs are satisfying an urgent Department of Defense requirement for increased system production in order to prevent the detonation of radio-controlled IEDs. These counter-IED devices are being used by soldiers, sailors, airmen and Marines on various armored vehicles and other military transport equipment, and are deployed to current military operations in Iraq and Afghanistan.

ITT's electronic systems business is a supplier of information and electronic warfare (EW) technologies, systems and services that enable mission success and survivability. Key technologies include integrated EW systems for a variety of aircraft, reconnaissance and surveillance systems for air and sea-based applications, force protection and counter-IED systems, precision landing and air traffic systems for military applications, and undersea systems encompassing mine defense, naval command and sonar systems, and acoustic sensors. In addition, the business produces aircraft armament suspension and release equipment, electronic weapons interface systems, and advanced composite structures and subsystems.

Lockheed Martin Completes Next-generation Long-range Surveillance Radar Demonstrations

Lockheed Martin has successfully completed a capability demonstration in the latest phase of the US Air Force's development of the next-generation mobile, long-range surveillance and ballistic missile defense radar. The demonstration of December 16 and 17, 2010, for the Three-Dimensional Expeditionary Long-Range Radar (3DELRR) was the second and final required under a $25 M, 20-month technology development contract awarded in May 2009. Lockheed Martin completed an initial demonstration of critical technology elements in March 2010 and an initial preliminary design review in October 2010.

"Lockheed Martin has made significant investments in 3DELRR to reduce risk and drive affordability."

The 3DELRR will serve as the principal long-range, ground-based sensor for detecting, identifying, tracking, and reporting aircraft and missiles for the Air Force. The system will replace the Air Force's AN/TPS-75 air surveillance radar. The Marines also are evaluating the system as a replacement for its AN/TPS-59 ballistic missile defense radar.

"Lockheed Martin has made significant investments in 3DELRR to reduce risk and drive affordability," said Program Director Mark Mekker. "We have applied both new technology advances and our knowledge gained from decades of experience developing and maintaining 178 long-range surveillance radars currently operational around the world."

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During the demonstration, Lockheed Martin unveiled a functioning system prototype to Air Force and Marine Corps officials as proof of the radar's maturity. The radar's design addresses 100 percent of 3DELRR requirements, including critical extended air surveillance reach for early warning from threats, such as aircraft and ballistic missiles.

The Electronic Systems Center at Hanscom Air Force Base, which is leading the acquisition for 3DELRR, plans to award one contract by early 2012 to complete the 3DELRR technology development and engineering manufacturing development phases.

Harris Awarded IDIQ Contract to Provide Tactical and Land Mobile Radios to US International Partners

Harris Corp., an international communications and information technology company, has been awarded an indefinite delivery, indefinite quantity (IDIQ) contract with a potential total value of $475 M to supply military and land mobile radio systems to international partners of the US State Department and US Department of Defense. The five-year contract, awarded by the US Army's Communications Electronics Command (CECOM), certifies Harris as a provider of radios, accessories, communication systems and services to assist US partners with their tactical communication needs. The contract is part of the US government's Foreign Military Sales program, which support coalition building and interoperability through sales of defense equipment, training and services. The contract covers the Harris RF Falcon II® and Falcon III® radio portfolio—such as the RF-7800M Multiband Networking, and RF-7800S Secure Personal radios—as well as public safety and professional communications land mobile radios.

...a potential total value of $475 M to supply military and land mobile radio systems...

Harris RF Communications is a global supplier of secure radio communications and embedded high-grade encryption solutions for military, government and commercial organizations. The company's Falcon® family of software-defined tactical radio systems encompasses manpack, handheld and vehicular applications. Falcon III is the next generation of radios supporting the US military's Joint Tactical Radio System (JTRS) requirements, as well as network-centric operations worldwide. Harris RF Communications is also a supplier of *assured communications®* systems and equipment for public safety, utility and transportation markets, with products ranging from the most advanced IP voice and data networks to portable and mobile single- and multiband radios.


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UniverSelf Initiative to Tackle Complexity of Communication Networks

A group of 17 leading European telecommunications service providers, IT corporations, infrastructure vendors and academic institutions have launched UniverSelf, a research initiative whose goal is to overcome the increasing complexity of managing communication networks and enable their future growth by generating innovations in autonomic networking—technologies that enable networks to manage themselves.

The solutions UniverSelf creates will benefit the European ICT industry by creating new business opportunities and standards and benefit EU citizens by improving Quality of Service and performance. It will also benefit telecommunications service providers and network operators by reducing time-to-market and increasing savings in operational expenditure through the optimization of human resources and a reduction in manual errors.

> *"UniverSelf… is an ideal instrument to start engineering autonomics and make them a reality in operational networks."*

UniverSelf is supported within the scope of the European Union's 7th Framework Programme (FP7) for Research and Technological Development from which it has received €10 M funding. The research initiative will last 36 months, until 2013.

Martin Vigoureux, Research Director at Bell Labs and Project Coordinator, said, "It is time to take self-management to the next level. UniverSelf, driven by customer needs and focused on the industrial impact of research, is an ideal instrument to start engineering autonomics and make them a reality in operational networks. Numerous challenges lie ahead, but delivering efficient, converged and trustworthy solutions, together with the appropriate standards, is essential to reach true operational benefits and wide deployments."

e2v and University of Nottingham Announce Collaboration

e2v and the University of Nottingham, UK, have formed a new partnership in the area of microwave semiconductor devices, which aims to drive forward the research and manufacturing of cutting-edge electronics. The aim of the collaboration is to develop and manufacture advanced semiconductor devices for use in microwave and terahertz applications.

Funding of £1 M from e2v will see a new purpose-built clean room built at the School of Physics and Astronomy on University Park, housing the e2v semiconductor fabrication facility. The company's engineers will also have access to the existing nano-fabrication facilities within the school, as well as the wide range of advanced materials characterization instruments available on campus. Physicists at Nottingham will also have access to the e2v fabrication tools.

> *"We will now be able to harness specialised semiconductor knowledge from both organisations and work together to provide new exciting solutions..."*

This initiative will enable close collaboration with researchers in the School of Physics and Astronomy and help e2v to develop the next generation of microwave electronic devices. An example of this is a range of devices known as PIN diodes, which are used in sensitive microwave receiver systems. The collaboration's initial focus will be to develop new devices which have a much faster response time than currently available and can work over wider frequency ranges.

RF/microwave frequency sources used in radar imaging, as well as mixers and detectors used in the receive chain, are also high on the agenda for the collaboration. In addition, the scope of work on novel devices will extend to sub-millimetre wave and beyond, where there is a strong interest in devices for high-resolution imagers which can 'see' through other materials such as clothing or buildings.

Nigel Priestley, Chief Engineer at e2v, said, "This is an excellent example of industry and academia making the decision to collaborate at both the research level and device realisation level. We will now be able to harness specialised semiconductor knowledge from both organisations and work together to provide new exciting solutions for the e2v business and customers."

NEULAND Project Addresses Energy Efficiency

Six partners from the semiconductor and solar industries are joining forces in the NEULAND project funded by the Federal Ministry of Education and Research (BMBF), Germany, to explore new avenues for the efficient use of electricity from renewable sources. NEULAND stands for innovative power devices with high energy efficiency and cost effectiveness based on wide bandgap compound semiconductors.

The project aims to reduce the losses in feeding electricity into the grid without significantly increasing system costs. This is to be achieved using innovative semiconductor devices based on silicon carbide (SiC) and gallium nitride on silicon (GaN-on-Si). The new semiconductor devices are also to be used in future in switched-mode

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NEULAND project… to explore new avenues for the efficient use of electricity from renewable sources…

power supplies for telecommunication systems, desktop and laptop PCs, flat-screen TVs and servers with the aim of reducing energy losses for such applications by about half.

The NEULAND project will run until mid-2013 and is headed by Infineon. The project consortium brings together outstanding expertise in SiC and GaN across a very wide area of the value chain. The project will receive funding at 52.6 percent to the tune of approximately €4.7 M from the BMBF under the German Federal Government's "High-Tech Strategy – Information and Communications Technology 2020," ICT 2020 program, as part of the call for proposals on Power Electronics for Energy Efficiency Enhancement.

ESA and Canada Renew Space Partnership

Jean-Jacques Dordain, Director General of the European Space Agency (ESA), and Steve MacLean, President of the Canadian Space Agency, signed a new Cooperation Agreement that will extend the partnership between ESA and Canada until 2020. The two space agencies have enjoyed a 30-year partnership that has led to many successful space projects and they will continue to build on their shared interests.

"[The agreement] will build a bridge across the Atlantic that is even more solid…"

ESA and Canada have joined forces in telecommunications, including Olympus, Artemis and Advanced Research in Telecommunications Systems (ARTES); Earth observation, including ERS, Envisat and Global Monitoring for Environment & Security (GMES); navigation, including Galileo; and related technologies, such as the General Support Technology Programme.

The benefits of the ESA-Canada relationship extend beyond good cooperation between the two space agencies. European and Canadian companies have forged strong alliances, creating teaming arrangements and opportunities for new markets.

"With this signature today, we are opening a new chapter that will offer opportunities for Canadian contributions to ESA's programmes and ESA contributions to Canadian programmes," said Dordain. "It will build a bridge across the Atlantic that is even more solid, and that will allow us to draw on our respective strengths and expertise while taking into account our respective evolutions."

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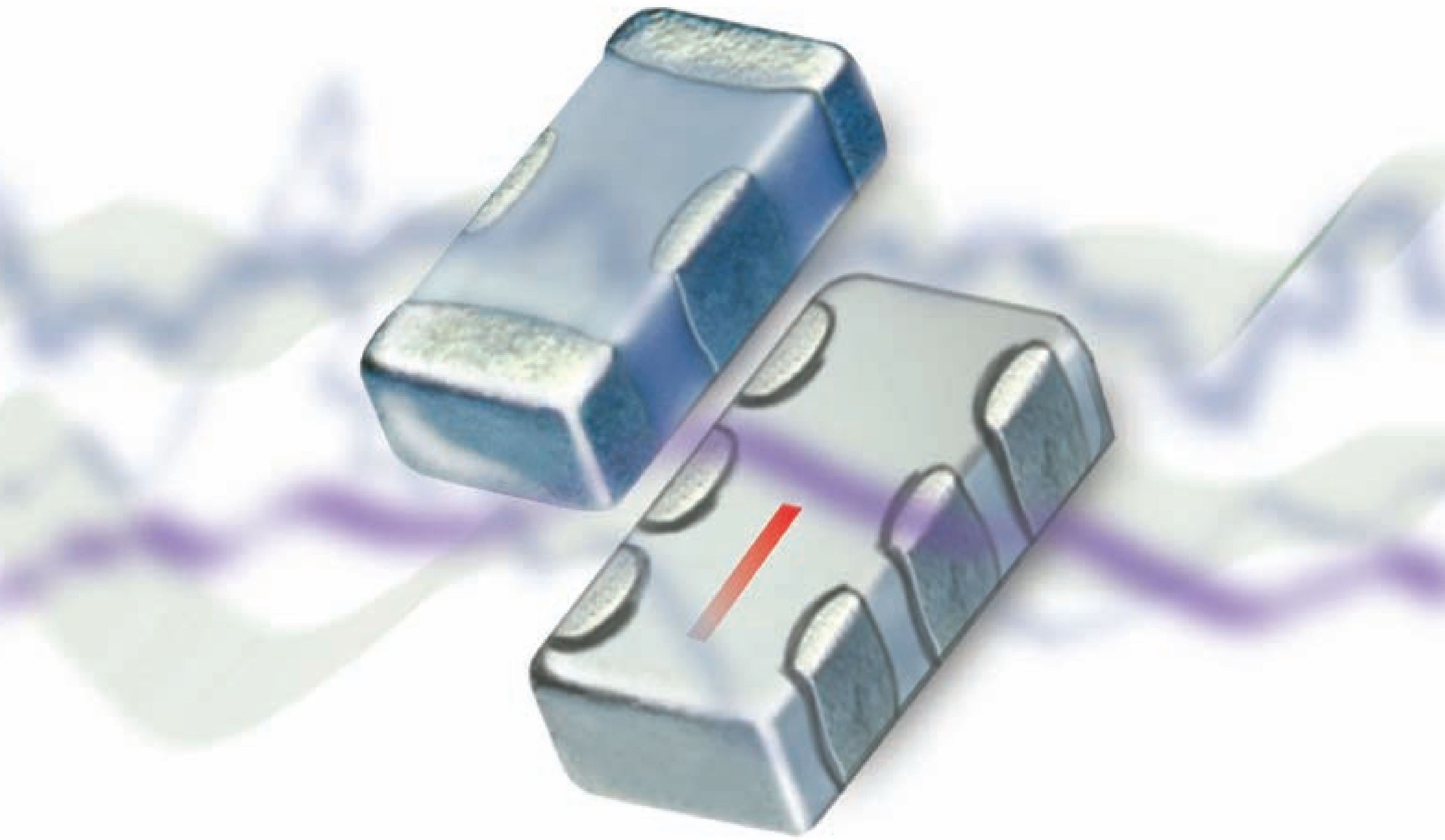
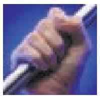




LTE Services in US Will Generate More Than $11 B in 2015

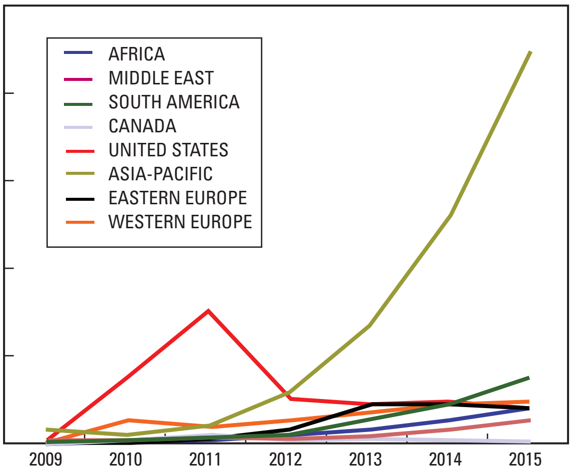
When it comes to mobile network infrastructure discussions, LTE is the name on everyone's lips. Yet the very meaning of the acronym—"Long-Term Evolution"—is a hint that it is not going to happen overnight. LTE's deployment as the mainstay 4G technology will take place gradually, and will not even begin to gather real steam until 2013. Nonetheless, LTE is forecast by ABI Research to generate more than $11 B in service revenue in the US in 2015, with nearly a further $650 M to come from Western Europe.

The LTE service revenue growth curve for Western Europe is practically a straight line. That contrasts sharply with constantly accelerating revenue growth in the US, and is largely due to the sometimes exorbitant amounts European network operators paid for their 3G spectrum; many of those operators want to squeeze every drop of value from their 3G investments before migrating to 4G.

… LTE is forecast… to generate more than $11 B in service revenue in the US in 2015…

- How many subscribers will LTE have in the long term?
- How fast will LTE grow until 2015?
- How much will be spent on LTE infrastructure and/or user equipment?

ABI Research's "LTE and LTE-Advanced" study gives an LTE and LTE-Advanced standards overview and update, considering trends, network architecture, and the elements that make up that architecture, as well as approaches and strategies. Forecasts include device and equipment shipments broken down by region, as well as subscribers, service revenue and ARPU. It is part of the 4G Research Service.



Source: ABI Research

Innovative Micro Technology Adds to Arsenal of Through Silicon Via Offerings

Innovative Micro Technology announced the addition of a new geometry point in its technology roadmap for Through Silicon Vias (TSV). Joining the copper-filled 15 by 60 micron depth TSV configuration that has been in production for nearly two years, IMT has been sampling its 50 by 250 micron copper-filled TSV, which is planned for production shortly after the first of the year.

Enabled to reach new system performance levels, RF applications are taking advantage of shorter signal paths achieved through vertical integration, while enjoying negligible insertion loss and resistivity offered by the copper-filled TSVs. TSV integration has propagated into a host of other functions exploiting the benefits of minimized signal loss and the reduction of device footprint, the latter driven primarily by mobile applications. Complemented by wafer- and system-level assembly and packaging, TSVs are a critical element in enabling next-generation 3D integration.

"We have a program in production today that implements over 140,000 TSVs on a single wafer."

While IMT offers a polysilicon TSV, recent emphasis has been placed on copper due to the material's high performance characteristics. IMT's copper-filled TSV exhibits less than 0.01 ohms of resistance and an insertion loss of 0.01 dB at 6 GHz. Responding to market demand, IMT is continuing development of metal-filled TSVs and plans to introduce TSVs with a 10:1 aspect ratio in the second half of 2011.

"There has been a steady increase in usage of our TSV technology over the last two years, initially driven by our work in the RF market," said John Foster, CEO of IMT. "More recently, interposer applications and markets such as optical and even life science have found it necessary to implement our TSVs as integration is on the rise in both areas. We have a program in production today which implements over 140,000 TSVs on a single wafer. We expect that TSV usage will continue to excel."

TD-SCDMA, China and GSM Still Lead RF Power Amplifier and Device Markets

Rapid Chinese TD-SCDMA rollouts and the often-maligned GSM/GPRS/EDGE equipment markets have benefited the base station RF power amplifier and RF power device markets. GSM/GPRS/EDGE RFPAs and devices are still shipping in the millions. The Asia-Pacific region is presently accounting for more than 50 percent of the RF power semiconductor devices sold into the mobile wireless infrastructure segment.

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"Recent Chinese TD-SCDMA base station deployments have been massive and have buoyed RF power vendor to a tremendous degree."

Now, according to Research Director Lance Wilson, "Recent Chinese TD-SCDMA base station deployments have been massive and have buoyed RF power vendor to a tremendous degree." That demand is expected to strengthen the market until at least sometime in 2011, and the Chinese deployments will probably only start to slow in 2012. And, in a happy coincidence for equipment vendors, 2011 is the expected time frame for LTE deployments in developing countries to really gather a head of steam. "Although LTE has not significantly impacted RF power amplifier and device sales in the near term," says Wilson, "it is going to bolster RF power sales in the wireless infrastructure space from about 2011 on." Wilson also notes that since the previous edition of ABI Research's report on this market, there have been some modest changes in the breakdown of market share held by the leading RF power device vendors.

"RF Power Amplifiers" examines evolving design parameters and materials, price versus performance and interdependent relationship of RF power semiconductors to RF power amplifiers. Quantitative forecasts are presented through 2015 for both segments. It is included in two of the firm's research services: Mobile Networks and Semiconductors.

Worldwide Digital Set-top Box Market to Hit 226 Million Shipments in 2015

The worldwide market for digital set-top boxes—including hard-to-track free-to-air satellite (DBS) boxes—will grow from 205 million in 2010 to 226 million in 2015. Shipments in North America and Western Europe are falling following largely successful digital transitions, while Asia-Pacific, Latin-America and Eastern Europe all see significant growth. Set-top boxes in China will grow at nearly 10 percent per year (CAGR).

"Cable Boxes decline in the short term due to cable's failure to compete in the North American markets; however, they grow in the long term due to significant numbers in China and, to a lesser extent, India," says ABI Research Senior Analyst Sam Rosen. "Digital terrestrial (DDT) boxes see the largest platform growth worldwide as countries in Asia-Pacific and Latin America move through their digital transitions and toward analog shutoff (ASO) of broadcasts."

In Memory of...

Microwave Journal's co-founder and first editor, **Ted Saad** passed away January 25th, 2011. In addition to putting his stamp on this magazine, Saad had a long and influential career that touched many in the industry and microwave technical society. Saad worked at MIT Radlab between 1942 and 1945, studying low pressure, high power waveguide components for the war effort. After the war, he and others, including Dr. Henry Riblet, formed the Microwave Development Lab (MDL) as well as Sage Labs in 1955. In 1958, he and William Bazzy launched *Microwave Journal,* and later Artech House. Saad was one of the organizers and first chairman of the Boston chapter of the PGMTT and the editor of *The Transactions* publications. Saad was a life fellow of the IEEE MTT-S. Look for the *Microwave Journal* remembrance of Ted Saad, coming in March.

INDUSTRY NEWS

Raytheon Co. announced that it has signed a definitive acquisition agreement with **Applied Signal Technology Inc.**, a leader in the collection and processing of communications signals to support tactical and strategic intelligence missions. The agreement has been approved by the boards of directors of both companies. Under the terms of the agreement, Raytheon will commence a tender offer to purchase all of the outstanding shares of Applied Signal Technology Inc. common stock at a price of $38.00 per share in cash for an aggregate purchase price of approximately $490 M, net of cash acquired. Pending the successful completion of the tender offer, the transaction is expected to close in the first quarter of 2011 subject to customary closing conditions and regulatory approvals. The transaction is not expected to have a material effect on Raytheon's earnings.

Mercury Computer Systems Inc., a trusted ISR subsystems provider, announced that it has completed the acquisition of **LNX Corp.** Based in Salem, NH, LNX designs and builds next generation RF receivers for signals intelligence, communications intelligence as well as electronic attack applications. Under the terms of a stock purchase agreement, Mercury acquired LNX for an all-cash purchase price of $31.0 M plus an earn-out of up to $5.0 M payable upon the achievement of financial targets in calendar years 2011 and 2012. The acquisition was funded with cash on hand, and is expected to be neutral to modestly accretive within the first year.

Peregrine Semiconductor Corp., a provider of high performance radio frequency (RF) integrated circuits (IC), and **Soitec** (Euronext Paris), a supplier of silicon-on-insulator (SOI) wafers and advanced solutions for the electronics and energy industries, announced the joint development and ramp in production of a new bonded silicon-on-sapphire (SOS) substrate that has been qualified for use in manufacturing Peregrine's next-generation STeP5 UltraCMOS™ RF IC semiconductors.

RFMW Ltd. announced the opening of direct sales and distribution offices in Europe. RFMW is a specialized distributor that uniquely provides customers and suppliers with focused distribution of RF/microwave components as well as customer specific component engineering support.

The Power Distribution Systems (PDS) Division of **Rogers Corp.** has been awarded International Railway Industry Standard (IRIS) certification for its laminated busbar manufacturing facility located in the Suzhou Industrial Park in Jiangsu Province, China. The Rogers PDS-China manufacturing facility is the first laminated busbar manufacturer in China to obtain IRIS certification. The IRIS certification, developed by the Association of the European Railway Industry (UNIFE), has been modeled on similar quality standards already in place in the aerospace and automotive industries. It complements the internationally recognized ISO 9001 quality standard for rail specific requirements.

Anritsu Co. announced that it has received a prestigious 4GWE Wireless LTE Visionary Award from Technology Marketing Corp. (TMC), a global media company, and Crossfire Media. Anritsu was the only award winner that was recognized for multiple LTE products, as its MT8820C Radio Communications Analyzer, ME7873L LTE RF Conformance Test System and MT8221B BTS Master Handheld Base Station Analyzer were acknowledged as three of the leading LTE test solutions.

Agilent Technologies Inc. announced its Infiniium 90000 X-Series oscilloscopes was named Test Product of the Year at Elektra 2010, the European Electronics Industry Awards. The Elektra awards are decided by an independent panel of judges focused on 16 award categories. The event, considered an annual highpoint within the electronics industry, recognizes the achievements of individuals and companies across Europe. The awards are designed to promote best practices in key areas such as innovation, sales growth and employee motivation.

CONTRACTS

Giga-tronics Inc. announced that it has received orders in excess of $4.8 M to supply microwave test equipment for the automation of production at contract manufacturers in China. The products supplied are part of Giga-tronics' microwave signal switching family. These orders are expected to ship this fiscal year.

Canada's rural population will keep in step with—and perhaps a little in front of—the rest of the country thanks to an aggressive 4G rollout timetable being implemented by Barrett Xplore Inc. The network will be powered by **DragonWave Inc.**'s Horizon Compact and **Horizon Quantum** wireless backhaul technology. The two companies have signed a multimillion-dollar contract that will help Barrett

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FSW2476-10	240 - 760	100	-98	-124
KFSW40110-50	400 - 1100	500	-95	-122
FSW50120-50	500 - 1200	500	-94	-118
FSW60170-50	600 - 1700	500	-90	-117
FSW80150-10	800 - 1500	100	-92	-118
FSW80210-50	800 - 2100	500	-90	-113
FSW85150-50	850 - 1500	500	-93	-120
FSH9496-20	940 - 970	200	-109	-134
KFSW100230-50	1000 - 2300	500	-92	-115
FSH127171-50	1270 - 1710	500	-96	-126
FSW150320-10	1500 - 3200	100	-79	-108
FSW170280-50	1700 - 2800	500	-86	-112
FSW190410-50	1900 - 4100	500	-82	-109
FSW200400-100	2000 - 4000	1000	-85	-110
FSW216265-50	2160 - 2650	500	-92	-122
FSH250300-100	2500 - 3000	1000	-94	-122
FSW300600-100	3000 - 6000	1000	-78	-100
FSH310410-1M	3100 - 4100	10000	-92	-98
SINGLE SUPPLY				
LFSW514-50	50 - 140	500	-115	-127
LFSW1545-50	150 - 450	500	-98	-120
LFSW2476-10	240 - 760	100	-100	-124
LFSW35105-20	350 - 1050	200	-98	-120
LFSH4055-10	408 - 552	100	-99	-108
LFSW50120-50	500 - 1200	500	-97	-118
LFSW60170-10	600 - 1700	100	-92	-117
LFSW80210-50	800 - 2100	500	-92	-113
LFSW110250-50	1100 - 2500	500	-92	-115
LFSW120205-100	1200 - 2050	1000	-96	-106
LFSW150320-25	1500 - 3200	250	-86	-112
LFSW168236-100	1680 - 2360	1000	-102	-117
LFSW170225-1M	1700 - 2250	10000	-102	-123
LFSW190410-12	1900 - 4100	125	-80	-105
LFSW190410-100	1900 - 4100	1000	-85	-110
LFSH196225-50	1960 - 2250	500	-96	-127
LFSW200400-100	2000 - 4000	1000	-82	-107
LFSW290342-100	2900 - 3420	1000	-87	-107
LFSW300600-20	3000 - 6000	200	-73	-98
LFSW397697-100	3970 - 6970	1000	-80	-100
LFSW400460-1M	4000 - 4600	10000	-95	-100

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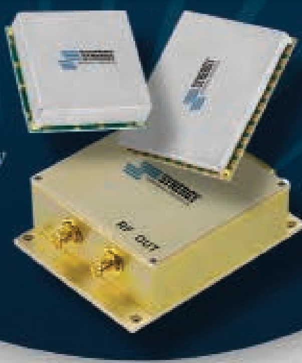

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Xplore—already rural Canada's leading broadband service provider—into a 4G broadband services offering, by delivering three to ten times the capacity of today's High Speed Packet Access (HSPA) service.

Wireless Telecom Group Inc. (WTG) announced that its wholly-owned subsidiary, **Boonton Electronics**, has been awarded a contract with the Department of the United States Navy to supply Boonton's 4500B RF Peak Power Meter in support of a Naval Sea Systems Command project. The total value of the contract is approximately $1.5 M and a considerable portion of the order is expected to be realized over the next two years.

Herley Industries Inc. announced that its Herley Lancaster division has received an award valued at approximately $1.3 M from a major US defense contractor. The Lancaster, PA, division will manufacture complex microwave hardware for an electronic attack aircraft for the US Navy. In related news, Herley announced that Herley Lancaster has recently been awarded an order for more than $1 M by the Japanese Ministry of Defense. This award is for the supply of high performance antennas to be installed in reconnaissance fighter aircraft operated by the Japan Air Self-Defense Force (JASDF).

TriQuint Semiconductor Inc., an RF front-end product manufacturer and foundry services provider, announced that handset manufacturer, **Samsung**, selected TriQuint for its complete 3G RF front-end for its new Samsung Galaxy Tab. This is in addition to Samsung choosing TriQuint's total 3G RF front-end solution for its flagship smartphone series, Galaxy S.

VTI Instruments Corp. announced that it has been selected to deliver the dynamic signal analysis (DSA) instrumentation solution for NASA Plum Brook's Reverberant Acoustic Test Facility (RATF). RATF houses the world's largest Space Environment Simulation Chamber and will use VTI's VT1432B high performance digitizer plus DSP, along with integrated arbitrary waveform generation (ARB) capability, as part of m+p international's Digital Acoustic Control System (DACS). The DACS will be used to configure and control servo-hydraulic and electromagnetic modulators, and acquire data from up to 24 individual microphones.

RF Micro Devices Inc. (RFMD) announced that **Samsung** has selected three highly integrated RFMD® components to deliver superior WiFi connectivity in the recently-introduced GALAXY Tab™ Android tablet.

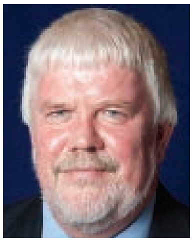
NEW MARKET ENTRIES

A.T. Wall Co., a supplier of superior precision tubing and fabricated metal components, announced that it provides flexible waveguide and waveguide components to the international market. Products include seamless flexible waveguide, flexible twistable waveguide, flexible waveguide and semi flexible waveguide. In addition to tubing, the company now offers components for all these flexible waveguide types.

Richardson Electronics Ltd. announced that it has once again teamed with **Scintera® Inc.** to bring the newly enhanced SC1887-03 Adaptive RF Power Amplifier Linearizer (RFPAL) to the UHF broadcast TV transmitter market. This fully adaptive, "RF-in, RF-out" amplifier pre-distortion solution operates directly at the carrier frequency, and requires only the addition of a few standard RF components to implement.

PERSONNEL

Georgia Tech Executive Vice President for Research Stephen Cross has named Battelle Memorial Institute's **Robert T. McGrath** the new Director of the Georgia Tech Research Institute (GTRI) and Georgia Tech Vice President. McGrath, currently a consultant on National Laboratory/University Partnerships, STEM Education, and Race to the Top initiatives for Battelle Memorial, has begun his new responsibilities as of February 1, 2011. He succeeds Cross, who served as GTRI Director from 2003 to 2010 before being named Georgia Tech's Executive Vice President for Research (EVPR) in May 2010.



▲ *Gareth Llewellyn*

Anatech Electronics announced the appointment of **Gareth Llewellyn** as Director of US sales. He will manage all of the company's sales activities throughout North America, including developing and implementing sales strategies and programs and managing sales representatives. Llewellyn has more than 20 years of experience in the RF and microwave industry, and has served in sales, business development and operations management capacities. He has held various management positions at Micro Networks, Device Technology, Emcore Corp. and several other leading microwave companies. He received his BSc degree from Cardiff University in the UK and is a member of the IEEE.

▲ *Ken Greenwood*

TRM Microwave announced that **Ken Greenwood** has joined the company as Director of Engineering. Greenwood brings over 25 years of extensive experience in engineering management, systems engineering, product development and customer relations to TRM, and he has co-authored multiple patents as a registered Electrical PE (Professional Engineering) in New Hampshire and California. His background includes the design and development of terrestrial, air-to-ground communications systems and Electronic Support Measures (ESM) systems, with Hughes Aircraft Co., Lockheed, Sanders and various commercial start-ups involved in telecommunications and optical infrastructures.

M/A-COM Technology Solutions Inc., a supplier of semiconductors, active and passive components and subassemblies for RF, microwave and millimeter-wave applications, announced that **Jack Kennedy** is the new Director of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▲ Jack Kennedy

Global Distribution, reporting to Bob Donahue, Chief Strategy Officer. He will oversee the strategic development of the company's global distribution channels to ensure they are all working toward the overall success of the company. Kennedy has a long history with the company in roles such as Strategic Account Lead, Global Account Director, as well as roles in sales management.

REP APPOINTMENTS

Tektronix Inc., a manufacturer of oscilloscopes, announced an expanded agreement with **Newark**, a multichannel electronics distributor in the Americas. This follows distribution agreements announced in November with Allied Electronics, Entest and Test Equity. US customers now have the choice of working with four leading electronic component and test instrumentation distributors who offer the full line of Tektronix test instrumentation. Newark now joins these distribution partners that together will provide an additional 500+ sales engineers, who will now be authorized to offer Tektronix higher performance oscilloscopes, signal generators, spectrum analyzers, logic analyzers and bit error rate testers.

TRU Corp. has announced the appointment of **Zerimar Sales** as its new Southern California sales representative. Zerimar has over 30 years of electronic industry experience and technical sales expertise in solving critical customer design challenges. TRU Corp. is a premier supplier of custom designed, high quality interconnect products and cable assemblies for demanding applications in defense, commercial wireless, medical, energy and high power industrial equipment.

Carlisle Interconnect Technologies announced the appointment of **Microwave Marketing Ltd.** as technical sales agents and representatives for Carlisle Interconnect Technologies' comprehensive range of RF and microwave connectors, cables and components within Ireland, Portugal, Spain and the United Kingdom.

Valpey Fisher Corp. announced it is adding **Pillar Marketing Group LLC** to its sales force. Pillar Marketing will be the authorized sales representative for all Valpey Fisher Corp. product lines in Colorado and Utah.

WEBSITE

Endwave Corp., a provider of high frequency RF MMICs and integrated transmit/receive modules, has announced a redesign of the company's website, www.endwave.com, which includes an e-commerce MMIC store for sample and volume purchases up to 999 pieces.

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Frequency Range: DC-18 GHz *Impedance: 50 ohms* *RoHS compliant*

Models	Length (inches)	Insertion Loss (dB)	Return Loss (dB)	Price $ ea.
.141" Diameter	Male to Male	Midband Typ.	Midband Typ.	Qty.(1-9)
141-3SM+	3	0.23	38	8.69
141-4SM+	4	0.14	35	8.69
141-5SM+	5	0.19	37	8.69
141-6SM+	6	0.25	39	8.69
141-7SM+	7	0.33	37	8.69
141-8SM+	8	0.30	38	8.69
141-9SM+	9	0.38	38	8.69
141-10SM+	10	0.39	37	8.69
141-12SM+	12	0.46	38	9.70
141-14SM+	14	0.52	37	9.70
141-15SM+	15	0.54	37	9.70
141-18SM+	18	0.62	37	9.70
141-24SM+	24	0.77	37	11.70
.086" Diameter				
086-3SM+	3	0.20	33	8.95
086-4SM+	4	0.23	33	8.95
086-5SM+	5	0.29	33	8.95
086-6SM+	6	0.34	34	8.95
086-7SM+	7	0.42	32	8.95
086-8SM+	8	0.46	36	8.95
086-9SM+	9	0.54	33	8.95
086-10SM+	10	0.58	35	8.95
086-12SM+	12	0.69	36	9.95
086-14SM+	14	0.79	34	9.95
086-15SM+	15	0.82	33	9.95
086-18SM+	18	0.97	34	9.95
086-24SM+	24	1.41	33	11.95
KHFC-1+				79.95

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SETTING NEW NOISE PERFORMANCE BENCHMARKS USING WIDEBAND LOW-NOISE, HIGH-LINEARITY LNAS

The weakest signal that a wireless receiver can recover is defined by its sensitivity[1]

$$\text{Rx\_sen(dBm)} = -174 + 10\log \text{BW} + \text{SNR} + \text{F} \quad (1)$$

where BW is the bandwidth in Hz, SNR the required signal to noise ratio and F the system noise figure. A low-noise amplifier (LNA), as its name implies, improves the receiver sensitivity by reducing the cascade noise figure. Friis's equation shows that the noise figure (F_1) of the first amplifying stage in the receiver chain (that is the LNA) has a predominant effect, while the noise performance of the subsequent stages (such as F_2, F_3, etc.) are of lesser importance. This is stated as

$$F = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2} + \ldots \quad (2)$$

where G_n is the gain of the nth stage in the receive chain.

Cellular base stations (BTS) and microwave relays have detached low-noise amplifier stages located up in the aerial tower in order to mitigate the NF degradation from pre-LNA cable loss. In the BTS architecture, the LNA stage is preceded by a transmit-receive (Tx-Rx) diplexer for duplexing a common aerial and an interference filter for preventing out-of-band blocking or desensitization. However, both the duplexer and filter have losses that must be minimized as they occur before amplification.[2] Therefore, an LNA with an extra margin in noise performance will relax the duplexer-filter's loss requirement.

Other critical performance parameters include high gain, to overcome loss in the long cable connecting the tower-mounted LNA and the ground-level radio shack, as well as high linearity, as the RF spectrum in the tower vicinity can be very crowded due to site sharing with other wireless transmitters.

A BRIEF SURVEY OF LOW-NOISE TECHNIQUES

In the '70s and '80s, low-noise microwave amplifiers were mostly realized using ceramic-packaged devices[3,4] because ceramic has extremely low loss (dissipation factor, tan δ = 0.001) and the stripline leads width could be matched to the PCB trace to minimize discontinuities. The shift to plastic surface-mount packaging (SMP) such as a SOT-23 or SC-70, for cost saving reasons, led to packaging that significantly degrades the noise performance because of the epoxy encapsulation's higher

CHIN-LEONG LIM
Avago Technologies, Penang, Malaysia

TABLE I

RELATIVE NOISE PERFORMANCE AND COST COMPARISON OF LNA SEMICONDUCTOR TECHNOLOGIES

Technology	Noise Rating [14]	Epitaxy cost/mm² [15]
InP HEMT	Very good	$10
GaAs PHEMT	Very good	$2
GaAs HBT	Good	$2
Si CMOS	Fair	$0.01

loss (tan δ = 0.006 to 0.014[5]) and also abrupt width changes at the die to bond-wire and led to microstrip interfaces.[6]

The Fukui equation for device noise[7] can be simplified to demonstrate the proportionality of noise to physical temperature (T_{PHY})

$$F_{min} = 1 + 2\sqrt{P}\,\frac{T_{PHY}}{290K}\,\frac{C_{gs}\omega}{g_{mo}}\cdot\sqrt{g_{mo}(R_s + R_g)} \Rightarrow F \propto T_{PHY} \qquad (3)$$

Due to this relationship, lowering T_{PHY} to near 0 K, using closed-cycle helium cooling, is by far the most effective noise-reduction method[8] and has demonstrated F ≈ 0.05 dB at 900 MHz.[9] The improvement is attributed to better electron-transport properties and reduced thermal noise generated by parasitic elements.[10] The flip side of cryogenic refrigeration is that it results in difficult maintenance[11] and high cost (~$10k per cooler),[12] thus limiting its use to performance-critical applications, such as radio telescopes and earth stations for interplanetary probes. Nevertheless, the future trend to replace a large radio telescope with thousands of smaller, low-cost ones distributed over a continent, such as the Square Kilometer Array,[13] may make LNA cooling untenable.

In addition, the transistor's F is strongly influenced by the choice of semiconductor material. Cutting-edge materials, such as indium phosphide (InP), allow unrivalled noise performance, but are usually too costly for routine commercial use. On the other hand, silicon CMOS offers unbeatable cost benefits but has a modest noise level (see ***Table 1***).

At the device level, shrinking the feature size (that is gate length) can improve most RF parameters.[16] It has been shown that halving the CMOS feature size from 0.18 µm to 90 nm results in a useful 0.2 dB noise improvement at approximately 1 GHz,[17] albeit at a significantly higher manufacturing cost.

Besides the device-level techniques, noise can also be reduced at the circuit level. The often significant difference between input conjugate match (Γ_S) and optimum noise match (Γ_{opt}) of LNA transistors requires the noise performance to be sacrificed during matching. Nevin, et al. have shown that adding a small inductance (L_S) in the source to ground path can minimize the Γ_S - Γ_{opt} divergence;[18] separately, a 0.15 dB noise reduction at 1.95 GHz has been reported using this technique.[19] In practice, only a tiny less-than-ideal amount of L_S can be added before undesirable peaks in the frequency response begin to form, far above the design pass band.[20]

FET-type devices have a relatively high optimum noise impedance (Z_{opt}); connecting two or more transistors in parallel can lower noise by reducing the mismatch between Z_{opt} and the generator impedance (Z_s). Designs reported using this method include using three FETs in the 76 to 109 MHz VHF FM broadcast range[21] and two HEMTs at 1.4 GHz.[22]

An input matching loss directly impacts F and the loss increases with the generator-to-input impedance transformation ratio (explained in the next section). The loss can be minimized by increasing the unloaded Q via a cavity[23] or silver-plated resonators.[24,25] However, these esoteric components are either too cumbersome or costly for mass-produced commercial products.

Feed-forward, a technique that is more commonly associated with power amplification, has also been described for noise reduction on CMOS LNAs[26,27] at VHF/L-band. The noise produced in the input matching loss is combined in anti-phase with the output signal in order to cancel the noise components. However, a subsidiary noise amplifier and a combiner are required in addition to the LNA. This increased complexity may be the reason why feed-forward is still uncommon in commercial designs.


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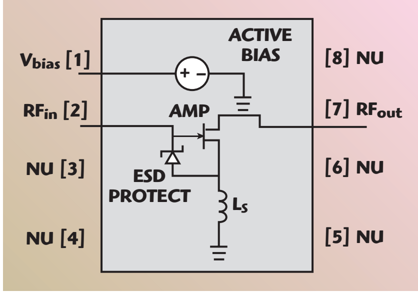
DEVICE PHYSICAL AND PARAMETRIC CHARACTERISTICS

One approach is to use a compact (2 × 2 × 0.75 mm) 8-pin quad flat non-lead (QFN) packaged microwave monolithic integrated circuit (MMIC) that consists of a common-source amplifier and an active bias regulator. Its 0.25 µm feature-size GaAs enhancement-mode, pseudomorphic high electron mobility transistor (ePHEMT) process[28] has a high gain-product bandwidth, f_T >30 GHz, that allows the target gain (>17 dB at 0.9 GHz) to be achieved in one stage. The Johnson noise generated in the interconnections is minimized by making the metal two times thicker than in previous process iterations. A small source inductance (L_S) enables good input return loss and F to be simultaneously achieved at one Γ_S value (see ***Figure 1***).



▲ *Fig. 1 MMIC simplified circuit.*

The gate width of the device was dimensioned to offer an input impedance close to 50 Ω in order to avoid requiring a large impedance transformation ratio in the external matching, which can increase losses and consequently degrade the noise figure F. The insertion loss (A) of a single transmission resonator at an evaluated frequency (f) is given by[29]

$$A(f) = -10\log\left[\frac{1+\left(2Q_l\,\frac{f-f_0}{f_0}\right)^2}{\left[1-\left(\frac{Q_l}{Q_u}\right)\right]^2}\right] \qquad (4)$$

where f_0 is the resonant frequency, Q_l the loaded Q of the matching network and Q_u the components' unloaded Q (usually the Q_u of the inductor as it is lower than that of the capacitor). At the center of the resonator's pass band, f_0 can be substituted for f; hence

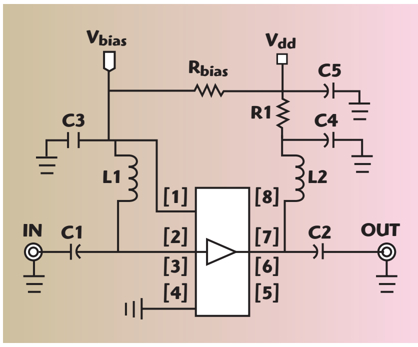
$$A(\mathrm{dB}) = 20\log\frac{Q_u - Q_l}{Q_u} \qquad (5)$$

The loaded Q_L of the matching network is given by[30]

$$Q_L = \sqrt{\frac{R_H}{R_L} - 1} \qquad (6)$$

where R_H/R_L is the resistance transformation ratio of the matching network. Substituting for Q_L gives

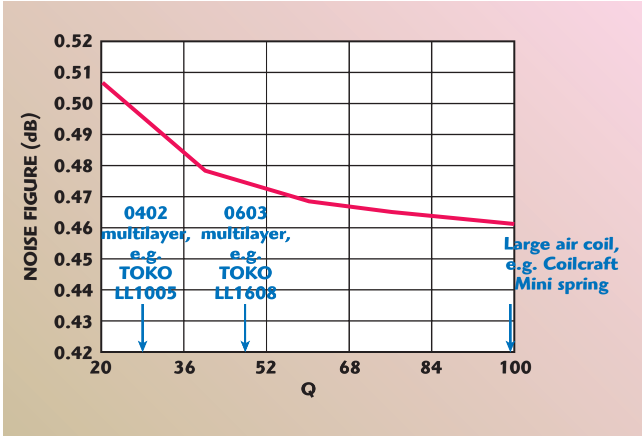
$$A(\mathrm{dB}) = 20\log\frac{Q_u - \sqrt{\frac{R_H}{R_L} - 1}}{Q_u} \qquad (7)$$



▲ *Fig. 2 Performance evaluation circuit.*

when $R_H/R_L \rightarrow 1$, $A \approx 0$ dB. That is, the lowest loss occurs when no impedance transformation is required. The best noise performance was extracted from this ePHEMT by dimensioning both the device geometry and its bias current to make the input close to 50 Ω, thus eliminating the input match requirement. The input inductor in the evaluation circuit (L1 in ***Figure 2***) essentially functions as an RF choke only, and so its Q does not appreciably influence the input loss. The simulation confirmed the relative insensitivity to the resonator Q_{UL} (see ***Figure 3***), where $\Delta F < 0.05$ for any Q_{UL} in the 20 to 100 range (the lower end of the range representing a 0402-size multilayer chip inductor and the upper end, a much larger air-core inductor). The uncritical input resonator requirement can enable low-cost and compact LNA designs.

The bias regulator allows the LNA quiescent current (I_{ds}) to be adjusted by either varying R_{BIAS} or an externally applied voltage, V_{BIAS} (see ***Figure 4***). The regulator's low current drive requirement ($I_{BIAS} \leq 1$mA) is compatible with most CMOS families, and it is possible to switch the LNA directly from a microcontroller in time domain multiplexed (TDM) applications. In applications that do not require this much linearity, an R_{BIAS} value that is larger than nominal (6.8 kΩ)



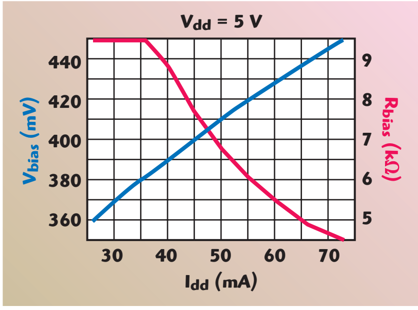
▲ *Fig. 3 Simulated 900 MHz noise figure vs. input resonator Q_{UL}.*

can be used to conserve power. The I_{ds} temperature stability is achieved by the regulator and the LNA having undergone similar processing; that is, V_{BIAS} and V_{GS} "mirror" each other to compensate against thermal drift[31] and between-wafer transconductance variation.

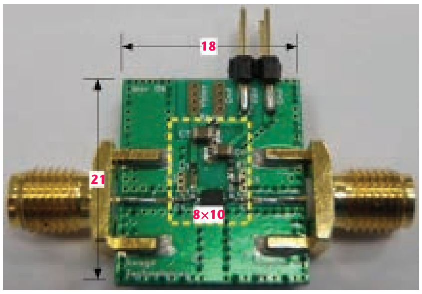
PERFORMANCE EVALUATION CIRCUIT AND ASSEMBLY

To evaluate the RF performance, a 900 MHz LNA for a cellular base station has been designed around the MMIC. A minimal number of external components (C1-L1 and C2-L2) provided the matching and biasing functions that were not feasible to integrate at the chip level. In addition to DC blocking and RF choking functions, C1-L1 also roll off undesirable gain below the operating frequency (f_0). Both L1 and L2 should be operated below their self-resonant frequency (SRF) for effective choking. C3-C5 decouple the RF from the bias lines. In the interest of reducing the gain below f_0, C4 is dimensioned for a reactance (X) of ~6 Ω at f_0. Therefore, at $f << f_0$, C4 gradually disappears from the circuit and R1 is directly in series with L1 to roll-off the gain. However, about 0.5 V is dropped across R1 at the nominal I_{dd} of 50 mA and so the supply voltage V_{dd} must be raised to 5 V for V_{ds} =4.5 V. When the LNA is switched via V_{BIAS} as in TDM, C3 should be reduced to the lowest value that can still decouple the bias line effectively at f_0; as a rule of thumb, X_{C3} = ~5 Ω at f_0. The smaller C3 will speed up the switching that is constrained by the R_{BIAS} - C3 time constant. Turn-on time is ~0.6 μs using C3 = 33 pF.

The printed circuit board (PCB) in ***Figure 5*** measures 21.5 × 18 × 1.4 mm and comprises microstrips with co-planar ground on a 10 mil Rogers RO4350, a mid-priced material with modest RF performance and FR4-

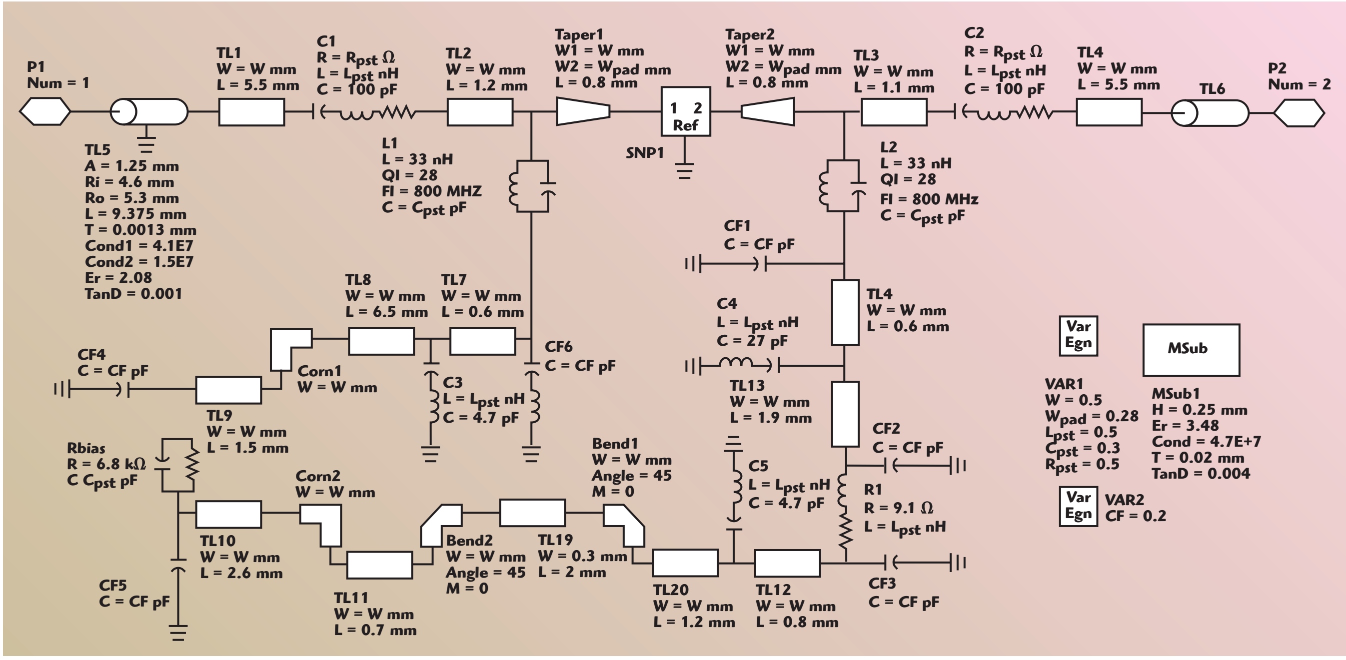


▲ *Fig. 4 Characteristics of the adjustable bias regulator.*



▲ *Fig. 5 Photograph of the assembled prototype.*

process compatible.[32] A lower cost FR4 material of 1.2 mm thickness is glued to the RO4350 ground-plane for stiffening. RF connections were made through edge-launch SMA-to-microstrip transitions (Johnson Component P/N 142-0701-856), while the DC supply was connected via a two-pin straight PCB header. Because of the non-critical input resonator requirement, 0402-size chips could be used to shrink the area populated by components to approximately 8 × 10



▲ *Fig. 6 900 MHz LNA simulation circuit.*

TABLE II

EVALUATION BOARD DEVICE LIST

Position	Value	Remark
C1, C2	100 pF	Murata GRM15
L1, L2	33 nH	TOKO LL1005
C4	27 pF	Murata GRM15
C3, C5	4.7 uF	Murata GRM15
R1	9.1 Ohm	
Q1	MGA633P8	Avago
NB. All SMD components 0402 size		

mm. The evaluation board device list is shown in ***Table 2***.

As preparation for the LNA circuit design, the MMIC was characterized with a custom-designed thru-reflect-line (TRL) fixture formed from the same PCB material (10 mil RO4350), which the prototype LNA was expected to use. After de-embedding the fixture effect, the device S-parameters and noise parameters were then imported into Agilent Technologies ADS2006A software for circuit simulation.

In the LNA circuit model illustrated in ***Figure 6***, the RLC chip components were modeled using simplified equivalent circuits instead of the manufacturer-supplied s2p data; this was mainly because such data lacked the convenience of changing the component values instantaneously as

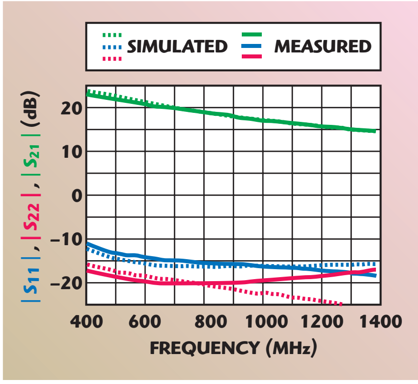
TABLE III

COMPARISON OF THE REPORTED MEASURED PERFORMANCE OF RESEARCH AND COMMERCIAL LNA DESIGNS (800 TO 1000 MHz)

Process [Ref.]	Package	F (dB)	G (dB)	f@RL≤ -10dB (MHz)	P_{DC} (W)	P1dB (dBm)	OIP3 (dBm)	OIP3–P1dB(dB)	OIP3/ P_{DC}	Research or Commercial
0.18 um CMOS [41]	die	3.8	20.2	30-930+	0.043	0	9	9	0.2	R
0.18 um CMOS [42]	die	0.6	16	500-1500	0.05	6	14.5	8.5	0.6	R
mHEMT [43]	die	1.4	16	1000-2500	0.135	-	-	-	-	R
GaAs PHEMT [44]	SOT-89	0.6	18.7	500-3000+	0.45	23	38	15	14.0	C
GaAs PHEMT [45]	QFN 3×3	0.9	18	n.a.	0.45	22	35	13	7.0	C
GaAs PHEMT [46]	QFN 3×3	0.6	16	540-2000+	0.44	21	37	16	11.4	C
This work	QFN 2×2	0.3	18	400-1500	0.25	22.3	37	14.7	20.0	C

needed. Secondly, such data were frequency limited to 6 GHz (so out-of-band stability could not be simulated). Additionally, the capacitor manufacturer's s2p data is severely limited in usefulness because its single reference plane lies along the chip's long axis[33] and is therefore only accurate for a shunt-connected capacitor functioning as RF-to-ground bypass. A capacitor in series within the RF path, however, will require referencing to the metalized end terminals. To reduce the model complexity, only the most important parasitics ("first-order" parasitics) for the RLC components were modeled. The inductor model used typical Q_{UL} values at the nearest frequency (800 MHz) published by the vendor[34] and extrapolated to other frequencies using a $Q \propto \sqrt{f}$ relation.

The inductors' parasitic capacitance (Cpst) was calculated from its published typical SRF values, but with an



▲ *Fig. 7 Simulated and measured S-parameters.*

extra 0.1 pF added to account for layout capacitance. The parasitic inductance (Lpst) in the capacitor model followed the values provided by the vendor-supplied software, "Murata Chip S-parameter & Impedance Library."[35]

The two-pin header and its associated pads were excluded because they were found to have little impact on the simulated results. The edge-launched SMA jacks (female) were modeled using the ADS2006A parameterized component for coaxial line with the parameter values obtained from the manufacturer. However, discontinuity effects at the coax to micro-strip interface were ignored because the parameters are non-trivial to extract by either measurement or electromagnetic simulation.

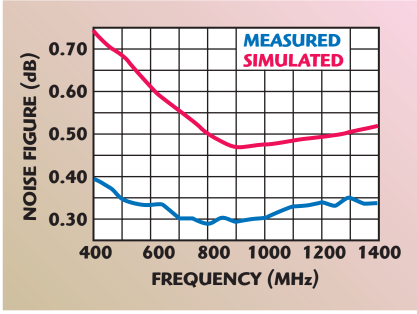
RESULTS AND DISCUSSION

The evaluation board nominal DC bias values are V_{dd} = 5 V and I_{dd} = 53 mA (set by R_{BIAS} = 6.8 kΩ). Key differentiators that will excite customers from the cellular BTS market segment are low noise in conjunction with good return loss (RL). This is because diplexers and filters are detuned by reflective terminations. At the 900 MHz nominal test frequency, the demonstration LNA achieved F ≈ 0.3 dB, G ≈ 18 dB and both IRL and ORL better than 15 dB.

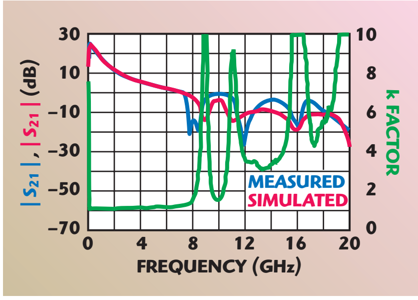
Traditionally, BTS LNAs rely on either isolator or quadrature hybrid coupler (balanced LNA) to achieve a desired input match. As shown in ***Figure 7***, this design's low IRL allows the high-loss and costly isolator/quadrature coupler to be eliminated in most applications. The very wide bandwidth of the input and output match (0.35 to 6 GHz at the RL ≤ 10 dB point) is favorable from the system standpoint, as it prevents detuning of the input/output filters' out-of-band

frequency response. Furthermore, there is reasonable agreement between simulated and measured G and RL at mid-band, where the differences are less than 2 dB.

As shown in ***Figure 8***, the simulated F is ~0.15 dB higher than the measured result at f_0. A discrepancy of this magnitude is not unusual and has been ascribed to a system-repeatability issue (an ATN source-pull system was used for device noise characterization, whereas a noise figure meter (Avago's 8970S) was used for the final measurement), as well as different samples or different day variations.[36] Although the main target market is narrowband cellular BTS, the RF performances (F < 0.4 dB and RL < 10 dB in the 400 to 1400 MHz range) are also adequate for many wideband/multi-band applications such as cable/satellite TV distribution infrastructure, scanners, military applications and multi-service radios.



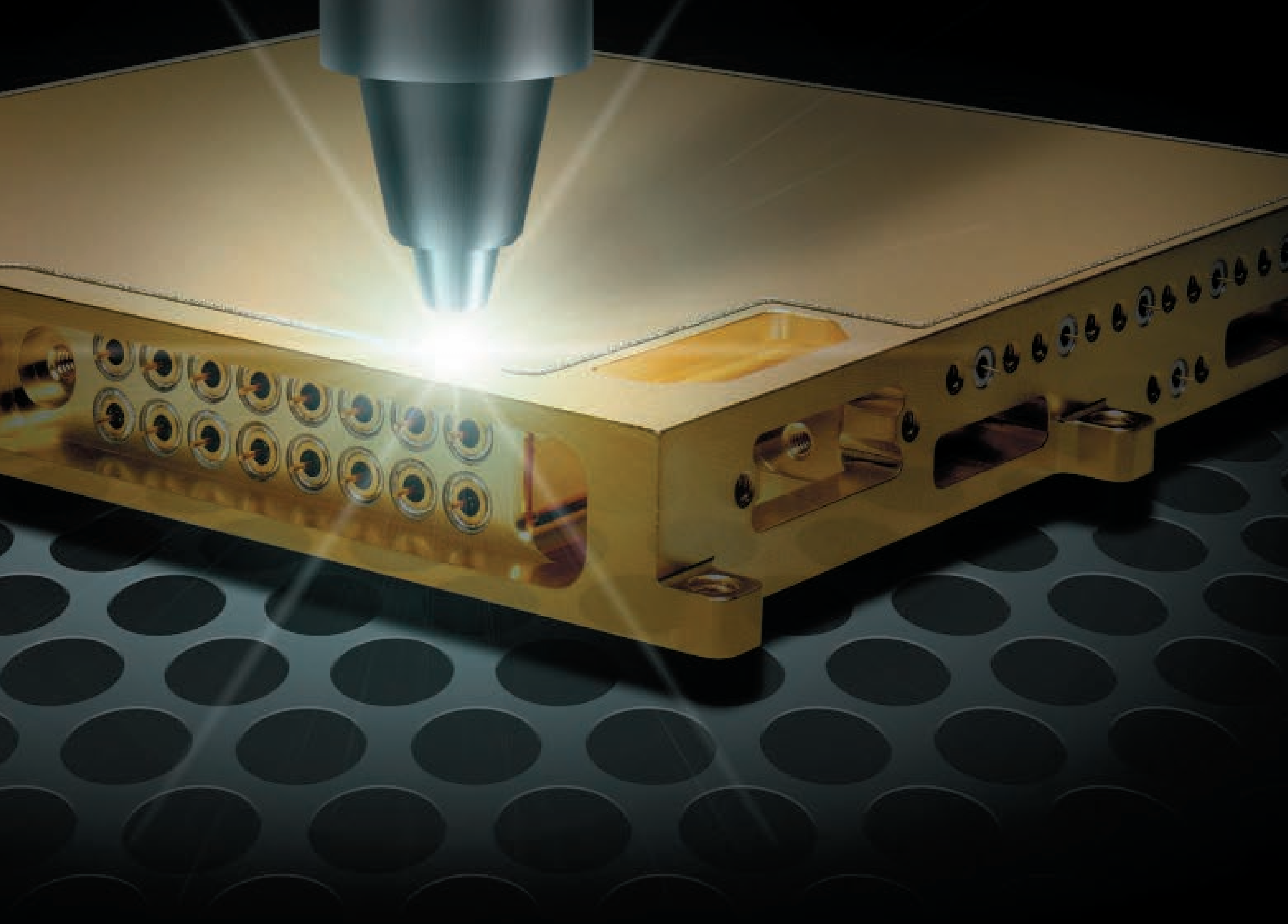
▲ *Fig. 8 Simulated and measured noise figure vs. frequency T_{PHY} = 27°C.*



▲ *Fig. 9 Measured and simulated wideband gain and k factor.*

As shown in ***Figure 9***, the measured frequency response exhibited minor out-of-band "gain peaks" at 10, 13.5 and 18 GHz. But the peaks are well below the unity gain level, and so are not expected to create a potential instability if the LNA is inadvertently housed in a metal enclosure with a coincident cavity resonance. The Rollett stability factor (k) is greater than 1 when evaluated from HF to approximately >20 times the design center f_0, meaning that the LNA will be unconditionally stable with any termination having a positive real part.

Blocking, which desensitizes the receiver by lowering the G and increasing F,[14] can be caused by either a non-synchronous interferer, such as a powerful transmitter sharing the same tower, or by a synchronous source, such as the transmission that leaks past the circulator or duplexer in a transceiver with simultaneous transmit and receive capability.[38] A component with high gain compression threshold can therefore resist blockers more effectively. Gain compression is primarily caused by nonlinear transfer characteristics in an amplifier that is driven beyond the linear region with increasing heat dissipation as a minor contributor. In this design, heat loss is minimized by the GaAs substrate's comparatively lower bulk conductiv-



ity. Furthermore, the low knee voltage (0.3 V) of the selected process permits a larger voltage swing before clipping.[39] The evaluation circuit's gain dropped 1 dB from nominal at an RF input drive (Pi) of 5.3 dBm. This corresponds to an output 1 dB compression point (P1dB) of 22.3 dBm. Due to the bias regulator's constant-voltage trait, the I_{dd} rose exponentially with overdrive. The up-shifted bias point prevented premature waveform clipping as Pi approached P1dB. This similarity with Class AB mode improved P1dB over current-limited designs, as shown in ***Figure 10***.

Due to receiver components' nonlinearity, adjacent-channel signals can create third-order intermodulation distortion (IMD3) such as 2f1-f2 or 2f2-f1 that virtually overlaps with the wanted signal. A key measure of linearity, the third-order intercept point, OIP3, is defined as the point where

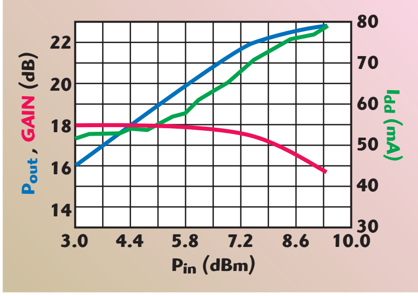


Fig. 10 Output power, gain and I_{dd} vs. input power.

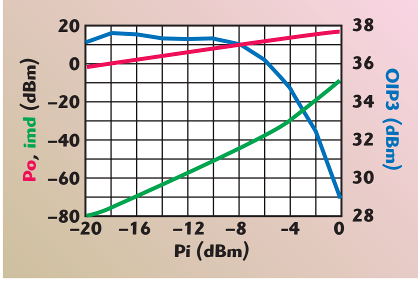


Fig. 11 Fundamental, IMO3 and OIP3 vs. Pi.

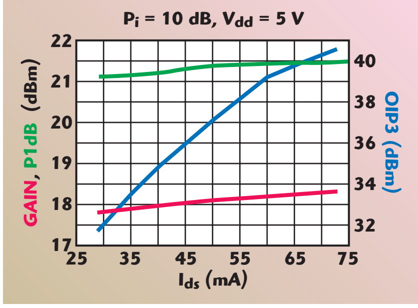


Fig. 12 OIP3 vs. I_{ds}.

the fundamental signal power (P_{fund}) and the IMD3 power theoretically intersect. In the linear region, OIP3 can be calculated from the IMD3 amplitude using

$$OIP3 = P_{fund} + \frac{\Delta IM}{2} \quad (8)$$

where ΔIM is the difference between the fundamental and the intermodulation product power in dB. Two input tones at 900 and 901 MHz were used for evaluating this design; however, a different frequency spacing is not expected to change the results much. In the linear operating region enclosed by Pi < -10 dBm, the OIP3 is slightly above 37 dBm at nominal bias, as shown in ***Figure 11***. The key to high linearity at low power (as given by the linearity figure of merit, OIP3/P_{DC} in ***Table 3;*** see page 66) is the processes' high transconductance (gm = 600 mS/mm) because harmonic dis-

tortion (such as 2f1) is inversely proportional to gm.[15]

The adjustable bias feature provides a convenient mean to trade-off OIP3 for power consumption (see ***Figure 12***). The OIP3 can be varied as much as 10 dB by sweeping I_{dd} over the 25 to 75 mA range while gain and P1dB are minimally affected (ΔG and $\Delta P1dB \leq 0.5$ dB). Microcontroller regulation of V_{BIAS} opens the possibility to an LNA that can adaptively respond to a degree of spectrum crowding.

DEVICE COMPARISON

The optimization of several design parameters of a wideband low-noise, high-linearity LNA can enable critical performances equaling or exceeding that of traditionally used devices. As shown in the example used in this article, low-noise performance can be achieved by scaling the transistor size for almost zero input reflection coefficient and minimizing internally generated thermal noise by using high-conductivity metallization. The resultant noise figure is comparable to that of ceramic devices. This design/device compares favorably with the prior art in key performance parameters, as shown in Table 3. Selecting a process with high gm can enable high linearity and best-in-class linearity figure of merit ($OIP3/P_{DC}$). The relative insensitivity to input resonator Q can allow low-cost components to be used without sacrificing noise performance. The beneficial IRL over a wide bandwidth allows the isolator to be eliminated in most applications. Additionally, the low external component count makes possible a very compact LNA. ■

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SPECIFICATIONS

Part Number	*Architecture*	*Block Diagrams A, B, C*	*LO Freq (MHz)*	*Phase Noise (dBc/Hz) at 2 GHz*		*Mixer RF/IF Port Freq Range (MHz)*	*Mixer IIP3 (dBm)*	*Supply Voltage (V)*	*Supply Current (mA) with one mixer active*	*Multi-Slice Mode*
				1 kHz	*10 kHz*					
RF2051	Frac-N PLL, VCO, 2 mixers	A	300 to 2400	-85	-90	30 to 2500	18	2.7 to 3.6	55 to 75	–
RF2052	Frac-N PLL, VCO, 1 mixer	B	300 to 2400	-85	-90	30 to 2500	18	2.7 to 3.6	55 to 75	–
RF2053	Frac-N PLL, 1 mixer	C	external VCO	-85	-90	30 to 2500	23	2.7 to 3.6	45 to 65	–
RF2056	Frac-N PLL, VCO, 2 mixers	A	50 to 500	–	–	30 to 500	25	2.7 to 3.6	50 to 65	–
RF2057	Frac-N PLL, VCO, 2 mixers	A	1900 to 2400	-85	-90	30 to 2500	18	2.7 to 3.6	55 to 75	–
RF2059	Frac-N PLL, VCO, 2 mixers	A	1550 to 2050	-85	-90	30 to 2500	18	2.7 to 3.6	55 to 75	–
RFFC2071	Frac-N PLL, VCO, 2 mixers	A	85 to 2700	-95	-102	30 to 2700	23	2.7 to 3.3	100 to 130	✓
RFFC2072	Frac-N PLL, VCO, 1 mixer	B	85 to 2700	-95	-102	30 to 2700	23	2.7 to 3.3	100 to 130	✓
RFFC5071	Frac-N PLL, VCO, 2 mixers	A	85 to 4200	-95	-102	30 to 6000	23	2.7 to 3.3	100 to 135	✓
RFFC5072	Frac-N PLL, VCO, 1 mixer	B	85 to 4200	-95	-102	30 to 6000	23	2.7 to 3.3	100 to 135	✓

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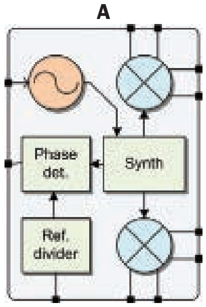

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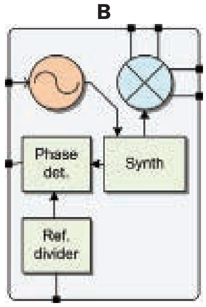

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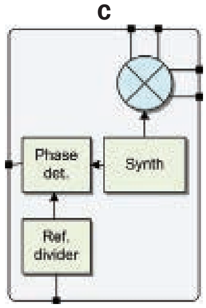

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CROSS CORRELATION IN PHASE NOISE ANALYSIS

Phase noise is a property of an oscillator that can extend in magnitude from the carrier of several volts down to a mere nano-volt far from the carrier. In many cases the lowest noise OCXOs, SAWs and other specialty oscillators have carrier to noise ratios in excess of -180 dBc/√Hz. The noise level of these oscillators often extends below that of even the mixers and low noise amplifiers at baseband. Cross correlation is a method used in phase noise analysis to extend the range of any single channel measurement by introducing a second channel and utilizing signal processing to locate the noise that is common to the DUT, yet uncommon to each individual channel. With this method, a typical noise floor improvement of 20 dB is very realistic, allowing for high accuracy measurements of extremely low noise oscillators. This article presents the mathematics with an example of how cross correlation can accurately identify signals or noise that is below the level of the measurement instrument.

Most phase noise measurement systems use what is called carrier cancellation. Phase noise is not measured directly, but down-converted to baseband. In an absolute phase noise measurement, where the absolute noise level of an oscillator is being measured, two oscillators are phase locked to one another. Once the two signals are locked with a mixer, the phase noise of both channels is down-converted directly to baseband without the carrier which is at DC and cancelled.

In a residual or additive phase noise measurement, whereby the additive noise of a component such as an amplifier is to be measured, the oscillator is split into two parts. One path drives the LO port of the mixer while the other path goes through the DUT prior to going into the RF port of the mixer. Within the noise level and isolation of the mixer, the carrier and its noise are canceled, being common between the two paths, while the noise of the DUT is measured directly at an offset and its carrier frequency centered at DC.

In both cases, low noise, low frequency techniques are then applied to amplify and sample this signal. However, in both cases, noise levels of system components may limit the measurement dynamic range or noise floor. In absolute measurements, the reference oscillator typically is the limitation. In additive measurements, even a very good mixer can often contribute as much noise as a low noise DUT.

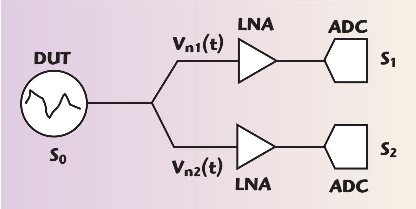
Cross correlation has been used by NIST for metrology level phase noise measurements for quite some time (see the references for more information or go to www.nist.gov). Through-

JASON BREITBARTH
Holzworth Instrumentation, Boulder, CO

TABLE I

VOLTAGE NOISE IN TERMS OF Vrms/√Hz AND dBV FOR VARIOUS RESISTANCES

Resistance (Ω)	*Voltage Noise @300k (91 nVrms/√Hz)*	*dBV (dBVrms/√Hz)*
50	0.91	-180.8
100	1.29	-177.9
10K	4.07	-167.8



▲ *Fig. 1 Block diagram of noise measurement system where one signal with noise is measured simultaneously by two channels with their own independent and uncorrelated noise sources.*

out this article noise is normalized to per root Hz from equation 1 where B = 1 Hz. Many times the reader may see per Hz, but usually that is an artifact of not having the proper symbol available. Since the square root of 1 is 1, many just ignore this difference even if it is not correct.

NOISE SOURCES

The need for cross correlation is best illustrated via an example. Assume a very high quality oscillator having a phase noise floor of -180 dBc/√Hz with +10 dBm output power. The white noise power of the oscillator is equal to 10 dBm (-180 dBc/√Hz) or -170 dBm/√Hz. A 50 Ω resistor exhibits about 0.9 nV/√Hz of noise or -174 dBm/√Hz in terms of power. A noise power of -170 dBm/√Hz is only 1.44 nV_{rms}/√Hz. The best low noise amplifiers are near 1 nV_{rms}/√Hz self noise, limiting both the accuracy and sensitivity of the measurement. This is assuming an ideal phase detector with no loss or noise itself.

To evaluate whether a 'real' mixer could deal with this level of noise, we continue with the example. A 13 dBm high quality mixer phase detector may be driven around 5 dBm at the RF port. At this level, the mixer is slightly in compression with a conversion loss of likely about 7 dB. The output phase conversion may be K_d=0.4 V/rad or about 0.282 V_{rms}/rad. With a 50 Ω resistor exhibiting about 0.9 nV_{rms}/√Hz, this leaves a dynamic range of -170 dBc/Hz (about 10 dB below that of the oscillator). A higher power mixer can increase this dynamic range, but shot noise and other effects can become more dominant (such as the combined impedance of the mixer and the termination at the IF port). ***Table 1*** shows the voltage noise of several different resistance values, demonstrating that higher equivalent resistances can significantly degrade the signal to noise ratio. An equivalent port impedance of 100 Ω can decrease the signal to noise ratio by 3 dB.

$$V_n = \sqrt{4kTBR} \tag{1}$$

In an absolute phase noise measurement, the reference oscillator will likely contribute significantly more noise than the mixer, especially at close to the carrier. In an additive measurement such as a low noise, silicon BJT-based RF amplifier, the RF amplifier may have noise that is on par with the silicon diodes used in a good phase detector. In both examples, it is clear that low noise devices require additional techniques to accurately measure them down to very low levels.

CROSS CORRELATION

A diagram of a two-channel cross-correlation system to measure noise or very small signals is shown in ***Figure 1***. Signal S_0 is common while each individual channel has its own independent, and higher, noise. The resultant time domain sampled signal is in the form of S_1 and S_2. The desired signal to be measured is S_0 and has a small-signal component and broadband noise:

$$S_0 = \alpha \sin(2\pi f/t) + v_{n0}(t) \tag{2}$$

The actual measured signal from channels 1 and 2 are defined as

$$S_1 = S_0 + v_{n1}(t) \tag{3}$$

$$S_2 = S_0 + v_{n2}(t) \tag{4}$$

MATHEMATICAL DEFINITIONS

Cross correlation can be computed via convolution or as a Fourier trans-

form. In the case of spectral analysis, it is easiest to deal with the Fourier transform version. Cross correlation in the time domain is defined by convolution as

$$(S_1 \star S_2) = S_1^*(-t) * S_2 \quad (5)$$

The star is representative of the mathematical function of convolution. The asterisk denotes the complex conjugates of signal S_1. Rewritten in terms of a Fourier transform, the Fourier transform of the cross correlation is the dot product of the complex conjugate of one Fourier transform to the other Fourier transform.

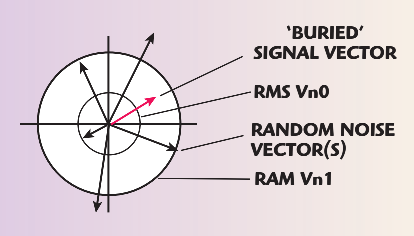
$$F\{S_1 \star S_2\} = F\{S_1\}^* \cdot F\{S_2\} \quad (6)$$

It is shown here that cross correlation makes use of the phase information relative to the two channels. ***Figure 2*** is a phasor diagram of the magnitude and phase of the Fourier transform for a given frequency component. The red signal vector is the buried signal representative of S_0 while the gray vectors are the random contributions of the whole system noise levels, S_1 or S_2. The gray vectors are unique and uncorrelated for each channel for each measurement while the red vector is common. Figure 2 illustrates how a buried signal phasor relates to the overall random noise vectors. Two channels will measure the buried signal vector identically with uncorrelated and larger noise in sum with it. Vector averaging the dot product of the two channels (one as a complex conjugate) will reduce the uncorrelated noise proportional to the number of correlations. Vector averaging a number of cross correlations is known as 'cross correlating' with a number of correlations.

The dot product of one signal with the complex conjugate of another for two identical signals results in just the magnitude squared of either signal and is real, having a phase of zero. The dot product of the complex conjugate of one uncorrelated signal to another will be random in both magnitude and phase.

VECTOR AVERAGING THE CROSS CORRELATION

In a single channel magnitude only system, each frequency bin magnitude is summed and then divided by the number of measurements to



▲ *Fig. 2 Phasor diagram of the vector Fourier component of any given frequency.*

TABLE II

CROSS CORRELATIONS CAN IMPROVE THE SENSITIVITY IN dB OF IDENTIFYING A SMALL-SIGNAL BY THE RELATION $5LOG_{10}(N)$ WHERE N IS THE NUMBER OF CORRELATIONS

Correlations (N)	Noise Floor Improvement (dB)
1	0
10	5
100	10
1000	15
10000	20

achieve averaging. In a cross-correlation system, both the magnitude and phase, or real and imaginary parts of the dot product from the cross correlation are vector summed. The dot product of the random noise vectors will eventually achieve a vector sum of zero assuming they are truly random and uncorrelated. The dot product of the small common signal will be in phase and real and eventually be the only signal left.

Vector averaging yields a maximum improvement relative to the number of averages (N) in dB as $5\log_{10}(N)$. In other words, it takes an order of magnitude increase in measurements for every 5 dB improvement. ***Table 2*** lists the improvement for a number of correlations.

EXAMPLE

To illustrate how cross correlation works, a mathematical equivalent of Figure 1 was defined in numerical computing software using the signals S_0, S_1 and S_2. S_0 represents a small-signal above a broadband low noise level equivalent to just over a 50 Ω noise floor. S_1 and S_2 contain noise components v_{n1} and v_{n2}, respectively, with noise levels that are above that of the small-signal of S_0. The example demonstrates that a single channel system could never measure S_0, given

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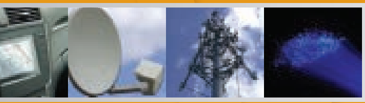

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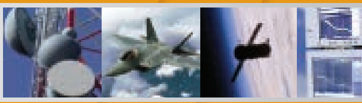

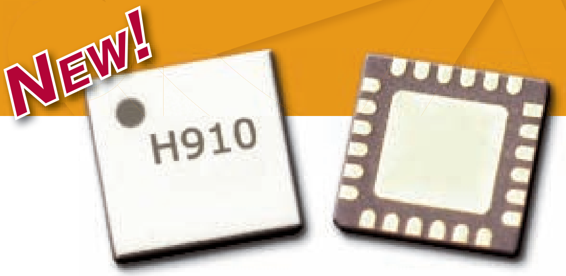

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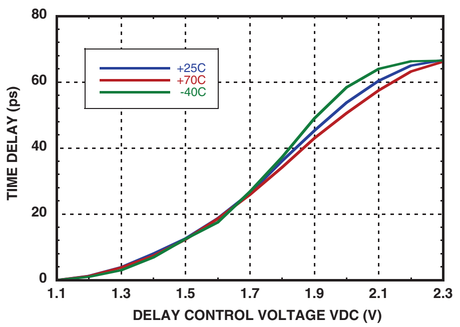
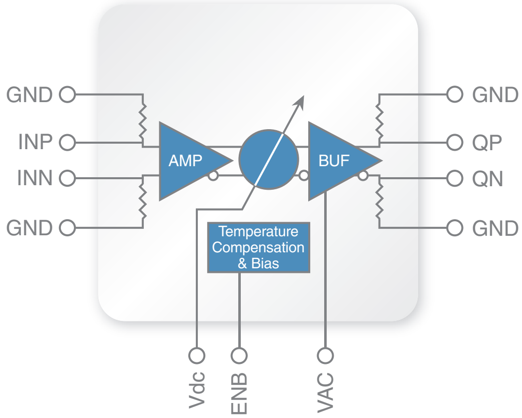
HMC910LC4B Time Delay vs. VDC & Temperature





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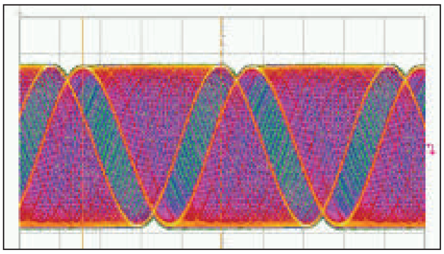
Continuous Snapshot for 24 GHz Input



Time Scale: 10 ps/div
Amplitude Scale: 80 mV/div

Test Conditions:
VCC = 3.3V, VAC = 2.6V,
VDC = varied from 1.6V to 1.9V (25% of the whole delay range)
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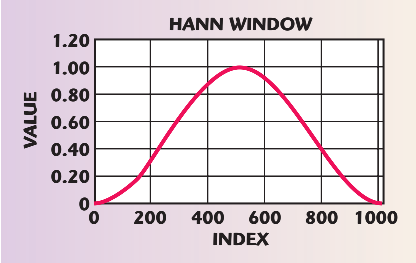
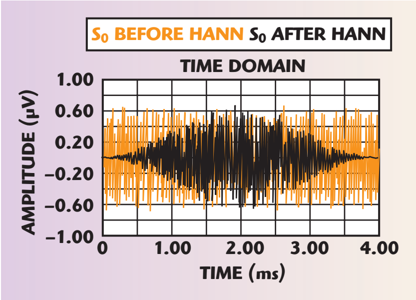
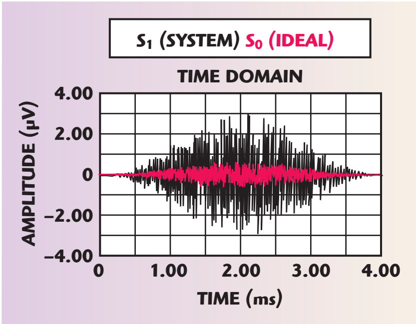


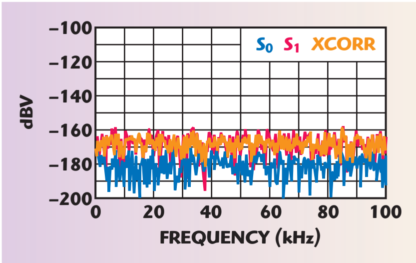
▲ *Fig. 3 Hann window filter to be applied to a 1024 point time domain sample.*



▲ *Fig. 4 Time domain signal of S_0 before and after application of a Hann filter.*



▲ *Fig. 5 Time domain of 'system' S_1 with superimposed time domain of desired signal.*

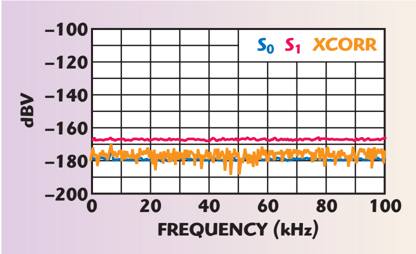


▲ *Fig. 6 The three traces represent signal S_0, S_1, and the cross-correlation of S_0 and S_1 with 1 correlation.*

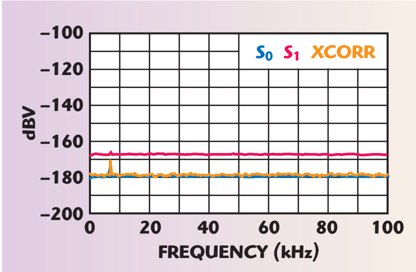
the noise levels of the receiver with resultant signal S_1.

WINDOWING

Window filtering is an important step in noise analysis. Discontinuities that occur during the start and stop of the finite sampling of a signal can cause spectral-leakage from one frequency to another, once the Fourier transform is applied. In low dynamic range systems,



▲ *Fig. 7 The three traces represent signal S_0, S_1, and the cross-correlation of S_0 and S_1 with 100 correlations.*



▲ *Fig. 8 The three traces represent signal S_0, S_1, and the cross-correlation of S_0 and S_1 with 10,000 correlations.*

such as a 6- or 8-bit oscilloscope, this may not have much of an effect. However, with higher dynamic range systems (>60 dB), this can cause significant problems. To overcome this, the input time domain signal is windowed with an additional function to reduce this effect. For this example, we use the Hann window shown in ***Figure 3***, one of the more common windows used with noise analysis. The Hann window is defined as

$$\omega(n) = \frac{1}{2}\left(1 - \cos\left(\frac{2\pi n}{N-1}\right)\right) \qquad (7)$$

where N is the number of time domain samples. In this example we use 1024 points. Windowing of the ideal signal S_0 is shown in ***Figure 4***. In a real (noisy) measurement system, with noise components v_{n1} and v_{n2} being greater than signal S_0, the actual measurement is going to look more like ***Figure 5***. For comparison, Figure 5 shows the ideal S_0 superimposed with the measured system signal S_1.

At this point, the cross-correlation algorithm is applied to signals S_1 and S_2 with vector averaging (cross correlations) at 1, 100 and 10,000 for a maximum improvement of 0, 10 and 20 dB, respectively. ***Figures 6, 7*** and ***8*** demonstrate the effectiveness of cross correlation for 1, 100 and 10k correlations, respectively. Each plot contains three curves. The blue curve is the

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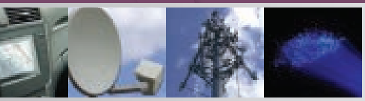

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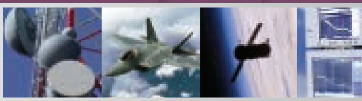

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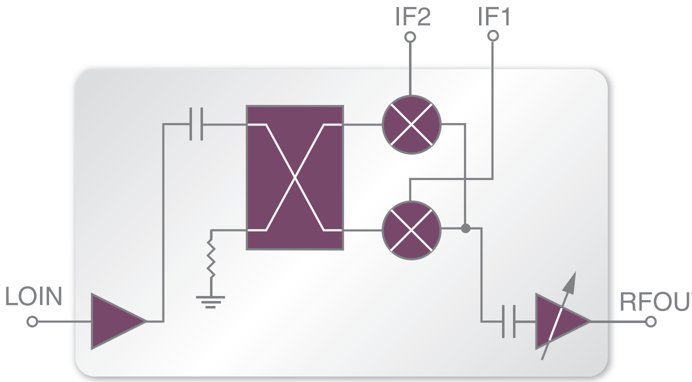

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	17.7 - 23.6	I/Q Upconverter / Transmitter	DC - 3.75	15	35	29	LC5	**HMC819LC5**
	16 - 21	I/Q Upconverter / Transmitter	DC - 3.5	12	20	30	LC5	**HMC710LC5**
	21 - 27	I/Q Upconverter / Transmitter	DC - 3.75	12	20	27	LC5	**HMC815LC5**

	RF / LO Frequency (GHz)	Function	IF Frequency (GHz)	Conversion Gain (dB)	Image Rejection (dB)	IIP3 (dBm)	Package	Part Number
NEW!	5 - 9	I/Q Downconverter / Receiver	DC - 3	12	20	2	LP4	**HMC951LP4E**
	12 - 16	I/Q Downconverter / Receiver	DC - 3.5	14	32	-1	LC5	**HMC869LC5**
	21 - 25	I/Q Downconverter / Receiver	DC - 3.5	10	20	5	LC5	**HMC571LC5**
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TABLE III
RESULTS OF THE EXAMPLE SHOWING AN IMPROVEMENT OF MEASUREMENT SENSITIVITY WITH A HIGHER NUMBER OF CORRELATIONS

XCORR	Input Noise (dBc/√Hz)	LNA (dBV/√Hz) Noise	Measured Noise (dBV/√Hz)
1	-179	-167	-167
100	-179	-167	-176
10k	-179	-167	-178.5

ideal signal S_0, having the number of correlations equal to the number of averages. The red curve is the signal S_1 of the individual channel, having the number of correlations equal to the number of averages. The yellow curve is the resultant cross correlation after vector averaging the number of 'correlations'. The results are tabulated in ***Table 3***, respective of the number of correlations.

CONCLUSION

Cross-correlation analysis trades measurement setup complexity and time for increased sensitivity. In situations such as measuring phase noise where hardware can limit the measurement sensitivity compared to the device under test, cross correlation may be applied to improve the sensitivity to acceptable levels. In cases where the measurement floor is still below the device under test, but very close, cross correlation will improve the overall accuracy of the measurement. For cross correlation to be most effective, each channel must be isolated as much as possible to reduce or eliminate common mode noise. Additionally, the lower the noise measurement capability of each individual channel, the fewer correlations will be required and the faster a measurement can occur. As shown in the example plots of Figures 6-8, cross correlation has the ability to pick up noise and small signals that are otherwise invisible to traditional measurement systems. ■

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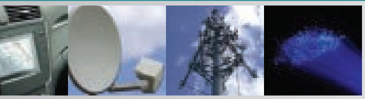

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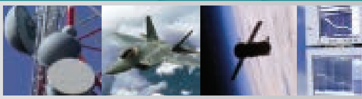

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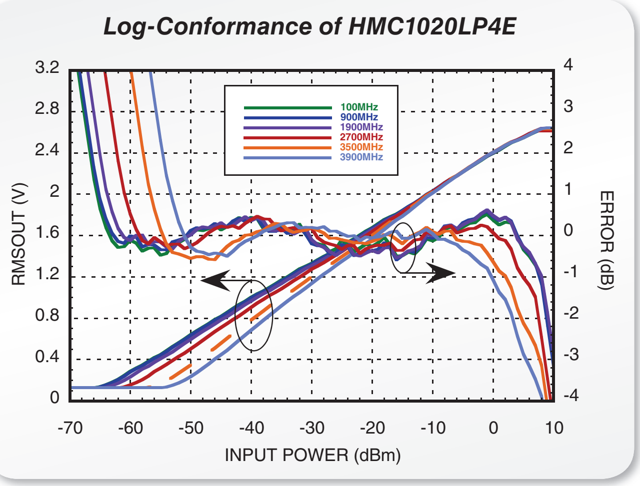

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NEW!	DC - 3.9	RMS, Single-Ended	75 ±1	35	-68	+5V @ 50 mA	LP4	**HMC1020LP4E**
NEW!	DC - 3.9	RMS, Single-Ended	71 ±1	35	-68	+5V @ 70 mA	LP4	**HMC1021LP4E**
	DC - 5.8	RMS, Single-Ended	40 ±1	37	-69	+5V @ 42mA	LP4	**HMC909LP4E**
	50 Hz - 3.0	Log Detector / 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**
	0.05 - 8.0	Log Detector / Controller	54 ±1	17.5	-55	+5V @ 17mA	LP3	**HMC713LP3E**
	0.1 - 2.7	Log Detector / Controller	54 ±1	17.5	-52	+5V @ 17mA	MS8	**HMC713MS8E**
NEW!	1 - 23	mmW Log Detector	54 ±3	14.2	-52	+3.3V @ 91mA	LP3	**HMC948LP3E**
	8 - 30	Log Detector	54 ±3	13.3	-55	+3.3V @ 88mA	LP3	**HMC662LP3E**
	0.1 - 20	SDLVA	59	14	-54	+3.3V @ 83mA	LC4B	**HMC613LC4B**
	0.6 - 20	SDLVA	59	14	-54	+3.3V @ 80mA	Chip	**HMC913**
	0.6 - 20	SDLVA	59	14	-54	+3.3V @ 80mA	LC4B	**HMC913LC4B**
	1 - 20	SDLVA	59	14	-67	+12V @ 86mA	C-10 / SMA	**HMC-C052**
NEW!	1 - 26	SDLVA	59	11	-52	+3.3V @ 135mA	Chip	**HMC813**
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Vector-receiver Load Pull Measurements

Editor's note: This month's RF/MW boards, components and systems issue considers all off-chip (non-MMIC/RFIC) circuit design. Since this type of design involves discrete component integration and component interconnect and matching circuit design, measurement-based characterization plays a key role in the design process. The following special report considers the improvements in large-signal device characterization brought on by a new class of vector receiver load pull systems compared to older scalar techniques using calibrated automated load pull tuners. Recent improvements to nonlinear device measurement systems have greatly enhanced load pull characterization, which in turn impacts RF board level circuit design, particularly power amplifiers using discrete transistors.

The automated load pull was introduced by Maury Microwave Corp. based on an automated slide-screw tuner in 1987. At least 20 years earlier, manual mechanical tuners of various forms were used to match transistor impedances when characterizing and designing amplifiers. Today, the importance of properly matching a transistor module when designing an amplifier is common knowledge; it is essential to use impedance matching networks on the input and output of a transistor in order to maximize power transfer, output power, gain and efficiency. The technique used to determine ideal matching network impedances is referred to as 'load pull'. This paper looks at some of the shortcomings of the older traditional methods and the improved accuracy introduced by techniques developed around the new class of nonlinear-based vector analyzers.

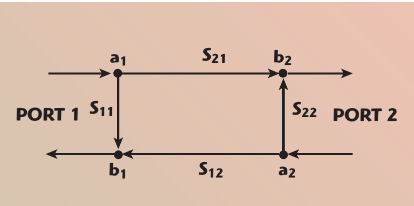


Fig. 1 Two-port scattering parameter model.

The goal of load pull is to present a set of controlled source and load impedances to the device under test (DUT) while measuring a multitude of parameters at each point. By varying the impedance, it is possible to characterize the performance of a device and design the ideal matching network for optimum realistic large-signal operating conditions.

The impedance presented to the DUT can be stated in various formats: Impedance Z_{load} (consisting of R±jX), voltage standing wave ratio (VSWR) (as a complex number in magnitude and phase) and reflection coefficient Γ_L (as a complex number in magnitude and phase). Considering the DUT as a two-port device shown in ***Figure 1***, the magnitude of reflection presented to the device, Γ_L, is nothing more than a_2/b_2, or the ratio between the reflected- and forward-traveling waves. The generalized formula can be written as

$$\Gamma_{x,n}(f_n) = \frac{a_{x,n}(f_n)}{b_{x,n}(f_n)} \quad (1)$$

From a system perspective, there are four impedances that affect our load pull measurements, as shown in ***Figure 2***:

Steve Dudkiewicz
Maury Microwave Corp., Ontario, CA

Z_{source}, the impedance looking from the DUT input into the source tuner and beyond

Z_{in}, the large-signal input impedance of the DUT

Z_{out}, the large-signal output impedance of the DUT

Z_{load}, the impedance looking from the DUT output into the load tuner and beyond

It is the value of these impedances that determine the amount of power delivered to and reflected from the device. While Z_{in} and Z_{out} are characteristics of the device itself and cannot be controlled directly, the load pull system is used to vary Z_{source} and Z_{load}.

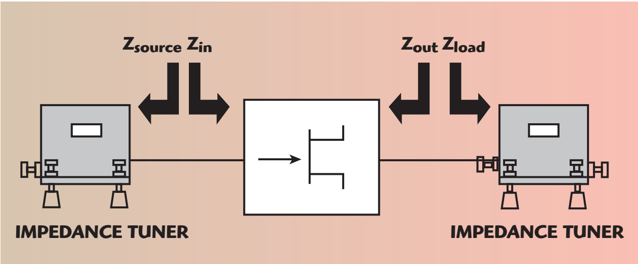


Fig. 2 Impedances of and presented to the DUT.

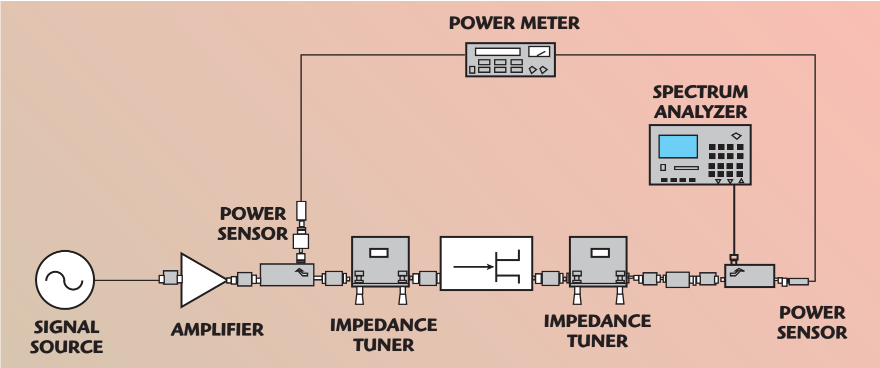


Fig. 3 Traditional load pull block diagram.

TRADITIONAL AND VECTOR-RECEIVER LOAD PULL SYSTEMS

A traditional load pull system (see ***Figure 3***) comprises a signal input path consisting of signal source and amplifier, source and load impedance tuners, and scalar measurement instruments such as mandatory power meters and an optional spectrum analyzer. In this type of system, the input and output powers of the DUT are determined by de-embedding the measured power from the power meters through the RF component chains and through the tuners.

Power meters are wideband in nature and measure the entire signal outputted from a transistor including fundamental and harmonic power. A highly compressed device can output significant second and third harmonic powers; however, there is no way of knowing the percentage of power allocated from each frequency. Therefore, the value read from the power meter is attributed entirely to the fundamental frequency and artificially increases the power assumed to come from the DUT. The only solution is to add a spectrum analyzer to the system which increases the cost and complexity, and it still relies on accurate de-embedding from the DUT to the instrument. In addition, these meters require considerable settling time to acquire an accurate power reading.

A vector-receiver load pull system (see ***Figure 4***) comprises a signal input path consisting of a signal source and amplifier, source and load impedance tuners, and a vector-receiver. The vector-receiver uses only the a- and b-waves calibrated at the DUT reference plane to determine measurement parameters. In this case, the a- and b-waves are analyzed on a per-frequency basis, so that each frequency component is accurately separated and used to calculate independent fundamental and harmonic powers. Additionally, a network analyzer is inherently a more accurate tool for measuring power than a power meter or spectrum analyzer.

By measuring a_1, b_1, a_2, b_2 and the instantaneous large-signal Z_{source}, Z_{in}, Z_{out} and Z_{load}, we can more accurately

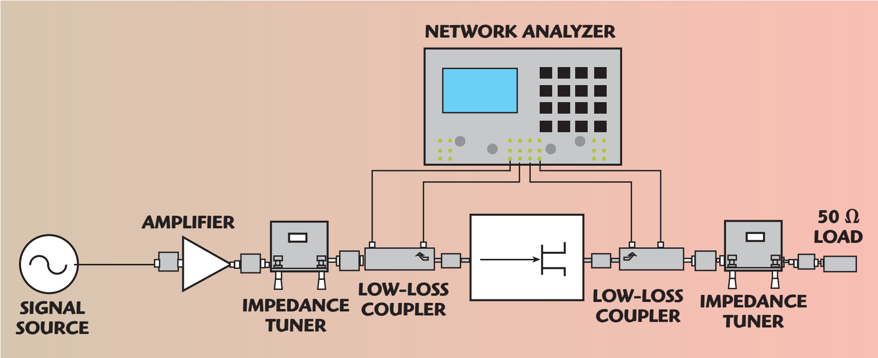


Fig. 4 Vector-receiver load pull block diagram.

calculate delivered power, gain and efficiency. The output power delivered by the device is represented as

$$P_{out} = \frac{1}{2}\left(\left|b_2\right|^2 - \left|a_2\right|^2\right) = \frac{1}{2}\left|b_2\right|^2 * \left(1 - \left|\Gamma_{load}\right|^2\right) \quad (2)$$

The input power delivered to the DUT at the tuned source impedance is

$$P_{in,del} = \frac{1}{2}\left(\left|a_1\right|^2 - \left|b_1\right|^2\right) = \frac{1}{2}\left|a_1\right|^2 * \left(1 - \left|\Gamma_{in}\right|^2\right) \quad (3)$$

In a traditional load pull system, the input impedance of the DUT is not known and the source tuner will be used to best match the input of the device in order to maximize power transfer. However, unless the source tuner is exactly matched to the complex conjugate of S_{11}, which varies with input power, full power transfer will not occur. Therefore, the delivered power to the device will not be known and the available power will be used to determine parameters such as transducer gain and compression. The offset in the input power, gain and efficiency is caused by the mismatch between the source tuner and the device input impedance. The available input power used by the traditional system is represented as

$$P_{in,avail} = \frac{P_{in,del}}{1 - \left|\frac{Z_{in} - Z^*_{source}}{Z_{in} + Z^*_{source}}\right|} \quad (4)$$

It is easy to see that the available and delivered input powers converge as $Z_{in} = Z^*_{source}$.

Likewise, the power gain measured in a vector-receiver load pull system is represented as

$$G_p = \frac{P_{out}}{P_{in,del}} = \frac{\left|b_2\right|^2 * \left(1 - \left|\Gamma_{load}\right|^2\right)}{\left|a_1\right|^2 * \left(1 - \left|\Gamma_{in}\right|^2\right)} \quad (5)$$

whereas in a traditional load pull system the transducer gain is represented as

$$G_t = \frac{P_{out}}{P_{in,avail}} = \frac{\left|b_2\right|^2 * \left(1 - \left|\Gamma_{load}\right|^2\right)}{\left|a_1\right|^2 * \left(1 - \left|\Gamma_{in}\right|^2\right)} * 1 - \left|\frac{Z_{in} - Z^*_{source}}{Z_{in} + Z^*_{source}}\right|^2 \quad (6)$$

Power-added efficiency measured in a vector-receiver load pull system is represented as

$$PAE = \frac{P_{out} - P_{in,del}}{P_{DC}} \quad (7)$$

whereas in a traditional load pull system the efficiency is represented as

$$Eff = \frac{P_{out} - P_{in,avail}}{P_{DC}} \quad (8)$$

As with input power, power and transducer gains converge and power-added and standard efficiencies converge as $Z_{in} = Z^*_{source}$.

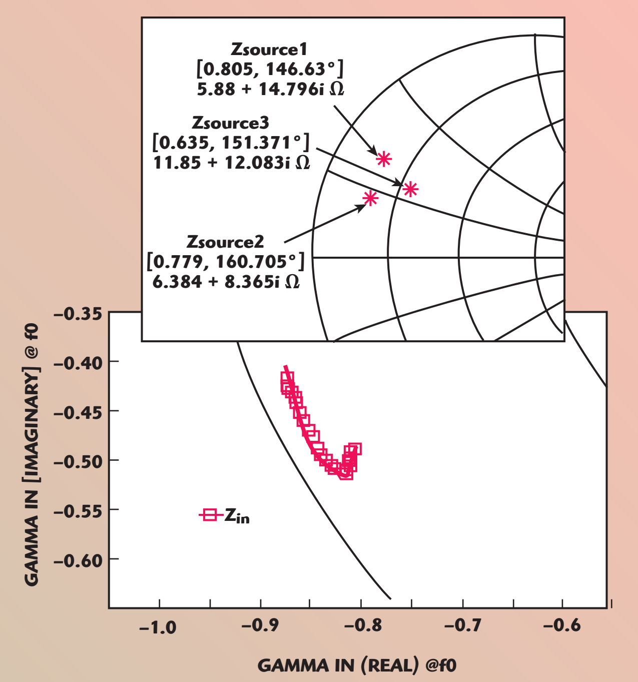
LARGE-SIGNAL INPUT IMPEDANCE AND GAIN

A common sequence for traditional load pull is to apply a fixed signal-source power and tune the source impedance for maximum gain. The load impedance is then tuned for some maximum parameter, output power or efficiency, for example. Source and load tuning iterations continue until the optimal impedances are determined, after which, a power sweep is

often performed to measure the gain compression of the device.

A DUT's large-signal input impedance varies with source power; therefore, the source impedance selected when performing source pull was optimal at only one specific power and not over the entire range of the power sweep, resulting in sub-optimal matching under the majority of conditions.

To illustrate, ***Figure 5*** shows the large-signal input impedance of a GaAs FET plotted as a function of power on the Smith Chart. In this case, the input impedance varies significantly with power. In the same example, three source impedances are tuned one at a time, and a power sweep is performed for each one (see ***Figure 6***). Since the traditional load pull system is only capable of measuring available input power, the level of mismatch between the actual device input impedance and the tuned source impedance will affect the overall transducer gain of the device and differ at each power level.



▲ *Fig. 5 Large-signal input impedance of DUT and three tuned source impedances.*

Because the vector-receiver load pull system measures the a- and b-waves in real time at the DUT reference plane, delivered input power is always known even if it is physically impossible to match the tuned source and DUT input impedances. The power gain G_p power sweep shows a significant improvement over transducer gain G_t power sweeps and gives a more realistic understanding of the capabilities of the DUT (see ***Figure 7***). Transducer gain can still be used to verify the performance of the device at specific source impedances.

SOURCE IMPEDANCE MATCHING

Whereas the traditional system requires actual source pull in order to visualize source contours for power and gain, vector-receiver load pull is able to mathematically compute contours. Knowing the large-signal input impedance of the device, it is possible to calculate source contours by comparing the mismatch between the proposed source impedance and the real-time large-signal input impedance, which changes as a function of power and tuned load impedance, as well as the actual input power drive (see ***Figure 8***). Measured source-pull contours and mathematically computed source contours have been compared with excellent agreement. The ability to virtually vary the source impedance seen by the DUT and compute contours eliminates the need for multiple source pull load pull iterations thereby significantly reducing measurement time.

TUNER CHARACTERIZATION AND DE-EMBEDDING

In a traditional load pull system, the most important factor in system accuracy is the characterization of each tuner at every frequency of interest. Characterization entails moving the tuner's internal RF probe (slug) to a multitude of horizontal and vertical positions and recording the associated S-parameters. These S-parameters are then used to calculate the loss through the tuner for power de-em-

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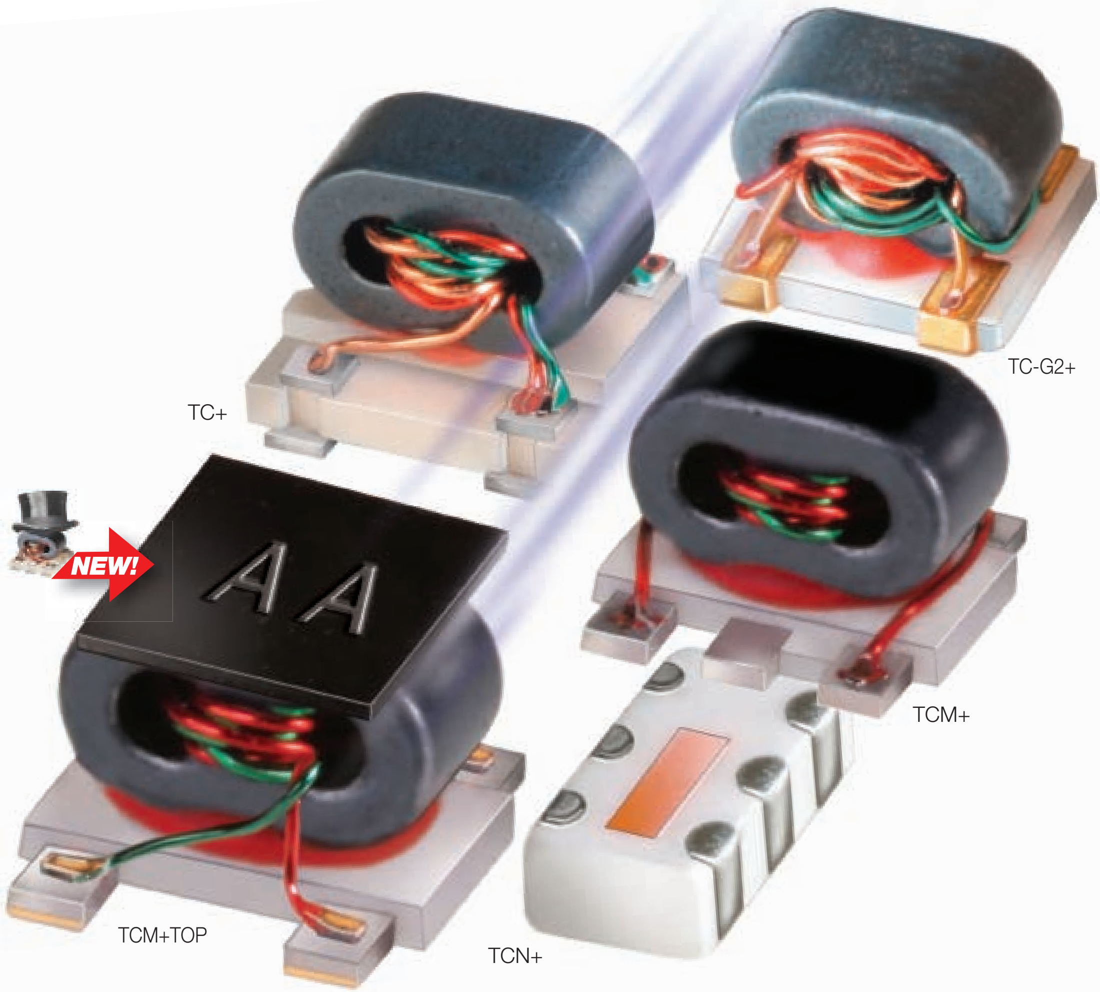

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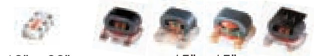

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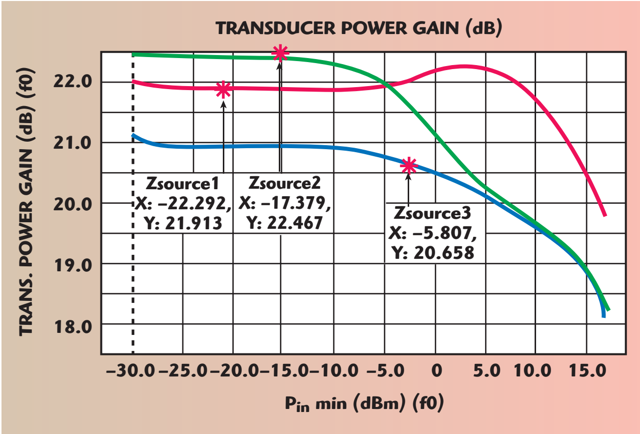
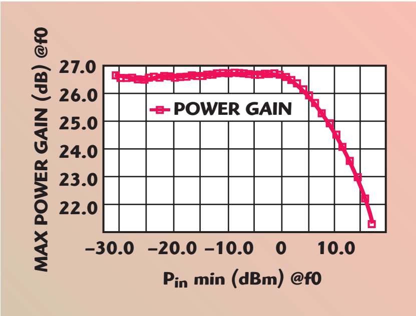


▲ *Fig. 6 Power sweeps at each of the three tuned impedances (three separate G_t sweeps).*

bedding and to calculate the impedance presented to the DUT. In order to improve the tuning accuracy, hundreds or thousands of individual tuner states are characterized. Interpolation is helpful in reducing the number of characterized states, but there are those who still insist on lengthy characterization procedures. Long-term tuner repeatability is paramount, as the S-parameters associated with each state are not re-measured.

In a vector-receiver load pull system, the impedances presented to the DUT are measured in real time. In this case, it is not important to fully pre-characterize the source and load tuners and only a small selection of points is needed, if at all. Likewise, tuner repeatability does not play a role in system accuracy as the impedances presented by the tuners to the DUT are constantly being measured. Power is determined from the a- and b-waves calibrated at the DUT reference plane, eliminating the need for tuner de-embedding.

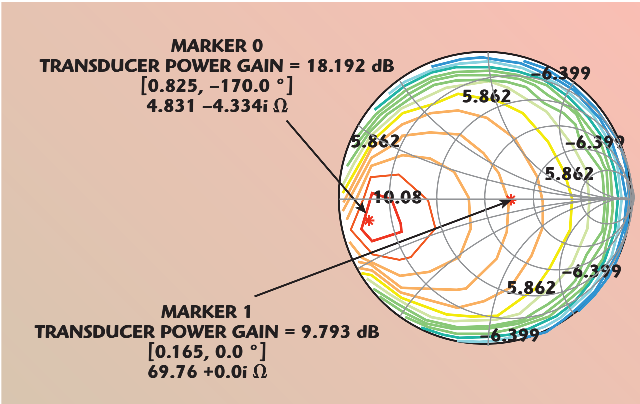


▲ *Fig. 7 Power sweep while matching large-signal input impedance and source impedance (one G_p sweep).*

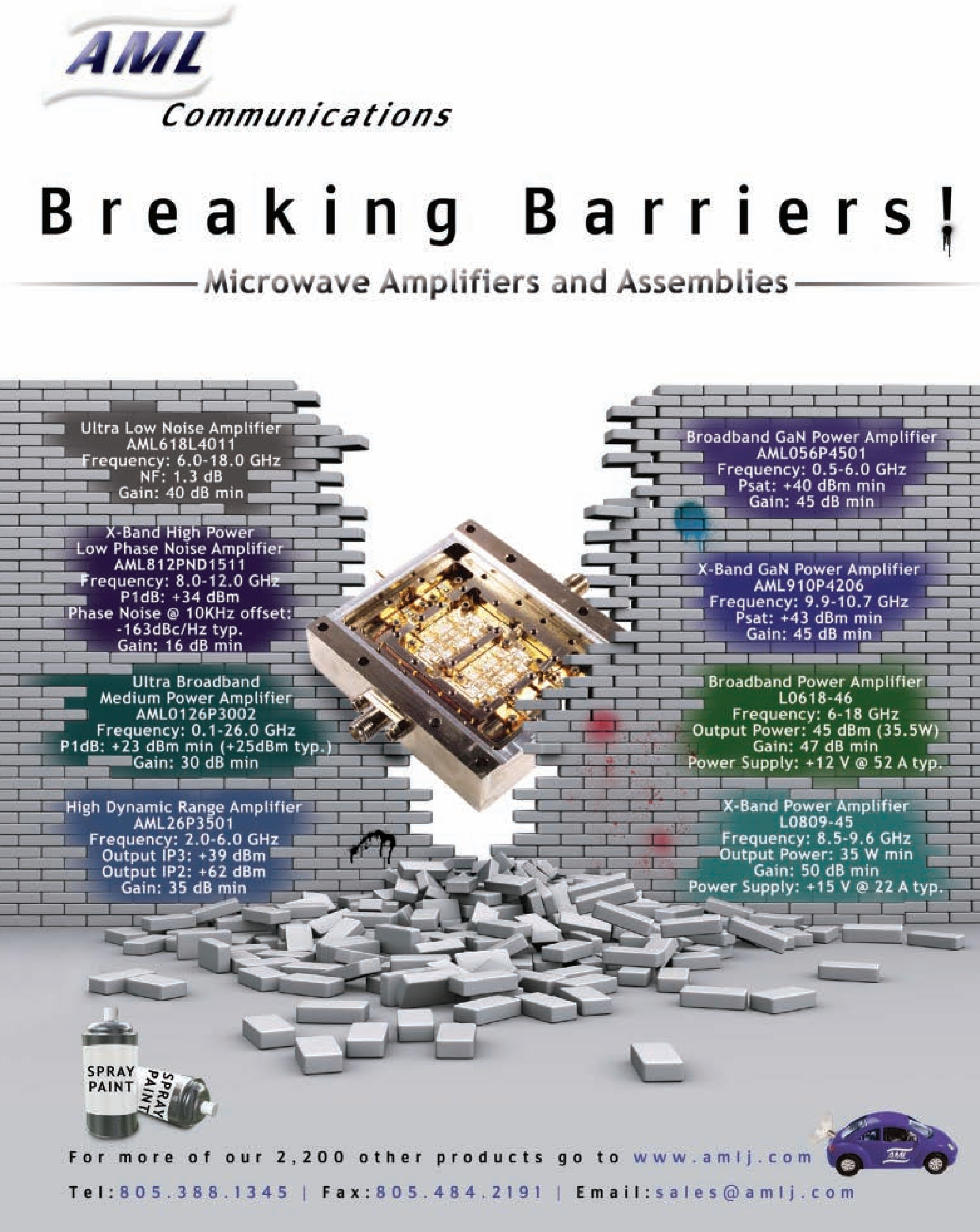
SYSTEM VERIFICATION

In traditional load pull systems, post-calibration system verification in the form of ΔG_t or complex conjugate matched verification is critical. ΔG_t compares the theoretical gain and the measured gain at any set of source and load impedances. For this measurement, an ideal or lossy THRU with an associated S-parameter file is used as the DUT. The input and/or output impedances presented to the DUT are adjusted and the gain is both calculated from known pre-characterized S-parameters and measured with the power meter and de-embedded to the DUT reference plane. Theoretically, the calculated and measured gains should match, resulting in a ΔG_t=0. However, a realistic variance up to ±0.4 dB is common across the Smith Chart.

Complex conjugate matched verification involves tuning the source and load tuners to positions that will present a conjugate match to the DUT, and measuring the gain on a THRU. The theoretical gain should be G_t=0 since the THRU is a lossless passive component, and the input and output impedances presented to the DUT are conjugate matched to eliminate mismatch losses. However, a



▲ *Fig. 8 Mathematically computed source contours for gain.*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Gain: 45 dB min
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realistic gain up to ±0.4 dB is common across the Smith Chart.

In a vector-receiver system, complex conjugate matched verification may be performed but is not essential since the impedances presented to the DUT and the powers measured from the DUT are calculated from the a- and b-waves calibrated at the DUT reference plane and not de-embedded through tuners. Verification is achieved by tuning the load tuner to some load impedance Z_{load} and comparing it to the measured Z_{in} on a THRU. Since the THRU line is transparent, Z_{in} of the THRU should be equal to Z_{load}. Verification is also achieved by measuring the actual power gain at any combination of source and load impedances on a THRU, with expectant power gain of G_p=0. Gain of up to ±0.2 dB is possible at highest tuned gammas, and can be greatly reduced by increasing the directivity of the low-loss couplers placed between the tuners and DUT.

TABLE I

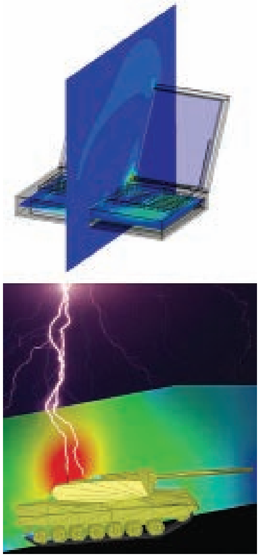
COMPARISON OF TRADITIONAL AND VECTOR-RECEIVER LOAD PULL METHODS

Measurement Parameter	Traditional Load Pull	Vector-Receiver Load Pull
Input Reflection Coefficient (Z_{in})	✗	✓
Available Input Power ($P_{in,avail}$)	✓	✓
Delivered Input Power ($P_{in,del}$)	✗	✓
Output Power (P_{out})	✓	✓
Power Gain (G_p)	✗	✓
Transducer Gain (G_t)	✓	✓
Power Added Efficiency (PAE)	✗	✓
Efficiency (Eff)	✓	✓
AM/PM	✗	✓
Calibrated Harmonic Power	Spectrum analyzer required	✓
Multi-tone Measurements	Spectrum analyzer required	✓
Modulated Measurements	Spectrum analyzer required	✗
Power Sweep Speed (for 25 power levels)	~20 seconds	~1 second

CONCLUSION

Traditional automated load pull has been used for over 20 years and is still a widely accepted method of a device characterization for amplifier design; however, it comes with the inherent weakness of not being able to accurately measure a device's large-signal input impedance. Without this device characteristic, it is impossible to accurately measure delivered input power, power gain and power-added efficiency. Because powers are measured from power meters and de-embedded through tuners, extremely accurate tuner characterization and tuner repeatability are required. Finally, multiple source-pull load pull iterations are required to converge on the optimal matching network source and load impedances. ***Table 1*** compares the capabilities and achievable measurement parameters between traditional and vector-receiver load pull methods.

Vector-receiver load pull overcomes these weaknesses by directly measuring the a- and b-waves of a device in real-time, thereby determining the large-signal input impedance at each input power and enabling the determination of delivered input power, power gain and power-added efficiency. Since the system is calibrated at the DUT reference plane, inaccuracies arising from tuner de-embedding, and possibly lengthy tuner characterizations are eliminated. Additionally, overall measurement time is greatly reduced by the system's ability to mathematically compute source contours and eliminate the multiple source-pull load pull iterations required by traditional load pull. ■



EM SIMULATION TRANSFORMS MICROWAVE AND SIGNAL INTEGRITY DESIGN

HFSS developers focus on product features and new technology that deliver expanded capability with accuracy, capacity and performance. HFSS 13.0 introduces a new 3D full-wave transient field solver based on the discontinuous Galerkin method (DGTD). This finite element-based time domain solution provides engineers with an additional tool for analyzing electromagnetic phenomenon, while maintaining the same gold standard for accuracy, provided by HFSS through adaptive meshing. A new solver technology, finite element-boundary integral or FE-BI, enables a combination of finite element and method of moment solvers to be employed for efficient simulation of large radiating or scattering problems. With FE-BI engineers can solve larger, more complex problems such as antenna placement analysis on an aircraft. Finally, simulation productivity is addressed through algorithm improvements and application of multiprocessing to parts of the solution and data processing. This product feature discusses in detail two of the newest technologies being introduced in HFSS 13.0: Transient and Finite Element - Boundary Integral (see ***Table 1***).

HFSS TRANSIENT

A new finite element-based transient or time domain field solver provides engineers with additional insight to electromagnetic phenomenon. Most commercial time domain solvers are based on a non-conformal brick mesh, which has problems with respect to accuracy and reliability. A finite element mesh conforming to geometry and allowing for an inhomogeneously sized mesh provides accuracy and efficiency when transient electromagnetic field analysis is of interest. Key technologies implemented in HFSS Transients such as local time stepping and a hybrid implicit/explicit solving scheme provides efficient and accurate solutions. This new solver complements the existing frequency domain solver technology in HFSS, allowing an engineer to investigate transient electromagnetic phenomenon in their designs.

TIME DOMAIN REFLECTOMETRY

Time domain reflectometry or TDR is a standard design parameter for evaluating the performance of devices in a high speed serial channel or data link. When designing to a TDR parameter the goal is to produce a flat response as close as possible to the nominal impedance of a system thereby minimizing signal reflection and loss in the system or channel.

As data rates for printed circuit board (PCB) applications have increased, a common practice for improving the performance of these “higher” speed channels has been the applications of a technique referred to as via back drilling. Back drilling eliminates any open ended via stubs that may extend to the bottom layer of a PCB.

Although relatively small, these stubs can act as resonating structures that can absorb, reflect and/or radiate energy of a digital signal carried by the channel. Their elimination means a high speed signal can propagate more easily with less reflection through the via geometry. Although very effective, back drilling can add cost to the manufacturing of a PCB; the designer needs to understand the impact of such a technique to the channel’s performance. ***Figure 1a*** shows the image of a differential via design in a 10 layer PCB with a stripline breakout layer at layer five, which results in via stubs extending to the bottom of the PCB with lengths of ~60 mils in FR4. A snapshot of the electric fields are taken in time at the moment when a pulse with a five picosecond rise time reflects at the end of these stubs. Much of this

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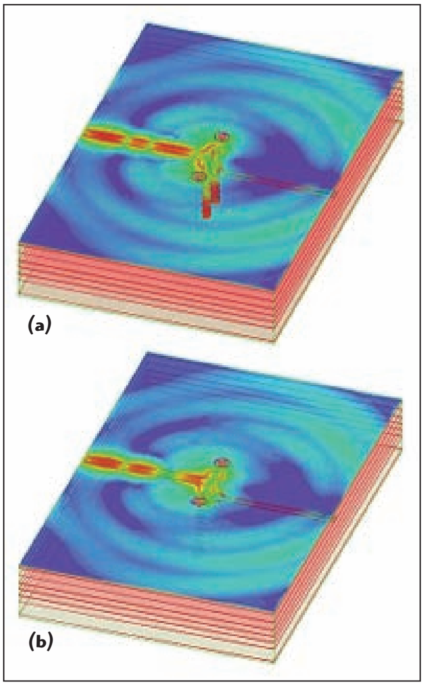
energy will undesirably reflect back to the differential microstrip input transmission line on the top layer. ***Figure 1b*** shows the same image for a similar via design where back drilling has been implemented to just short of the breakout layer. Significantly less energy has been reflected at this transition.

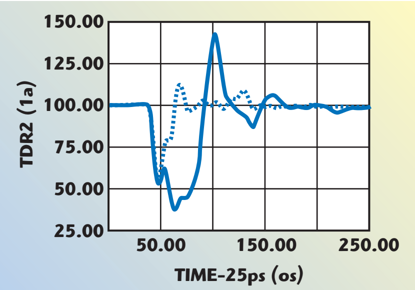
In the lab this behavior is identified through the TDR measurement technique. ***Figure 2*** shows the corresponding TDR plot from the analyses described in Figure 1. The responses align through the microstrip transmission line until reaching the stripline breakout layer where the design without back drilling exhibits a sharp and undesirable capacitive response in the TDR.

FINITE ELEMENT – BOUNDARY INTEGRAL

Inspired by recent advancements in domain decomposition techniques, a new hybrid finite element/integral equation technique is introduced in HFSS 13.0 for modeling large unbounded radiation and scattering problems. This technique, more commonly referred to in the literature as finite element-boundary integral (FE-BI), effectively truncates a nominally bounded finite element solution with a boundary integral. In HFSS 13.0 this new truncation is implemented as a full-wave integral equation, i.e. method of moments solution that satisfies the Sommerfeld radiation condition at infinity. This effectively utilizes the two simulation techniques, FEM and MoM, in their respective areas of strength; finite elements for handling complex geometries, materials and excitations and method of moments in solving directly for surface currents satisfying an open boundary problem. Engineers are able to model much larger systems such as antenna placement or radar cross-section studies.



▲ *Fig. 1 Electric field plot for differential via design without (a) and with back drill to stripline breakout layer (b).*



▲ *Fig. 2 TDR from design in Figure 1a (solid) and b (dashed).*

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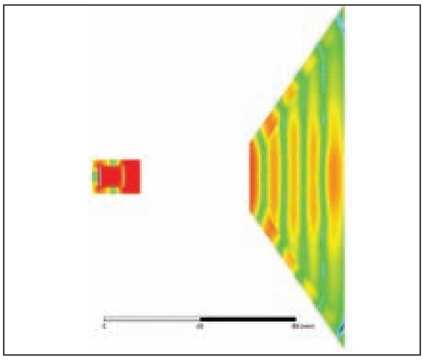
TABLE I: HIGHLIGHTS OF HFSS 13.0

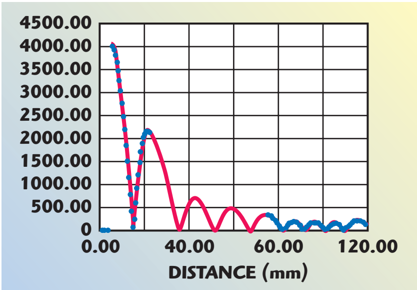
Feature	Comment
Transient, DGTD, full-wave solver	Accuracy for transient electromagnetic phenomenon
Finite Element – Boundary Integral technique for open boundary condition	Accuracy and capacity for radiating and scattering problems
Faster meshing via multiprocessing	Faster simulations for complex geometries
Faster solution field recovery via multiprocessing	Faster simulations for large, complex simulations with large excitation counts
Faster far field post-processing via multi-processing, algorithm improvements and data management	Significant speed up in far field post-processing
Generalized, multi-pole Debye frequency dependent material input	Ensures generation of causal S-parameter models
Automated settings for material properties	DC thickness for 3D conductors Causal material models for lossy dielectrics

SEPARATE FINITE ELEMENT VOLUMES

An interesting aspect of the FE-BI technique is its ability to act as a two-way "field link" between two physically separate volumes. To demonstrate, see ***Figure 3***, which shows a snapshot of the electric fields in a cut plane between a rectangular waveguide radiator illuminating a composite dielectric microwave lens. An FEM only solution would require the simulation of the entire air volume contained between the horn and lens. For the system in Figure 3, however, only the air volume immediately surrounding the radiating horn and lens need to be included in the FEM portion of the simulation. The equivalent surface currents capturing the coupling between these air volumes are computed via the integral



▲ *Fig. 3 Dielectric lens with rectangular waveguide feed with FE-BI and separate air volumes (left) and traditional PML with all surrounding air volume (right).*



▲ *Fig. 4 Field along line through center of feed antenna and lens for FE-BI model (blue circle) and PML model (red line).*

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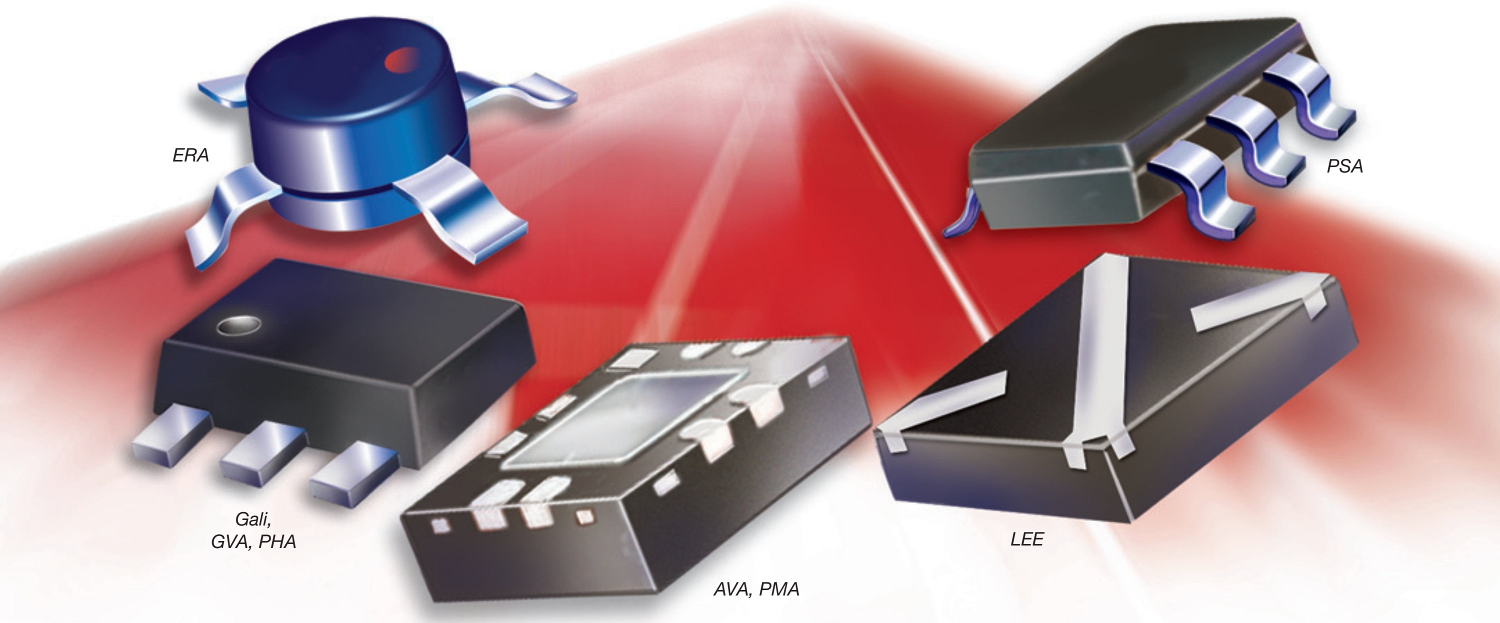

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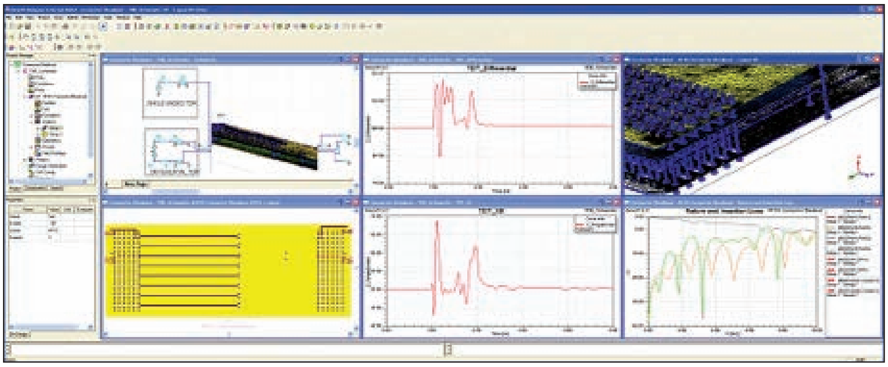


▲ *Fig. 5 Backplane in Designer layout interface solved with HFSS SoD.*

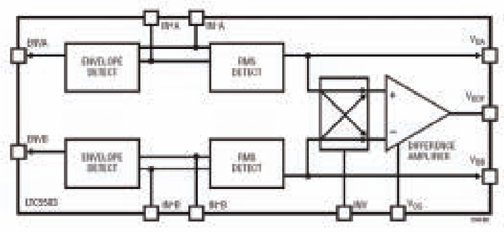
equation solver. Thus, the overall computational domain for this system can be significantly reduced through the application of the FE-BI technique. Also note that the separation between the horn and lens may be varied without affecting the computational effort since the FEM volume and IE surface area will not change with separation. ***Figure 4*** is a plot of the electric fields along the center connecting axis of the system in Figure 3. The line represents the fields for a full FEM solution with the entire air volume between horn and lens simulated; the data points represent the same system with the FE-BI technique coupling the fields between separate air volumes.

HFSS – SOLVER ON DEMAND

Ease of use and accessibility are two very critical aspects of simulation software design. Many electrical engineers are familiar with layout-based design flows for chip package and board design. These designs, although 2D in the nature of their creation, are representations of 3D designs, which at higher frequencies and data rates require a rigorous full-wave 3D simulation. The HFSS Solver on Demand technology enables users to drive HFSS directly from the intuitive parametrically driven stack-up based layout interface of Ansoft Designer (see ***Figure 5***). With Solver on Demand technology, the material properties, port definitions and boundary conditions are set automatically within the Ansoft Designer layout interface. Integration to Cadence Design Systems, Mentor Graphics, Altium, Zuken, Autocad and GDSII support exists through AnsoftLinks.

HFSS version 13.0 introduces new solver technologies and integrated design flows to allow engineers to solve large, more complex designs. HFSS Transient and the new hybrid finite element – boundary integral solvers provide additional insight and higher solution capacity for the toughest electrical design challenges. HFSS Solver on Demand in Designer provides an easy to use layout driven interface for the HFSS solver technology to enable simulation of chip, package and printed circuit board designs generated from layout.

ANSYS Inc., Canonsburg, PA
(724) 746-3304,
ansysinfo@ansys.com,
www.ansys.com.



MATCHED DUAL-CHANNEL 6 GHZ RMS POWER DETECTOR

The Linear Technology LTC5583 is a 40 MHz to 6 GHz dual-channel, matched RMS power detector, offering over 55 dB isolation at 2.14 GHz. In RF power amplifier (PA) applications, the LTC5583 provides a simple solution for accurately measuring forward power, reverse power and voltage standing wave ratio (VSWR). The device comprises a pair of 60 dB dynamic range RMS detectors that are matched to 1.25 dB. This provides accurate RF power measurement of high crest-factor signals such as those used in LTE, WiMAX, W-CDMA, TD-SCDMA and CDMA2000 3G or 4G base stations and other high-performance radios employing complex modulation waveforms. Each channel can detect signals accurately from as small as -58 to 2 dBm in a log-linear response with a typical linearity of better than ±0.5 dB covering all cellular frequency bands. At higher frequencies, the device is capable of providing 47 dB of useful dynamic range up to 6 GHz. Unique to the LTC5583, each detector simultaneously tracks the envelope of the modulated input waveform, providing on-chip capability to measure both peak and average signal power.

The LTC5583 has best-in-class channel-to-channel isolation of over 55 dB at 2.14 GHz when driven differentially. Unlike other detectors, the LTC5583 can operate single-ended for RF input frequencies up to 2.14 GHz, requiring no external balun transformers. This configuration greatly reduces costs without trading off dynamic range and provides isolation better than 40 dB. An integrated amplifier measures the difference between the two detector outputs. For applications where one RF input is measuring the forward power and the other the reflected power, the difference output provides real time VSWR results. The two matched detectors are also useful in applications such as monitoring and controlling RF amplifier

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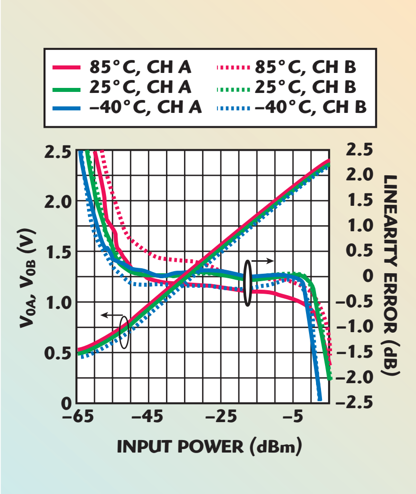
Milpitas, CA



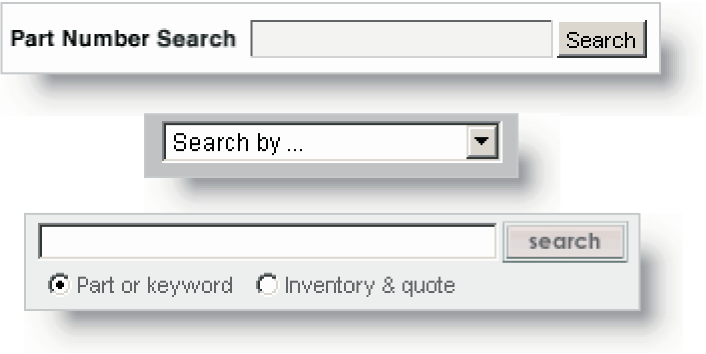
▲ *Fig. 1 Output voltage and linear error vs. RF input power at 2140 MHz (CW inputs, single-ended drive).*

stage gain. The LTC5583's matching and isolation performance minimize calibration requirements, thus simplifying designs and reducing costs.

The detectors exhibit outstanding temperature performance. Each detector maintains accuracy of ±1 dB error over a 53 dB dynamic range over its specified operating temperature range of -40° to 85°C (see ***Figure 1***). This enables the LTC5583 to be used in rugged environments such as Remote Radio Units (RRU) or Outdoor Units (ODU) deployed on cellular towers. Moreover, the device has on-chip provisions for first- and second-order temperature compensation, which enable easy calibration for improved temperature performance. Typical applications include VSWR monitor, MIMO transmit power control, base station PA control, transmit and gain control, and RF instrumentation.

The LTC5583 operates on a single 3.3 V supply with total current consumption of 80.5 mA. This 266 mW is 25 percent lower power than other available solutions. The device has an enable pin, allowing the chip to power down. In shutdown mode, the device draws a maximum current of 10 uA. The LTC5583 is available in a 4 × 4 mm 24-pin QFN package.

Linear Technology,
Milpitas, CA
(408) 432-1900,
www.linear.com.



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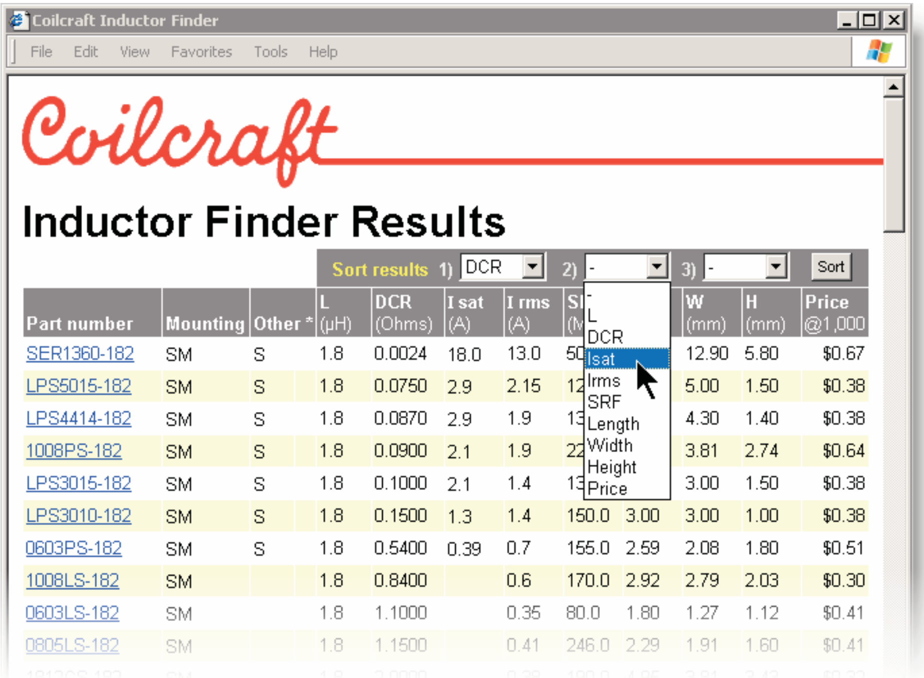

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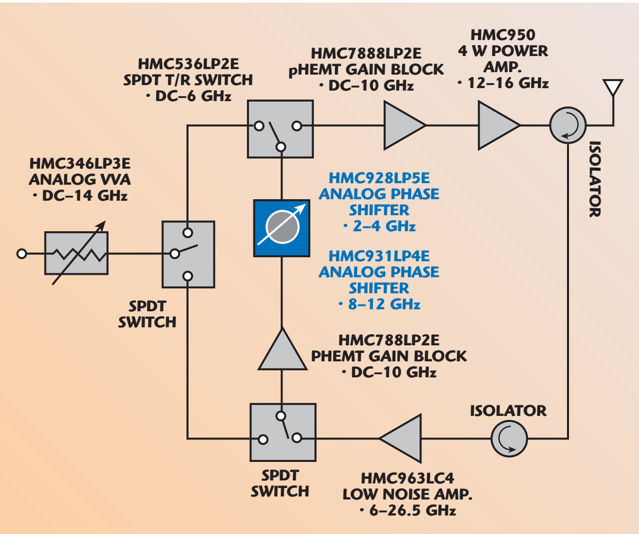
WIDEBAND ANALOG PHASE SHIFTERS COVER 2 TO 24 GHZ

Hittite has developed five new wideband analog phase shifters that are designed to deliver superior performance and innovative features, all within a miniature surface-mount package. These phase shifters—HMC928LP5E, HMC929LP4E, HMC931LP4E, HMC932LP4E and HMC933LP4E—are appropriate for radar systems, satellite communications, EW receivers, amplifier linearization applications and beamforming modules from 2 to 24 GHz.

A primary application of these phase shifters is in radar systems where transmit/receive beamforming modules contain one or more phase shifters in the T/R circuit. The phase shifter supplies the incremental phases to each antenna element, which adjusts the beam in different directions. The reciprocal nature of the phase shifter allows it to be placed in a common path, as illustrated in ***Figure 1***. Therefore, a key requirement for a good phase shifter is reduced phase error and good input/output matching. Given that the phase shifter matching does influence the relative phase shift error, a flat insertion loss curve across the tuning range is essential for accurate phase shift across the 360-degree of phase shift range. The insertion loss curves for the new line of Hittite



▲ *Fig. 1 Typical T/R module diagram.*

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Temperature Range:	-55°C to +155°C

Materials

Dielectrics:	PTFE Fluorocarbon, Type 1, GR1, CLA
Contacts (Female):	Phosphor bronze
Male Outer Contacts:	Phosphor bronze
Gaskets:	Silicone rubber, Class II, GR 50-60
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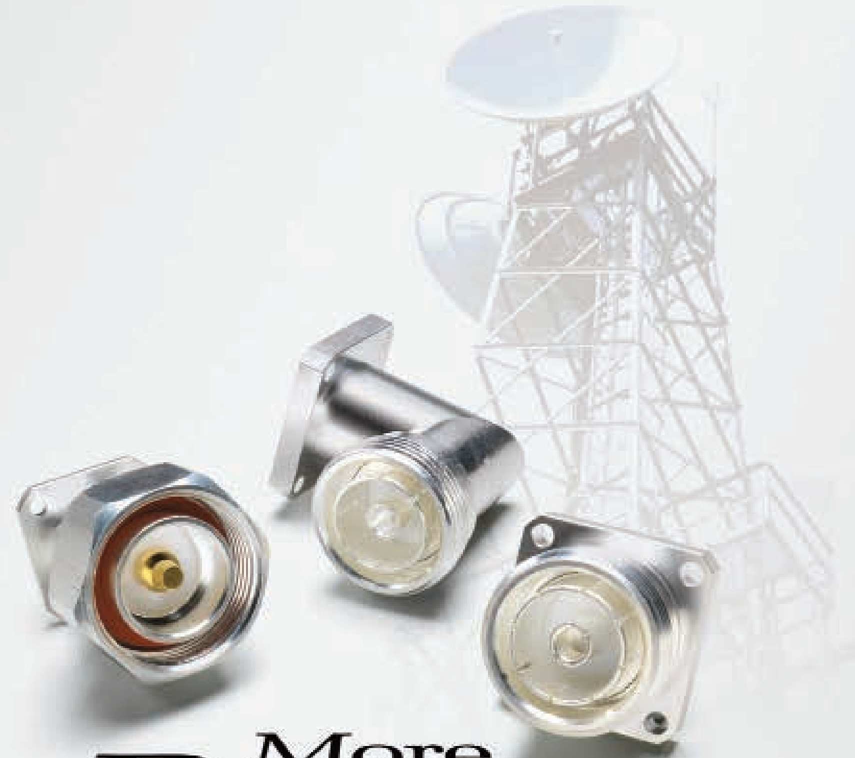

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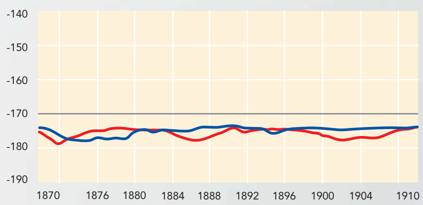

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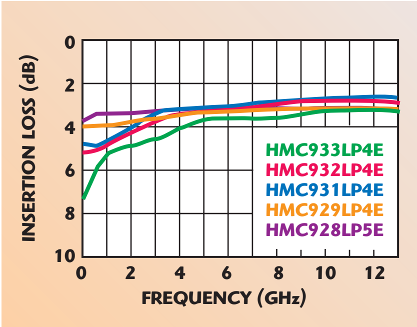
phase shifters are given in ***Figure 2***.

Another application where these phase shifters are useful is in the area of feed-forward amplifier linearization. Highly linear amplifiers are needed in order to generate the higher data rates and increased spectral efficiency required by microwave radio modulation techniques, such as QPSK, 64 QAM, etc. Linearization is a desirable alternative to backing off a Class A amplifier that would otherwise result in relatively high heat dissipation as well as low power efficiency. These phase shifters can be used to add a variable delay in the feed-forward linearization circuit, as illustrated in ***Figure 3***.

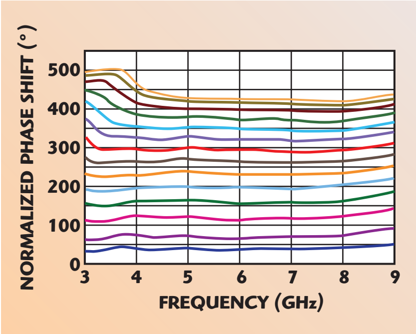
The HMC928LP5E provides a continuously variable phase shift of 0 to 450 degrees from 2 to 4 GHz, with extremely low insertion loss variation versus tuning voltage and frequency. The high accuracy HMC928LP5E is monotonic with respect to control voltage and features very low phase error of ±5 degrees over an octave bandwidth. The HMC928LP5E exhibits typical 3.5 dB insertion loss, accepts an analog control voltage from 0 to +13 V and is housed in a leadless surface-mount QFN 5 × 5 mm package.

The HMC929LP4E provides a continuously variable phase shift of 0 to 430 degrees from 4 to 8 GHz, with extremely consistent insertion loss versus tuning voltage and frequency. The high accuracy HMC929LP4E is monotonic with respect to control voltage and features very low phase error of ±10 degrees across all phase shift ranges over the rated bandwidth. The HMC929LP4E demonstrates a relatively linear phase response as a function of input control voltage, as illustrated in Figure 3. A phase shift range of up to 360 degrees can be achieved with 0 to +9.5 V tuning; a range of up to 430 degrees can be achieved with 0 to +13 V tuning. The HMC929LP4E is housed in a leadless surface-mount QFN 4 × 4 mm package.

The HMC931LP4E is an analog phase shifter that is controlled via an analog control voltage from 0 to +13 V. The HMC931LP4E provides a continuously variable phase shift of 0 to 410 degrees from 8 to 12 GHz, with



▲ *Fig. 2 Insertion loss vs. control voltage.*



▲ *Fig. 3 HMC929LP4E relative phase shift vs. tuning voltage.*

TABLE I

A SELECTION OF HITTITE'S ANALOG PHASE SHIFTER ICS – TYPICAL PERFORMANCE

Part Number	Freq. (GHz)	Insertion Loss (dB)	Phase Range (deg)	2nd Harmonic Pin= -10dBm (dBc)	Control Voltage Range (V)	Package
HMC928LP5E	2-4	3.5	450	-40	0 to +13	LP5
HMC929LP4E	4-8	4	400	-42	0 to +13	LP4
HMC931LP4E	8-12	3.5	410	-35	0 to +13	LP4
HMC932LP4E	12-18	4	390	-40	0 to +13	LP4
HMC933LP4E	18-24	4.5	470	-37	0 to +13	LP4

extremely consistent low insertion loss versus phase shift and frequency. The high accuracy HMC931LP4E is monotonic with respect to control voltage and features a typical low phase error of +12/-7 degrees over a wide bandwidth. The HMC931LP4E is housed in a RoHS compliant 4 × 4 mm QFN leadless package.

The HMC932LP4E is an analog phase shifter that is controlled via an analog control voltage from 0 to +13 V. The HMC932LP4E provides a continuously variable phase shift of 0 to 390 degrees from 12 to 18 GHz, with extremely consistent low insertion loss versus phase shift and frequency. The high accuracy HMC932LP4E is monotonic with respect to control voltage and features a typical low phase error of ±10 degrees over a wide bandwidth. The HMC932LP4E is housed in a RoHS compliant 4 × 4 mm QFN leadless package.

The HMC933LP4E is an analog phase shifter that is controlled via an analog control voltage from 0 to +13 V. The HMC933LP4E provides a continuously variable phase shift of 0 to 470 degrees from 18 to 24 GHz, with extremely consistent low insertion loss versus phase shift and frequency. The high accuracy HMC933LP4E is monotonic with respect to control voltage and features a typical low phase error of ±10 degrees over a wide bandwidth. The HMC933LP4E is housed in a RoHS compliant 4 × 4 mm QFN leadless package.

A summary of the newly released Hittite phase shifters is given in ***Table 1***. Released data sheets for the HMC928LP5E, HMC929LP4E, HMC931LP4E, HMC932LP4E and HMC933LP4E may be found at www.hittite.com. Samples and evaluation PC boards are available from stock and can be ordered via the company's e-commerce site or via direct purchase order.

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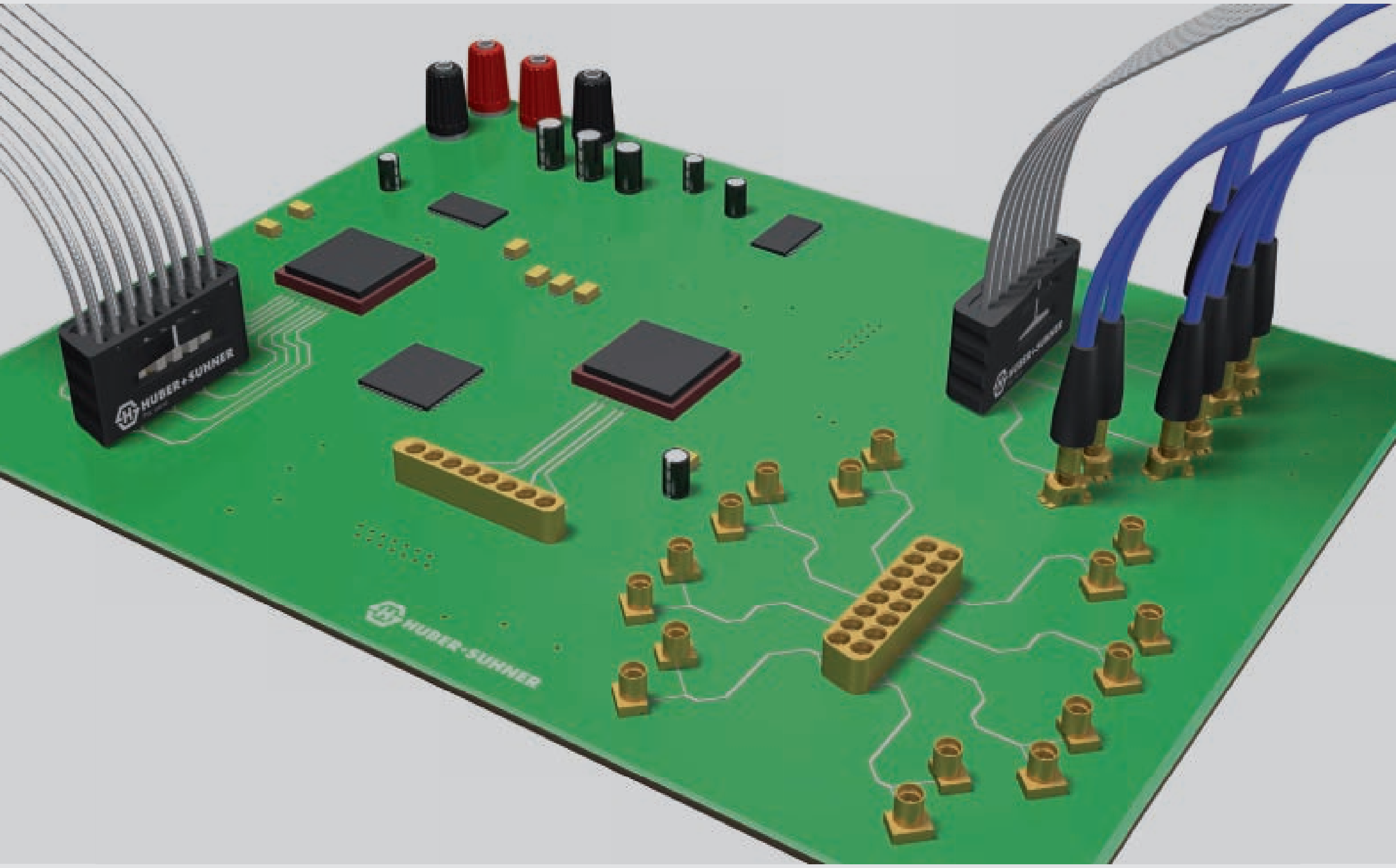

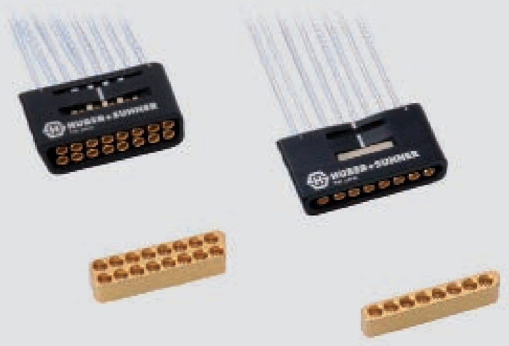

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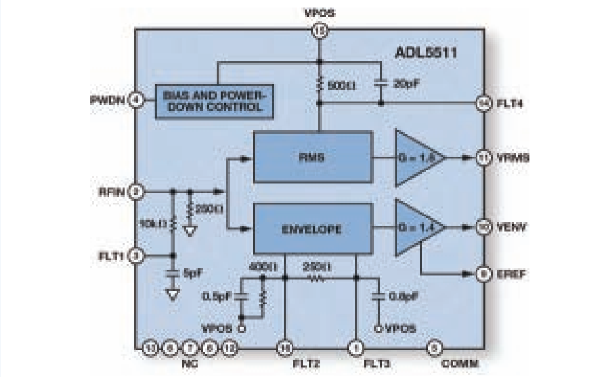

RF Power Detector Simultaneously Delivers RMS and Envelope Outputs

Next-generation WiMAX systems and LTE mobile data and voice systems are adopting OFDM modulation that supports a large number of subcarriers. The high peak-to-average ratio of these modulated signals causes PAs to be significantly backed off from their maximum transmit powers, thereby making the PA less efficient. To improve PA efficiency, an envelope detector has become increasing popular.

Analog Devices has introduced a highly integrated, high-performance RF detector for use in wireless, instrumentation, defense and other broadband applications. ADI's new ADL5511 TruPwr RMS and envelope detector offers a high level of integration and functionality by combining two RF functions into one small chip, thereby simplifying designs and reducing BOM cost.

Operating within the 1 MHz to 4 GHz frequency range, ADI's new ADL5511 TruPwr RMS and envelope detector provides a unique approach to improving PAE with a smaller footprint and reduced cost. It is a highly accurate, easy-to-use means of extracting the envelope of a modulated signal. The envelope output is presented as a voltage that is proportional to the envelope of the input signal. The RMS output is a linear in V/V output voltage that is independent of the peak-to-average ratio of the input signal. The extracted envelope can be used for power amplifier linearization and efficiency enhancements; the RMS output can be used for true power measurement.

The ADL5511 offers best-in-class performance including ±0.25 dB RMS detection accuracy versus temperature, ±0.25 dB envelope detection accuracy versus temperature and a ± 1 dB dynamic range of 40 dB. The ADL5511 is specified across the industry's widest temperature range of -40° to +125°C, making it ideal for high-temperature environments found in remote radio heads and power amplifiers.

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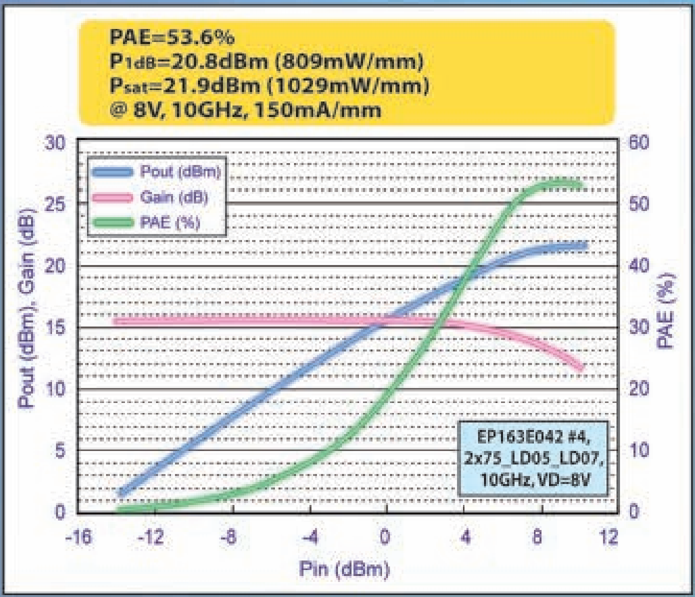

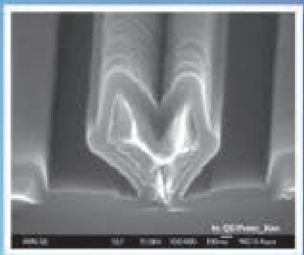

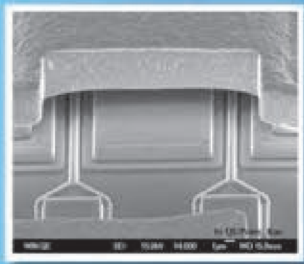

Comparison Table for 0.1μm, 0.15μm, 0.25μm and 0.5μm pHEMT

	PP10	PP15	PP25-21	PP50-11
Vto (V)	-0.9	-1.2	-1.2	-1.4
Idss (mA/mm)	450	500	345	350
Idmax (mA/mm)	720	650	460	480
GM (mS/mm)	750	495	380	310
VDG (V)	9	10	19.2	20
ft (GHz)	130	85	65~72	32
Fmax (GHz)	175	180	160	85
PldB (mW/mm)	533.25 (3.5V)	670 (5V)	809 (8V)	587 (8V)
Psat (mW/mm)	764.3 (3.5V)	820 (5V)	1029 (8V)	851 (8V)
Gain (dB)	14.35	18.1	15.6	15.5
PAE (%)	53.57	55	53.6	53.5
Frequency	29 GHz	10 GHz	10 GHz	10 GHz

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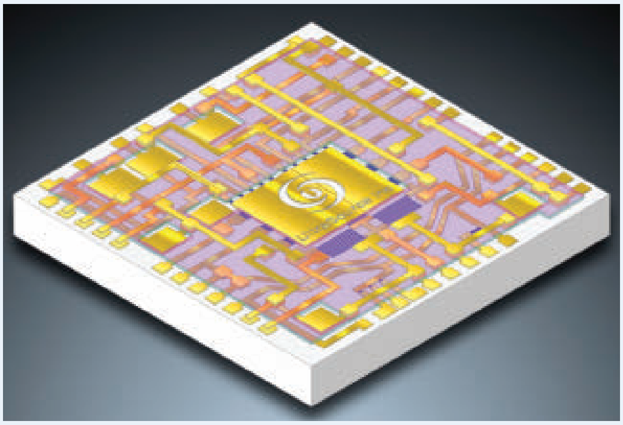

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The platform starts with BASIC solutions consisting of conventional single and double sided 2D designs. The BASIC product family can incorporate all classic thin film substrate materials, plated through holes, sheet resistors, high conductivity traces, pre-deposited AuSn solder and solder damming options. The INTEGRATED solutions allow selection from the UltraVia®, UltraBridge®, UltraCapacitor®, or UltraInductor® suite of solid state passive elements to provide higher levels of passive integration and performance. Conductor traces, resistors, capacitors, inductors, multilevel connections and filled vias can be integrated onto a single microcircuit. The MULTILAYER solution provides a five layer system that includes three layers of custom patterned gold conductors separated by two layers of polyimide dielectric. The ADVANCED solution is the ultimate in miniaturization and integrated performance. It combines the BASIC or INTEGRATED platform on one side of the device and the MULTILAYER features on the other side of the circuit. Front to back connections are made using UltraVia® filled vias. These modular processes can be tailored to meet precise specifications and provide cost-effective and versatile thin film solutions.

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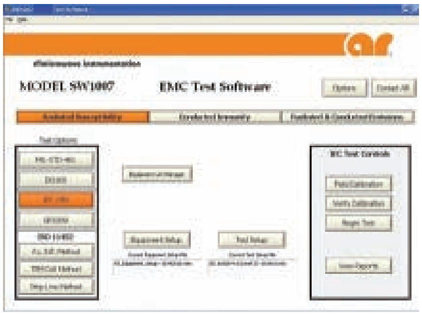
SYSTEM SIMULATION SOFTWARE

ACS has recently released a new version of the LINC2 Visual System Architect (VSA) system simulation software. Version 1.10 adds a new mixer model to the VSA's components menu for enhanced modeling of mixer spur generation. Also included in this version of the VSA is a new Accumulate Spectrum mode in the Spectrum Analysis display that captures and holds the output spectrum from multiple simulation runs. This new feature works like the Max Hold function on an actual spectrum analyzer. The Visual System Architect offers the flexibility and ease of use of schematic-based RF system simulation combined with a comprehensive array of analysis methods and graphic displays for designing at the system level.

Applied Computational Sciences (ACS) LLC,
Escondido, CA (760) 612-6988,
www.appliedmicrowave.com.



SOFTWARE FOR COMPLIANT TESTING

VENDORVIEW

AR's SW1007 software is a standalone program that combines conducted immunity test software and radiated susceptibility 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. The new version has an updated user interface including a tab system and organizes all the features for quick, easy access and makes selecting test standards much easier. The SW1007 also has the ability to control more equipment and the report generating feature has been enhanced to offer more control and customization.

AR RF/Microwave Instrumentation,
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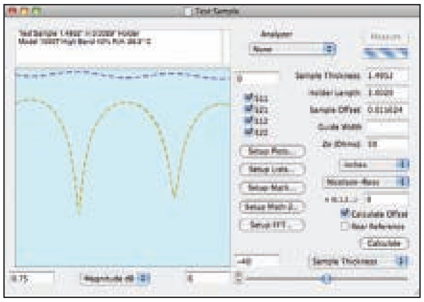

MU-EPSLN™ SOFTWARE

MU-EPSLN™ software has been upgraded so that it can be used over a wider range of frequencies extending from sub kHz to over 100 GHz. Instrument drivers are available for all of the major vector network analyzers. The program has many data reduction algorithms that can be used to enhance the quality of measurements in different parts of the frequency spectrum. It offers a variety of graphical and digital output. Damaskos provides coax, waveguide, free-space and parallel plate fixturing for measuring liquids, solids, soils, absorber and shielding materials that can be used with this program.

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USB DESIGNER'S KIT

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The HMC-DK008 Serial/Parallel USB Interface Designer's kit has been expanded to provide a user friendly interface for programming Hittite's family of interface driver/controllers, digital attenuators and variable gain amplifiers. This kit allows the designer to set desired attenuation and gain states, toggle between serial and parallel control modes, and construct custom serially clocked input signals. The HMC-DK008 Designer's Kit includes a Serial/Parallel USB Interface Board, custom USB and ribbon cable assemblies, and software CD-ROM.

Hittite Microwave Corp.,
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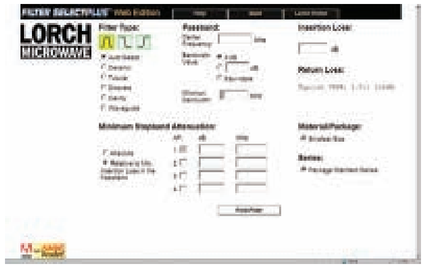

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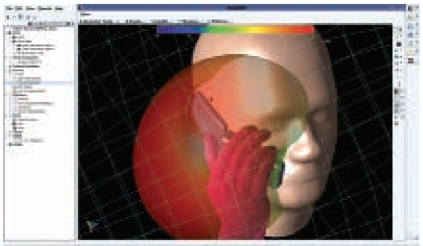
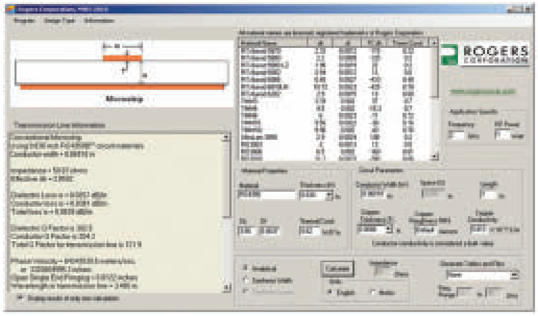


EM SIMULATION SOFTWARE

VENDORVIEW

Remcom's XFdtd® (XF7) is the market's most modern 3D electromagnetic simulation software for FDTD-based modeling and simulation. XF7 simplifies workflow with a streamlined user inferface, cross-platform functionality and several unique time-saving features. XF7 includes XStream, Remcom's GPU acceleration technology, for free. Using the power and flexibility of NVIDIA's CUDA architecture, XStream improves EM simulation performance with ultra-fast FDTD numerical computations — from 30 to 300 times faster than a modern 64-bit CPU. Other notable features include XACT Accurate Cell Technology for resolving the most intricate designs with fewer computational resources and the XTend Script Library, a suite of pre-loaded and customizable scripts for creating custom features.

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



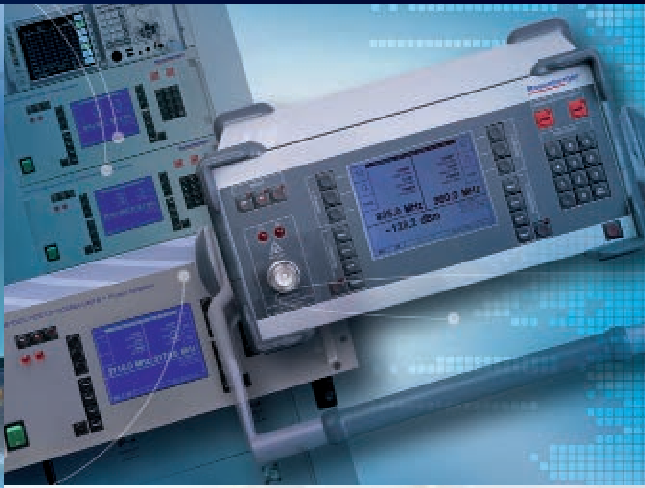
IMPEDANCE CALCULATOR

VENDORVIEW

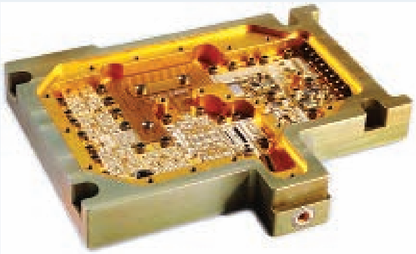
Rogers Corp. is offering its MWI-2010 Microwave Impedance Calculator software free to RF/microwave designers. The utility program calculates transmission-line parameters for a variety of high-frequency circuits, including microstrip and stripline, based on conductor dimensions and substrate characteristics. The easy-to-use software runs on Windows-based computers. Users enter parameters specific to their circuit application, including target frequency and RF power level, and generate transmission-line parameters, such as conductor width and spacing for a desired impedance. Results can be saved and reused in other programs. A free 22-page user manual is available on the Rogers' site in PDF form.

Rogers Corp.,
Chandler, AZ (480) 961-1382,
www.rogerscorp.com.

Rosenberger
Rosenberger



Low Phase Noise Assembly



This integrated microwave assembly (IMA) is an example of AML's capabilities to design, test and deliver physically small multi-functional assemblies. These application specific designs offer the system designer complex functions housed in a high-density package. The illustrated product comprises a 4 W low residual phase noise amplifier, a digitally-controlled attenuator, detector, drain pulser switch function, power supply conditioning and gain temperature compensation. Performance characteristics of this design include fast rise/fall time (< 50 ns) and minimum pulse droop (< 0.5 dB). Product is hermetically sealed and fully supports wide temperature operation in military environments.

AML Communications Inc.,
Camarillo, CA (805) 388-1345,
www.amlj.com.

High Pass Filters

Encased in a rugged SMA housing, this new line of high pass filters, the CHPFL series, is designed for test equipment and general lab use. Five models, with frequency ranges from DC to 100 MHz through 1 GHz, compose the CHPFL line. The Crystek CHPFL high pass filter line has excellent out-of-band rejection, and features seventh order Butterworth response and 50 ohm SMA connectors. All filters in the CHPFL family are rated at +36 dBm (4 W), with an operating temperature of -40° to 85°C and storage temperature of -55° to 100°C.

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

High Q Porcelain Capacitors

DLI introduced the new C18 series of enhanced voltage high-Q porcelain capacitors. With voltage ratings up to 2000 V, the C18 is designed to be the most robust "1111" high-Q capacitor available today. The C18 is available in both ultra stable (0±15 ppm/°C) CF and temperature compensating (+90 ppm/°C) AH dielectrics, and is form-factor compatible with its existing line of C17 "1111" capacitors.

Dielectric Labs,
Cazenovia, NY (315) 655-8710,
www.dilabs.com.

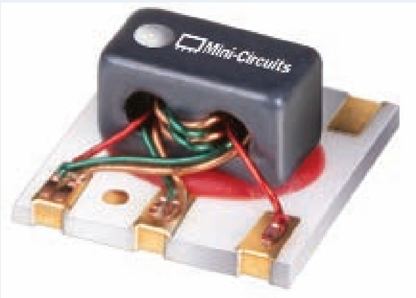
Chip Termination

IMS announced the availability of its compact 0505 size chip termination rated at 25 W characterized for DC to 40 GHz operation. The NDX-0505SG features Aluminum Nitride (AlN) substrate material that is an environmentally-safe alternative to BeO and has demonstrated return loss better than 20 dB over DC to 40 GHz. Terminal finishes for the NDX-0505SG can be RoHS compliant Platinum Silver or Sn62 solder fused over Platinum Silver. Applications for the NDX-0505SG chip termination include, but are not limited to, handheld radio terminals, RF test and measurement instrumentation, amplifier circuits and power converters.

International Manufacturing Services Inc.,
Portsmouth, RI (401) 683-9700,
www.ims-resistors.com.

Unbalanced to Unbalanced RF Transformer

VENDORVIEW



The Mini-Circuits TRS2-252+ is a 4 to 2500 MHz, unbalanced to unbalanced RF transformer featuring good return loss, 20 dB typical at 1 dB band. These transformers offer high IP2 of 105 dBm typical and high IP3 of 53 dBm typical. This 100 to 50 ohm RF transformer is small in size and aqueous washable. Applications include VHF/UHF, receivers/transmitters, impedance matching and push-pull amplifiers. This transformer is RoHS compliant in accordance with EU Directive (2002/95/EC). Price: $2.75 each (Qty. 100).

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

L-band to Ka-band or Ka-band to L-band Mixer

VENDORVIEW

MITEQ is offering a new line of mixers designed specifically for satellite applications. The

TBS2731LW1 is ideally suited for converting from L-band to Ka-band or Ka-band to L-band. The mixer has superb conversion loss and VSWRs as well as excellent spurious response and outstanding LO isolations. This device meets rugged environmental MIL specs, operates over a -54° to +85°C temperature range and is ideal for rugged military and commercial system applications.

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

63 dB Attenuator

VENDORVIEW

The model DA64-63B switched-bit attenuator offers the high level of performance required in electronic warfare and radar systems as well as precision automated test equipment. Model DA64-63B is a 6-bit device that provides attenuation of 0 to 63 dB in 1 dB steps, and operates from 2 to 6 GHz with a switching speed of 30 ns (50 percent TTL to 90 percent RF) and rise and fall times of 10 ns. It has insertion loss of 4.3 dB or less, VSWR of less than 2:1, and attenuation flatness of ±0.5 dB to 31 dB and ±1 dB to 63 dB. The model DA64-63B will handle up to +23 dBm RF input power, operates from +5 VDC at 350 mA, and measures 1" × 0.75" × 0.24". Control is provided by TTL.

Narda Microwave-East,
Hauppauge, NY (631) 231-1700,
www.nardamicrowave.com/east.

Two-way Power Divider

Pulsar model PS2-54-450/18S covers the frequency range of 2 to 40 GHz with 2.5 dB insertion loss, 13 dB isolation and a maximum VSWR of 1.90:1. Amplitude and phase balance are 0.6 dB and ±8 degrees, respectively. Maximum input power is 10 W. 2.92 female connectors are utilized in a housing with dimensions 1.25" × 1.0" × 0.40".

Pulsar Microwave Corp.,
Clifton, NJ
(973) 779-6262,
www.pulsarmicrowave.com.

Size 22 Socket Contacts

The NSX series Size 22 socket contact helps reduce the cost of ARINC 600 connectors. The contact combines a stamped and rolled clip in-

UP TO 100 Watt AMPLIFIERS

NOW! 5 MHz to 18 GHz

from $945 ea. qty. (1-9)

Heavy duty, ruggedness and reliable operation to meet your demanding communication applications describe ***Mini-Circuits collection of 3, 5, 10, 16, 20, 30, 32, 50 and 100 Watt high power amplifiers!*** Covering 5 MHz up to 18.0 GHz, these broadband solutions are available with or without integrated heat sink/fan to fit your system requirements. Each amplifier operates with low current consumption and is designed to work off a single DC supply, including the fan! Plus, each model can withstand open or short output load without damage under full CW output power. They also offer built-in protection against over-voltage, thermal overloads, and an internal regulated power supply to handle fluctuations from the supply source and *still* deliver high performance. Need a ***robust*** power amplifier solution? Then come to Mini-Circuits where quality & reliability is built into every unit.

IN STOCK! FAST DELIVERY!

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

Model	Freq. (MHz) f_L-f_U	Gain (dB) Typ.	P_{out} (dBm) @Comp 1dB Typ.	P_{out} (dBm) @Comp 3dB Typ.	Dynamic Range NF (dB) Typ.	Dynamic Range IP3 (dBm) Typ.	DC Pwr. Volt (V) Nom.	DC Pwr. Current (A) Max	Price $ ea. Qty. 1-9	Price *X suffix*
With Heat Sink/Fan										
LZY-1+	20-512	43	+45.7	+47.0	8.6	+54	26	7.3	1995	1895
LZY-2+	500-1000	46	+45.0	+45.8	8.0	+54	28	8.0	1995	1895
ZHL-5W-1	5-500	44	+39.5	+40.5	4.0	+49	25	3.3	995	970
ZHL-5W-2G+	800-2000	45	+37.0	+38.0	8.0	+44	24	2.0	995	945
ZHL-10W-2G+	800-2000	43	+40.0	+41.0	7.0	+50	24	5.0	1295	1220
ZHL-16W-43+	1800-4000	45	+41.0	+42.0	6.0	+47	28	4.3	1595	1545
• ZHL-20W-13	20-1000	50	+41.0	+43.0	3.5	+50	24	2.8	1395	1320
ZHL-30W-252+	700-2500	50	+44.0	+46.0	5.5	+52	28	6.3	2995	2920
• ZHL-50W-52	50-500	50	+46.0	+48.0	6.0	+55	24	9.3	1395	1320
• ZHL-100W-52	50-500	50	+47.0	+48.5	6.5	+57	24	10.5	1995	1920
NEW ZVE-3W-183+	5900-18000	35	+34.0	+35.0	5.5	+44	15	2.2	1295	1220
ZVE-3W-83+	2000-8000	36	+33.0	+35.0	5.8	+42	15	1.5	1295	1220
• ZHL-100W-GAN+	20-500	42	+49.0	+50.0	7.0	+60	30	9.5	2395	2320
ZHL-30W-262+	2300-2550	50	+43.0	+45.0	7.0	+50	28	4.3	1995	1920

• ***Protected under U.S. Patent 7,348,854***

*For models without heat sink, add **X suffix** to model No.*
Example: (LZY-1+ LZY-1X+)

ZHL-16W-43X
ZHL-30W-262X

ZHL-5W-2GX

LZY-1X+
LZY-2X+
ZHL-10W-2GX
ZHL-50W-52X
ZHL-100W-52X
ZHL-100W-GAN+

ZHL-20W-13X

ZVE-3W-83+
ZVE-3W-183+

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U.S. patent 7739260

IF/RF MICROWAVE COMPONENTS

IEEE
Advancing Technology for Humanity

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David Intercontinental Hotel, Tel Aviv, Israel, November 7-9, 2011

Call for Papers

COMCAS 2011 continues the tradition of providing a multidisciplinary forum for the exchange of ideas in the areas of microwaves, antennas, communications, solid state integrated circuits, sensing and electronic systems engineering. The conference re-visits the venue which has proven to be attractive and enjoyable, with many opportunities for networking, candid exchange of ideas and the building of a strong sense of community. This year we will continue to expand the program to include RF and microwave photonics, biomedical technologies, cognitive radios and networks, radio frequency identification, electron devices and photonic means for IC inspection among other topics.
A diverse assembly of researchers, engineers and scientists will be invited to present their ideas and discuss new results, providing a unique opportunity for attendees to view a variety of interesting and innovative technologies in one location. Invited papers and tutorial talks from international experts will be presented in key topical areas.

Technical Topics:

- Antennas (components, modeling, phased array, etc.)
- Biomedical Technologies
- Circuit Modeling / Theory
- Cognitive and Software-Defined Radios
- Communications Systems Modeling, Simulation and Analysis
- Electromagnetic Compatibility
- Energy Harvesting
- MEMS Modeling, Devices, Applications
- Mixed Signal Analog/RF/Digital Circuits and Systems
- Microwave and MM-Wave Circuit Technologies
- RF/Microwave Photonics
- Power Amplifiers and Devices
- Power Management of Integrated Circuits and Devices
- Plasmonics
- Radar and Electronic Systems
- Remote Sensing
- RFID Devices, Technologies and Systems
- Solid State Devices, RFICs, Circuits and Modeling
- Terahertz and Applications
- New and Emerging Technologies

Regular oral presentations will be 20 min. in length; there will also be Poster sessions. All submitted papers will be peer reviewed and assessed on key accomplishments, technical contribution, advancement of the state-of-the-art, originality and interest to the attendees. Accepted papers will be published in the COMCAS 2011 Proceedings which will be available through IEEE Xplore® after the conference.

Papers should first be submitted as a 1 to 2 page summary to
http://www.mtt-tpms.org/symposia_v6/COMCAS2011/start.html

Please refer to the detailed author instructions provided on the conference web site
www.comcas.org
The official language of the Conference is English

Deadline for summary submission: 15 June 2011
Final manuscript submission: 1 September 2011

The technical program will be complemented with a technical Exhibition, which will be held on November 7-8, offering companies and agencies a unique opportunity to visit Israel and present related products and services in display and printed advertisement.
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side a screw machined body. This clip provides low insertion force and low electrical resistance through the use of three points of electrical contact. The new design also avoids stubbing since the three springs center the pin during mating. The PC tail contacts are completely intermateable with existing ARINC 600 plug connectors, are compatible with existing PC board layouts and are fully qualified under ARINC 600 specifications. The clip members are plated with 50 microinches of gold, with flash gold on the contact body to eliminate tin-lead and achieve RoHS compatibility. The contacts are also available in a removable version for use with existing two-piece inserts.

Radiall USA Inc.,
Chandler, AZ (480) 682-9400,
www.radiall.com.

Low Pass Filters

RLC Electronics now offers fourth order tubular Bessel low pass filters with 3 dB cutoffs from 1 to 22 GHz. Computer design and tubular construction allow RLC to maintain excellent group delay characteristics with reasonable rejection while extending its 3 dB cutoff approaching 30 Giga bits. These filters should be regarded as compromise designs for pulsed systems where truthful reproduction of the pulse shape is important. Primarily used on lightwave receivers to reduce the impact of higher order distortion and noise, these high frequency filters are essential for today's high bit rate applications.

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

Digital Attenuators

VENDORVIEW

Skyworks introduced two digital attenuators with superior attenuation accuracy for base station, cellular head end, repeater, test equipment and femtocell manufacturers. The 6 bit device has a 0.5 dB least significant bit (LSB) and the 7 bit device has a 0.25 dB LSB. These attenuators provide precise control over multi-standard radio transmitters and receivers, allow the user to configure the device for serial or parallel control, and do not utilize blocking capacitors so that low frequency operation is possible.

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

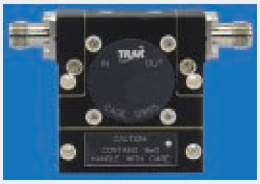
Lightning Protection Products

The new LP-STRL series is part of its Times-Protect™ line of RF lightning and surge protection products. The LP-STRL series is an exceptional DC blocked design with outstanding surge performance designed for the new Long Term Evolution (LTE) and Public Safety requirements in the 680 to 2200 MHz range. With its excellent PIM performance, low insertion loss and low return loss over the entire operating band and superior surge performance, the Times-Protect™ LP-STRL product family is unequaled. Its fully weatherized construction meeting IP67 standard allows for outdoor as well as indoor installation. The LP-STRL series has high power handling capability and will withstand multiple strikes.

Times Microwave Systems,
Wallingford, CT
(203) 949-8400,
www.timesmicrowave.com.

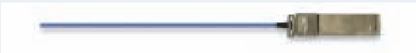
L-band Space-qualified Isolator

The model FMP145 is a new space qualified L-band high power isolator. The device offers 400 W peak/150 W CW operation over critical altitude with no multipaction breakdown events. Integrated with custom high power TNC connectors and termination screened to MIL-PRF-55342, the isolator provides superior voltage breakdown performance and low insertion loss over harsh thermal and dynamic environments.



TRAK Microwave Corp.,
Tampa, FL
(813) 901-7200,
www.trak.com.

Next-gen Cable Technology



W.L. Gore & Associates has introduced the next generation in cable technology for high data-rate applications. This technology consists of a new differential cable design with lower SCD21 (differential-to-common-mode conversion) and a very high level of signal fidelity. Additionally, it provides the only cable solution that addresses the degradation in performance caused by SCD21. Engineered for InfiniBand® and other high data-rate applications, this new design has yielded SCD21 values that are typically below -40 dB and consistently well below -25 dB across a 20 GHz bandwidth.

W.L. Gore & Associates,
Newark, DE
(410) 506-7787,
www.gore.com.

Amplifiers

Power Amplifiers

VENDORVIEW

These two new gain block solutions expand its high performance power amplifier family targeting cellular infrastructure applications. The new MGA-31589 and MGA-31689 0.5 W gain blocks feature high linearity, high gain, superior gain flatness and low power dissipation. The MGA-31589 gain block addresses cellular and WiMAX wireless base station and other wireless systems operating between 450 to 1500 MHz, while the MGA-31689 device addresses these applications operating between 1500 to 3000 MHz. The MGA-31x89 power amplifier family is optimized for frequency in order to deliver improved performance across all the major cellular bands—GSM, CDMA and UMTS—plus next-generation LTE bands.

Avago Technologies,
San Jose, CA (800) 235-0312,
www.avagotech.com.

Compact Communications Amplifier

VENDORVIEW

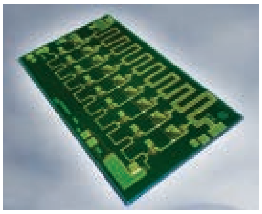
The PCM3R3SCO (SKU 7091) is one of a series of communications amplifiers. This 900 MHz compact linear power amplifier is one of a series that covers 450, 700, 800, 900, 1800, 1900 and 2100 MHz bands and is suitable for use in commercial LTE networks and public safety wireless communication applications. The amplifier employs latest generation LDMOS device technology and is highly efficient. The amplifier has an advanced built-in predistortion engine with wide instantaneous correction bandwidth, which ensures low distortion and wide dynamic range operation. Efficiency of up to 40 percent is possible in this series where the high performance is achieved by employing advanced RF design techniques.

Empower RF Systems Inc.,
Inglewood, CA (310) 412-8100,
www.empowerrf.com.

MMIC Distributed PA

VENDORVIEW

The model EWH2001ZZ distributed power amplifier (PA) is designed for commercial, industrial and military applications from DC to 20 GHz. Based on GaAs pseudomorphic high-electron-mobility-transistor (PHEMT) technology, the monolithic-microwave-integrated-circuit (MMIC) distributed PA delivers +26 dBm typical output power at 1 dB compression (P1dB) through 12 GHz and typically +23

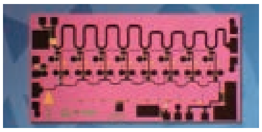


dBm through 20 GHz. The amplifier features impressive gain and gain flatness over its broad bandwidth, with small-signal gain of typically 19 dB at 2 GHz and typically 18 dB at 20 GHz, with gain flatness of ±2 dB from DC to 20 GHz. In fact, the broadband amplifier provides usable gain of 10 dB through 30 GHz. In addition, gain remains flat with temperature, with typical temperature-dependent gain variations of only 0.03 dB/°C from DC to 20 GHz and at operating temperatures from -55° to +85°C.

Endwave Corp.,
San Jose, CA (408) 522-3100,
www.endwave.com.

MMIC Power Amplifier

VENDORVIEW



The HMC930 is a GaAs PHEMT MMIC distributed power amplifier die that operates between DC and 40 GHz, and delivers up to 13 dB of gain, +33.5 dBm output IP3 and +22 dBm of output power at 1 dB gain compression. The input and output return losses of the HMC930 are better than 12 and 16 dB respectively, across the band. The gain flatness is excellent at ±0.3 dB from 12 to 32 GHz, while a slightly positive gain slope in this same band makes the HMC930 ideal for microwave radio, and military EW and ECM applications. This compact power amplifier die occupies less than 4.25 mm^2, consumes only 175 mA from a +10 V supply, and is specified for operation over the -55° to +85°C temperature range.

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

RF Driver Amplifier

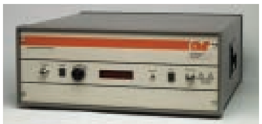
VENDORVIEW

M/A-COM Technology Solutions Inc. introduced the MAAM-009563, a two-stage HBT driver amplifier for cellular and WiMAX infrastructure applications. This driver amplifier covers a broad frequency range of 250 to 3000 MHz with excellent linearity of 47 dBm output IP3 and typical gain of 19.5 dB. The broad operation is achieved using external matching components, where component values are selected to center the 200 MHz instantaneous bandwidth within the overall frequency range. The lead-free SOIC-8EP surface-mount plastic package is RoHS compliant and compatible with solder reflow temperatures up to 260°C. The ESD susceptibility achieves a class 2 ESD rating.

M/A-COM Technology Solutions Inc.,
Lowell, MA (978) 656-2539,
www.macomtech.com.

Solid-state Amplifiers

VENDORVIEW



AR RF/Microwave Instrumentation has introduced a family of new solid-state amplifiers that are more compact, more efficient, and more powerful than previous models. The new "S" Series covers 0.8 to 4.2 GHz and powers up to 1200 W. These models employ a new design that delivers more than twice the power of older models. With these improvements, AR has maintained the superior rugged design for mismatch tolerance and excellent linearity.

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

Detector Log Video Amplifier

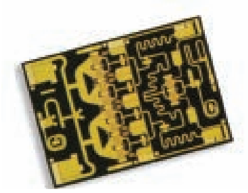
PMI model SDLVA-218-71-70MV is a CW Immune, extended range detection log video amplifier (ERDLVA) that offers 71 dB dynamic range over the frequency range of 2 to 18 GHz. This model offers a maximum rise time of 35 nsec and a recovery time of less than 350 nsec. The unit is temperature compensated such that log linearity over temperature remains less than ±1.5 dB over the full operating temperature range of -20° to +85°C. This model is supplied in a compact housing measuring only 3.5" × 2.5" × 0.5".

Planar Monolithics Industries,
Frederick, MD
(301) 662-5019,
www.pmi-rf.com.

GaN Power Amplifier

VENDORVIEW

TriQuint's new 30 W GaN power amplifier, TGA2576, supports C-IED and general EW applications across a 2.5 to 6 GHz frequency range. The new device is fabricated using TriQuint's production-released GaN on SiC process; it typically offers 30 percent PAE and 25 dBm of small-signal gain. Die-level samples were available beginning November 2010; packaged samples are expected to be available in early 2011.



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

Semiconductor/IC

High Power Pulsed Transistor

The high power pulsed transistor part number ILD2735M120 is designed for S-band radar applications operating over the 2.7 to 3.5 GHz instantaneous frequency band. Under 300 us/


Are you Thermally Stressed?
Our Thermopads® & Diamond Rf™
Resistives are the solution
Thermopads® Temp
Variable Attenuators
• Passive Temp Compensation
• SMT versions
• DC to 50GHz
• Positive or negative temp comp
• As small as 0805 package
• Engineering kits available
Resistors & Terminations
on CVD Diamond
• 8x power of AlN
• 1/5 size of AlN
• Resistance up to 500Ω
• Attenuators to 30dB
• 0402, 0505, 0603, 1310 sizes
• Broadband performance
EMC
Technology
8851 SW Old Kansas Avenue, Stuart, FL 34997 USA
Phone: 772-286-9300 or 800-544-5594 | www.emc-rflabs.com

10 percent pulsing conditions, it supplies a minimum of 120 W of peak output power with 8 to 9 dB gain typically. Maximum reliability is achieved through all-gold metal contacts, wire-bonding and package.

Integra Technologies Inc.,
El Segundo, CA (310) 606-0855,
www.integratech.com.

Software

Electromagnetic Analysis Software

VENDORVIEW

Remcom announces a new version of XGtd®, a tool for far zone radiation, RCS and EMI/EMC for electrically large platforms. The most important benefits of XGtd Release 2.5 are performance enhancements that shorten run times and increase customer productivity. A new 64-bit version and the inclusion of an optimized ray engine (ORE) make even complex ray-tracing computations faster. Improvements to graphical displays also eliminate steps in workflow and shorten the time it takes to achieve results. New enhancements in XGtd 2.5 include: 64-bit version supports larger, more complex models and factor of 1.5 to 2 times speedup; and Optimized Ray Engine increases speed for large or complicated models.

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

Sources

Ultra-miniature SMT Synthesizer

The SLX-1350 is an ultra-miniature SMT synthesizer that operates over the frequency range 675 to 1350 MHz in 1 MHz steps, features low spurs (<-60 dBc), low harmonics (<-15 dBc), 0 dBm nominal output power and low phase noise (<-85 dBc/Hz at 10 KHz (Fout at 675 MHz)). Because of exceptional performance and its small (0.5" sq × 0.15") size, this low-cost unit is ideally suited for use in SWaP-C applications. The SLX Series is available in designs from 50 MHz to 6 GHz, in fixed-frequency or serially-programmable bandwidths to an octave. Custom units utilize external references from 5 to 125 MHz, select supply voltages (+3, +3.3, +5 or +8 VDC), 10 KHz to 10 MHz step sizes and temperature range (-40° to +85°C).

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

High Accuracy TCXO

The Charon is a high stability 7×5 SMD digitally-controlled temperature controlled crystal oscillator (DCTCXO) designed and specified to bring together the highest stability TCXO performance with digital frequency control, separate low frequency output, timer and alarm functionality. Serial Peripheral Interface (SPI) controlled high accuracy TCXO with embedded timer and alarm function. Using Rakon's advanced Pluto™ analogue frequency compensation system, the DCTCXO achieves unrivalled frequency stability. A custom ASIC, Charon (Pluto's moon) has been designed to closely interface with the Pluto ASIC to provide the extra enhanced functionality in a miniature 7×5 SMD package. In addition to market leading stability, the Charon device features integrated timing and control functions.

RAKON Ltd.,
Auckland, New Zealand
+64 9 571 9216,
www.rakon.com.

Voltage-controlled Oscillator

Z-Communications announces a new RoHS compliant VCO model CRO2595A-LF in S-band. The CRO2595A-LF operates at 2570 to 2620 MHz with a tuning voltage range of 0.5 to 4.5 VDC. This VCO features a typical phase noise of -110 dBc/Hz at 10 KHz offset and a typical tuning sensitivity of 21 MHz/V. The CRO2595A-LF is designed to deliver a typical output power of 9 dBm at 5 VDC supply while drawing 27 mA (typical) over the temperature range of -40° to 85°C. This VCO features typical second harmonic suppression of -20 dBc and comes in Z-Comm's standard MINI-16-SM package measuring 0.5" × 0.5" × 0.22". It is available in tape and reel packaging for production requirements. The CRO2595A-LF is also ideal for automated surface-mount assembly and reflow.

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

Test Equipment

RF Signal Generator

Introducing the SG384, a 4 GHz RF signal generator from SRS. It offers a DC to 4 GHz frequency range with 1 µHz resolution, AM, FM, ΦM and PM, with -116 dBc/Hz phase noise at 20 kHz offset from 1 GHz, full octave frequency sweeps, an OCXO timebase and standard RS232, GPIB and Ethernet interfaces. Options include clock outputs, analog I/Q inputs and a rubidium timebase. US list price $4,600.

Stanford Research Systems Inc.,
Sunnyvale, CA
(408) 744-9040,
www.thinkSRS.com.

Passive Intermodulation Analyzer

VENDORVIEW

Anritsu introduces the MW8219A PIM Master, a field test solution that can accurately and quickly locate the source of passive intermodulation (PIM), whether it is at the base station or in the surrounding environment. Covering the PCS and AWS cellular frequency ranges, the MW8219A provides field personnel with a test system that can help ensure optimum network performance and also locate PIM faults before intermodulation distortion adversely affects signal transmission. PIM Master has been designed to work with Anritsu's S332E/S362E Site Master™, MS2712E/MS2713E Spectrum Master™ and MT8212E/MT8213E Cell Master™ handheld analyzers, as well as the MT8221B/MT8222A/MT8222B BTS Master™ handheld analyzers.

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

Signal Analyzer

Tektronix Inc. announced a significant expansion of its spectrum and vector signal analysis offerings with the introduction of the new RSA5000 Series Signal Analyzer. The new instruments raise the price-performance bar for mid-range signal analyzers by offering more than double currently available acquisition bandwidth and the world's best real time capabilities. By combining reduced time-to-insight and lower cost, the new series is ideal for numerous design and operations applications including spectrum management, radar, electronic warfare, radio communications and EMI/EMC. Featuring advanced time, amplitude and DPX™ trigger functions combined with swept DPX, the RSA5000 Series delivers discovery and capture of these intermittent and rapidly changing signals and up to 85 MHz bandwidth.

Tektronix Inc.,
Beaverton, OR
(800) 833-9200,
www.tek.com.

eLEARNING center

February Short Course Webinars

RF/Microwave Training Series
Presented by Besser Associates

RF Power Amplifiers - Digital Pre-Distortion Techniques: This webinar, presented by Dr. John Wood, discusses modern communications signals and the impact of RF power amplifier design on linearity and efficiency. Topics include: linearizer basics, memory effects, digital pre-distortion techniques, system architecture and linearization results.
Live webcast: 2/15/11. 11:00 AM EST
Sponsored by Scintera Networks, Inc.

Innovations in EDA Series
Presented by Agilent Technologies

Memory Effects in RF Circuits: Manifestations and Simulation: This Webcast defines memory effects in RF circuits commonly used in various radio blocks and demonstrates how these effects can adversely impact the accuracy of simulations using traditional behavioral approaches. Finally, new techniques are presented for sufficient simulation speed and accuracy.
Available for on demand viewing after 2/3/11
Sponsored by Agilent Technologies

Technical Education Series - March Installment
Presented by Rohde & Schwarz and AWR Corp.

LNA design and characterization using modern RF/microwave software together with T&M instruments: In this webcast, Microwave Office is used to develop a prototype of an LNA design, applying the simulator to reveal and quantify sensitive circuit parameters. The ZVA, a R&S Vector Network Analyzer, is used to characterize the LNA design built according to the simulation results. Microwave Office and the ZVA are plugged together to bring the measured and simulated results together for instantaneous comparison and virtual model verification.
Live webcast: 3/8/11. 12:00 PM EST
Sponsored by Rohde & Schwarz and AWR Corp.

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Microwave Journal

Frequency Matters.

Substrate Noise Coupling in Analog/RF Circuits

Stephane Bronckers, Geert Van der Plas, Gerd Vandersteen and Yves Rolain

Substrate noise coupling—the coupling of signals from one node to another via a substrate—is a frequent problem that occurs in integrated circuits especially where digital circuits or several analog device types are integrated on the same die. It is critical that today's engineers address this issue, as analog circuits are widely used to interface with the outside world and wireless applications are used pervasively. *Substrate Noise Coupling in Analog/RF Circuits* offers detailed guidance on the impact of substrate noise on a wide range of circuits operating from baseband frequencies up to millimeter-wave frequencies.

This book investigates in detail the mechanisms of creation and propagation of substrate noise and analyzes its impact on analog circuits. Emphasis is on the modeling and simulation of the effects, as needed by circuit designers during their designs, as well as on design measures to alleviate the problems. It presents case studies to illustrate that careful modeling of the assembly characteristics and layout details are required to bring simulations and measurements into agreement.

Practitioners will learn how to use a proper combination of isolation structures and circuit techniques to make analog/RF circuits more immune to substrate noise. They will learn how to simulate noise sources and how to analyze the effectiveness of the design measures that they should take. In this way, they will be able to design better and more robust mixed-signal systems. *Substrate Noise Coupling in Analog/RF Circuits* is a practical and well organized book that should be useful to practicing engineers and designers.

To order this book, contact:

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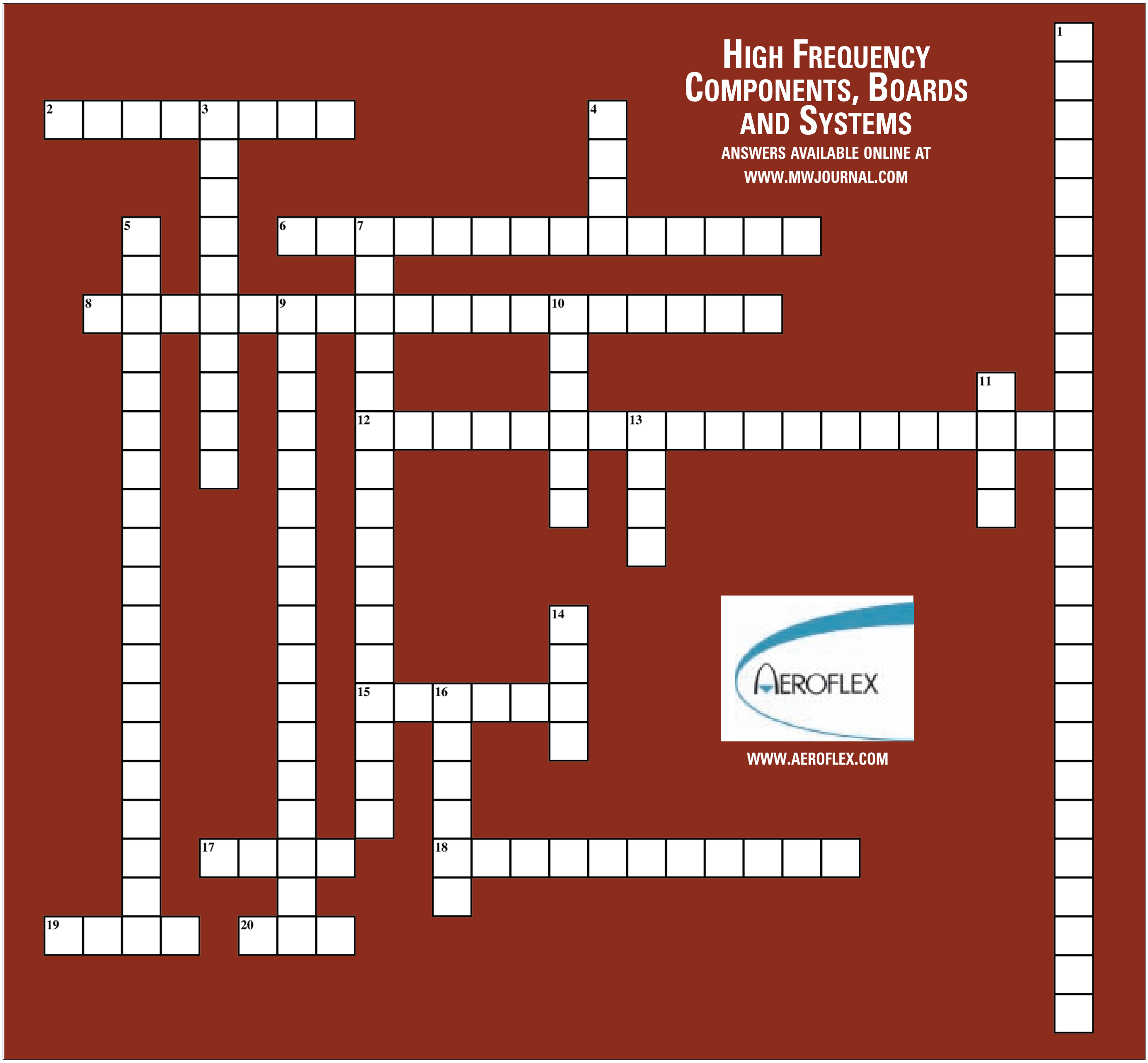
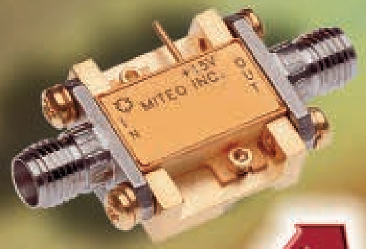


ACROSS

2 The technique used to determine ideal matching network impedances is referred to as _______________ (2 words)
6 A _____________ load-pull system has a signal input path consisting of a signal source and amplifier, source and load impedance tuners, and a vector receiver (2 words)
8 SNR (4 words)
12 Most phase noise measurement systems use what is called _____________ (2 words)
15 PTFE
17 Microwave monolithic integrated circuit
18 The weakest signal that a wireless receiver can recover is defined by its ____________
19 Third-order intermodulation distortion
20 A popular glass fabric and epoxy resin laminate material widely used in the printed circuit board industry

DOWN

1 MIC (3 words)
3 Short-term random frequency fluctuations of a signal (2 words)
4 Low temperature co-fired ceramic
5 PCB (3 words)
7 Method used in phase noise analysis to extend the range of any single channel measurement by introducing a second channel and utilizing signal processing to locate the noise that is common to the DUT (2 words)
9 LNA (3 words)
10 Enhancement-mode, pseudomorphic high electron mobility transistor
11 Digital instantaneous frequency measurement
13 Commercial off-the-shelf
14 One of the more common windows used with noise analysis
16 __________ equation shows that the noise figure of the first amplifying stage in the receiver chain has a predominant effect



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OCTAVE BAND AMPLIFIERS								
AFS3-00120025-09-10P-4	0.12-.25	38	0.50	0.9	2.0:1	2.0:1	+10	125
AFS3-00250050-08-10P-4	0.25-0.5	38	0.50	0.8	2.0:1	2.0:1	+10	125
AFS3-00500100-06-10P-6	0.5-1	38	0.75	0.6	2.0:1	1.5:1	+10	150
AFS3-01000200-05-10P-6	1-2	38	1.00	0.5	2.0:1	2.0:1	+10	150
AFS3-01200240-06-10P-6	1.2-2.4	34	1.00	0.6	2.0:1	2.0:1	+10	150
AFS3-02000400-06-10P-4	2-4	32	1.00	0.6	2.0:1	2.0:1	+10	125
AFS3-02600520-10-10P-4	2.6-5.2	28	1.00	1.0	2.0:1	2.0:1	+10	125
AFS3-04000800-07-10P-4	4-8	32	1.00	0.7	2.0:1	2.0:1	+10	125
AFS3-08001200-09-10P-4	8-12	28	1.00	0.9	2.0:1	2.0:1	+10	125
AFS3-08001600-15-8P-4	8-16	28	1.00	1.5	2.0:1	2.0:1	+8	100
AFS4-12001800-18-10P-4	12-18	28	1.50	1.8	2.0:1	2.0:1	+10	125
AFS4-12002400-30-10P-4	12-24	24	2.00	3.0	2.0:1	2.0:1	+10	85
AFS3-18002650-30-8P-4	18-26.5	18	1.75	3.0	2.2:1	2.2:1	+8	125
MULTIOCTAVE BAND AMPLIFIERS								
AFS3-00300140-09-10P-4	0.3-1.4	38	1.00	0.9	2.0:1	2.0:1	+10	125
AFS2-00400350-12-10P-4	0.4-3.5	22	1.50	1.2	2.0:1	2.0:1	+10	80
AFS3-00500200-08-15P-4	0.5-2	38	1.00	0.8	2.0:1	2.0:1	+15	125
AFS3-01000400-10-10P-4	1-4	30	1.50	1.0	2.0:1	2.0:1	+10	125
AFS3-02000800-09-10P-4	2-8	26	1.00	0.9	2.0:1	2.0:1	+10	125
AFS4-02001800-24-10P-4	2-18	35	2.00	2.4	2.5:1	2.5:1	+10	175
AFS4-06001800-22-10P-4	6-18	25	2.00	2.2	2.0:1	2.0:1	+10	125
AFS4-08001800-22-10P-4	8-18	28	2.00	2.2	2.0:1	2.0:1	+10	125
ULTRA WIDEBAND AMPLIFIERS								
AFS3-00100100-09-10P-4	0.1-1	38	1.00	0.9	2.0:1	2.0:1	+10	125
AFS3-00100200-10-15P-4	0.1-2	38	1.00	1.0	2.0:1	2.0:1	+15	150
AFS1-00040200-12-10P-4	0.04-2	15	1.50	1.2	2.0:1	2.0:1	+10	50
AFS3-00100300-12-10P-4	0.1-3	32	1.00	1.2	2.0:1	2.0:1	+10	125
AFS3-00100400-13-10P-4	0.1-4	30	1.00	1.3	2.0:1	2.0:1	+10	125
AFS3-00100600-13-10P-4	0.1-6	30	1.25	1.3	2.0:1	2.0:1	+10	125
AFS3-00100800-14-10P-4	0.1-8	28	1.50	1.4	2.0:1	2.0:1	+10	125
AFS4-00101200-22-10P-4	0.1-12	34	1.50	2.2	2.0:1	2.0:1	+10	150
AFS4-00101400-23-10P-4	0.1-14	24	2.00	2.3	2.5:1	2.5:1	+10	200
AFS4-00101800-25-S-4	0.1-18	25	2.00	2.5	2.5:1	2.5:1	+10	175
AFS4-00102000-30-10P-4	0.1-20	20	2.50	3.0	2.5:1	2.5:1	+10	125
AFS4-00102650-42-8P-4	0.1-26.5	24	2.50	4.2	2.5:1	2.5:1	+8	135

Note: Noise figure increases below 500 MHz.

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