Vol. 52 • No. 4

April 2009

Microwave Journal

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The III-V vs. Silicon Battle

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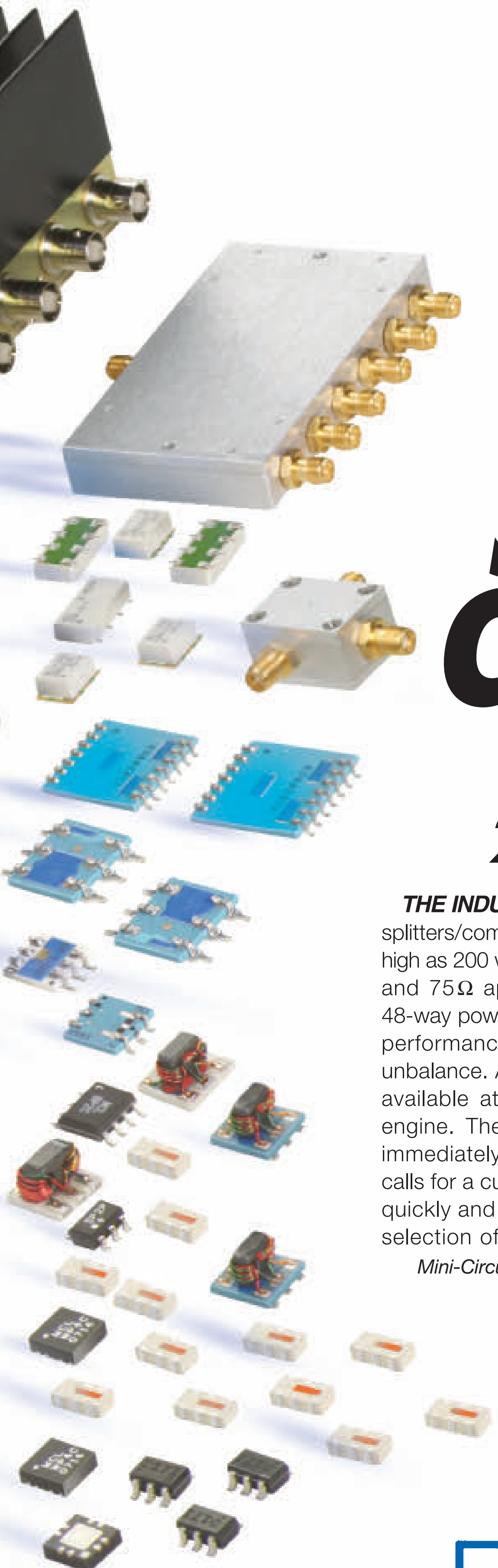

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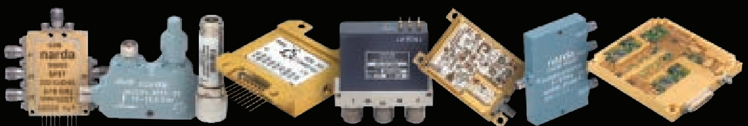

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APRIL 2009 VOL. 52 • NO. 4

FEATURES

COVER FEATURE

22 **The III-V vs. Silicon Battle**

Darcy Poulin, SiGe Semiconductor Inc.

Introduction to the advantages and disadvantages of the various underlying semiconductor technologies in determining the winner of the III-V versus Silicon battle for power amplifier applications

TECHNICAL FEATURES

60 **A Custom III-V Heterojunction Bipolar Transistor Model**

Sonja R. Nedeljkovic, John R. McMacken, Paul J. Partyka and Joseph M. Gering, RFMD

Discussion of the features of a custom III-V heterojunction bipolar transistor model and its scaling for cellular power amplifier applications

86 **Managing Crystal Oscillator Acceleration Sensitivity in Mobile Applications**

Steven Fry, Greenray Industries

Understanding and mitigating the effects of acceleration forces on crystal oscillator performance

96 **LDMOS Ruggedness Reliability**

S.J.C.H. Theeuwen, J.A.M. de Boet, V.J. Bloem and W.J.A.M. Sneijers, NXP Semiconductors

Description of various ruggedness reliability tests for radio frequency laterally diffused metal-oxide semiconductor transistors

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FEATURES

PRODUCT FEATURES

106 **VHF OCXO with Extra-low Noise Floor**

Pascall Electronics Ltd.

Introduction to a new series of oven-controlled crystal oscillators combining close-in phase noise performance with lower noise floor and higher output power

114 **Millimeter-wave MMICs Deliver Ka-band Power**

Mimix Broadband Inc.

Introduction to 4 and 6 W Ka-band power amplifiers

120 **Drop-in Industry Replacement Frequency Synthesizers**

EM Research Inc.

Development of a series of drop-in frequency synthesizers with models operating from 800 MHz to 3.8 GHz

DEPARTMENTS

17 ...Mark Your Calendar
18 ...Coming Events
43 ...Defense News
47 ...International Report
51 ...Commercial Market
54 ...Around the Circuit
124 ...Catalog Update
128 ...New Products
138 ...The Book End
140 ...Career Corner
142 ...Ad Index
144 ...Sales Reps
146 ...MWJ Puzzler

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Future Technologies and Testing for Fixed Mobile Convergence, SAE and LTE in Cellular Mobile Communications

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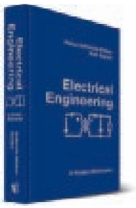
Reinventing the Transmit Chain for Next-generation Multimode Wireless Devices

Richard Harlan, Director of Technical Marketing, ParkerVision

Expert Advice

Mesuro is a spin off from Cardiff University, UK, and its CTO, **Johannes Benedikt**, describes the need for a large-signal measurement system that integrates the measurement of large-signal parameters and an active harmonics source/load pull system to facilitate a first-pass power amplifier design process.

Read the advice from this industry expert, respond with your comments and win a complimentary copy of *Electrical Engineering: A Pocket Reference* from Artech House (see www.mwjournal.com for details).



MWJ Blog

April is a big conference month. See what happened at the International CTIA Wireless 2009 Convention in Las Vegas, NV, April 1-3 with blog entries from MWJ Technical Editor, Pat Hindle. We'll also check in on WAMICON 2009 and the ARMMS RF & Microwave Society Conference. Visit http://microwavejournal.blogspot.com/.

Executive Interview

MWJ asks **Graham Jefferies**, Executive Vice President and COO of **Emrise Corporation** (parent company of Pascall Electronics), about the company's reorganization, product development strategy and strict environmental policy, together with his perspective on operating in the current market conditions.

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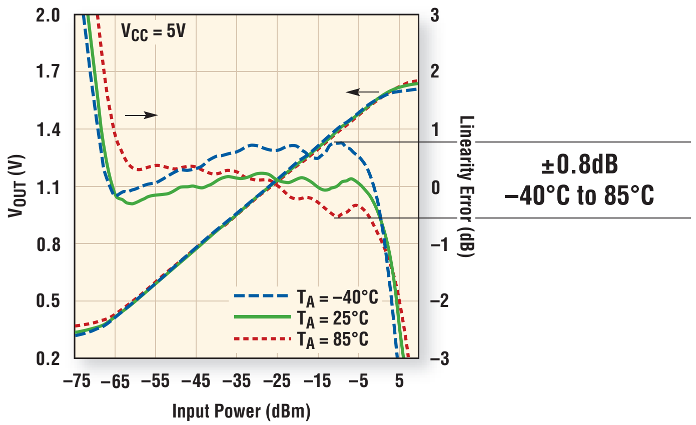

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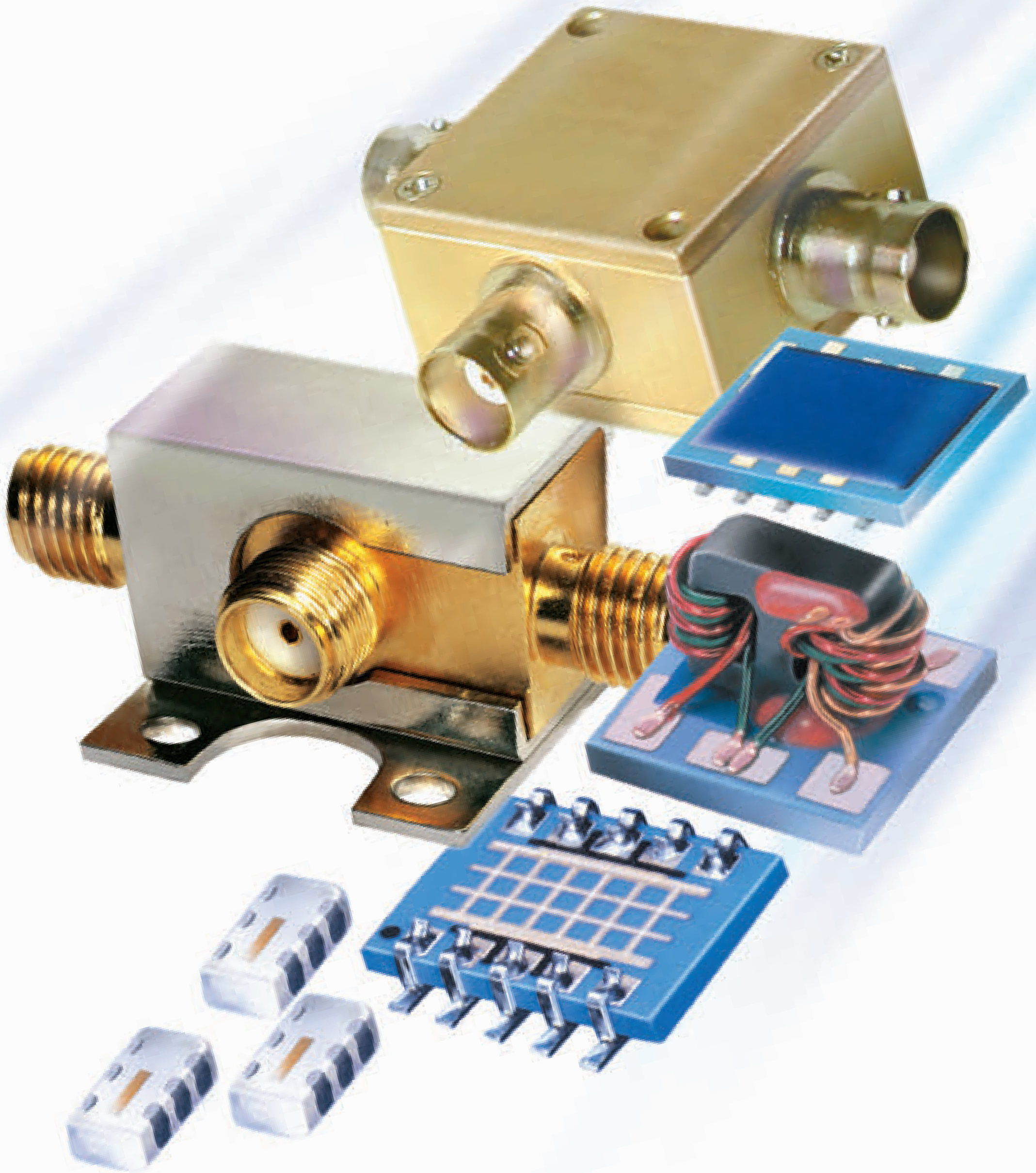

MAY 2009

SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
26	27	28	29	30	1	2
3	4 **IEEE Radar Conference** Pasadena, CA (May 4–8); **PAC 2009 Particle Accelerator Conference** Vancouver, Canada (May 4–8)	5	6	7	8	9
10	11 **Keithley S400 Maintenance Training Course** Munich, Germany (May 11–15)	12 **CST MICROWAVE STUDIO® Microwave and Antenna Training** Nottingham, UK	13	14	15	16
17	18 **16th RF and Microwave Measurement Training Course** Middlesex, UK (May 18–22)	19 **Tektronix Webinar: Next Generation Active Load-pull**; **MWJ/Besser Webinar: Impedance Matching**	20	21	22	23
24 **Microwave Industry Exhibition in China National Conference on Microwave and Millimeter Wave in China** Xi'an, China (May 24–26)	25	26 **TriQuint Webinar: Green Power**	27 **Ansoft Q3D Extractor Product Training** Ann Arbor, MI (May 27–29)	28	29	30
31	1	2	3	4	5	6

Dr. Bob Froelich

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The International IEEE Conference on Microwaves, Communications, Antennas and Electronic Systems
Deadline: June 15, 2009

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APRIL

WAMICON 2009
IEEE Wireless and Microwave Technology Conference
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www.wamicon.org

ARMMS RF and Microwave Society Conference
April 20–21, 2009 • Oxfordshire, UK
www.armms.org

MAY

IEEE Radar Conference
May 4–8, 2009 • Pasadena, CA
www.radarcon09.org

16th RF and Microwave Measurement Training Course
May 18–22, 2009 • Middlesex, UK
www.theiet.org/microwave-course

MIE 2009
Microwave Industry Exhibition in China
NCMMW 2009
National Conference on Microwave and Millimeter Wave in China
May 23–26, 2009 • Xi'an, China
www.cnmw.org

JUNE

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June 1–5, 2009 • Charleston, SC
www.apsursi2009.org

RFIC 2009
IEEE Radio Frequency Integrated Circuits Symposium
June 7–9, 2009 • Boston, MA
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International Exhibition on Electromagnetic Compatibility
June 16–18, 2009 • Beijing, China
http://expo.ces.org.cn

China MW 2009
China Microwave 2009 Exhibition
June 16–18, 2009 • Beijing, China
http://chinamw2009.ces.org.cn

JULY

ASQED 2009
1st Asia Symposium on Quality Electronic Design
July 15–16, 2009 • Kuala Lumpur, Malaysia
www.isqed-asia.org

AUGUST

EMC 2009
IEEE International Symposium on Electromagnetic Compatibility
August 17–21, 2009 • Austin, TX
www.emc2009.org

SEPTEMBER

4G World 2009
September 14–18, 2009 • Chicago, IL
http://global.wimaxworld.com

EuMW 2009
European Microwave Week
September 28–October 2, 2009
Rome, Italy
www.eumweek.com

OCTOBER

RF & Hyper 2009
October 6–8, 2009 • Paris, France
www.rfhyper.com

International Radar Conference
October 12–16, 2009 • Bordeaux, France
www.radar09.org

46th annual AOC
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www.crows.org

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Antenna Measurement Techniques Association
November 1–6, 2009 • Salt Lake City, UT
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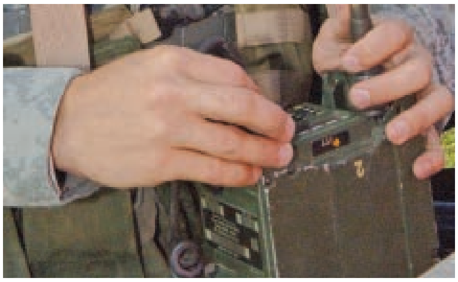

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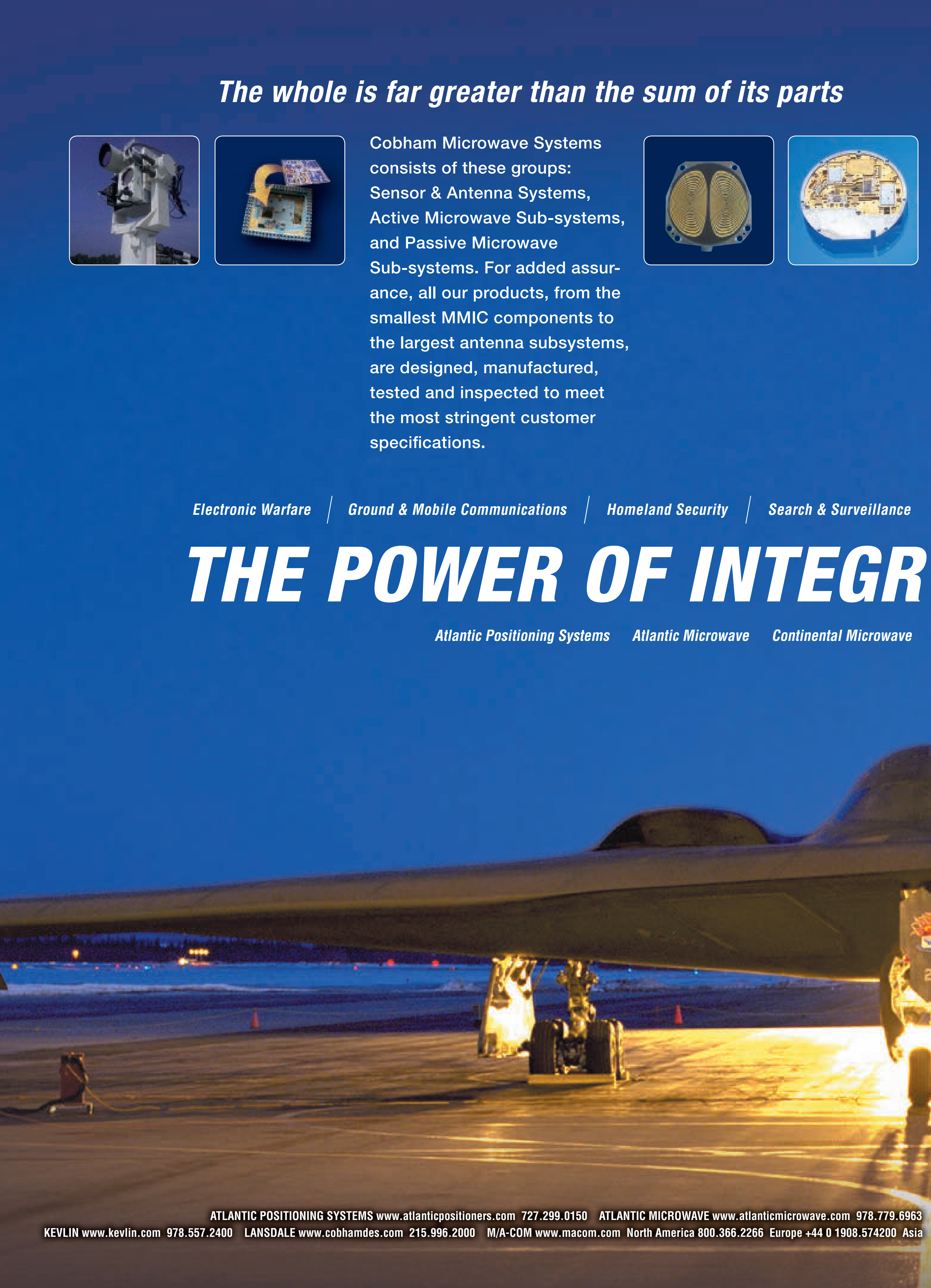
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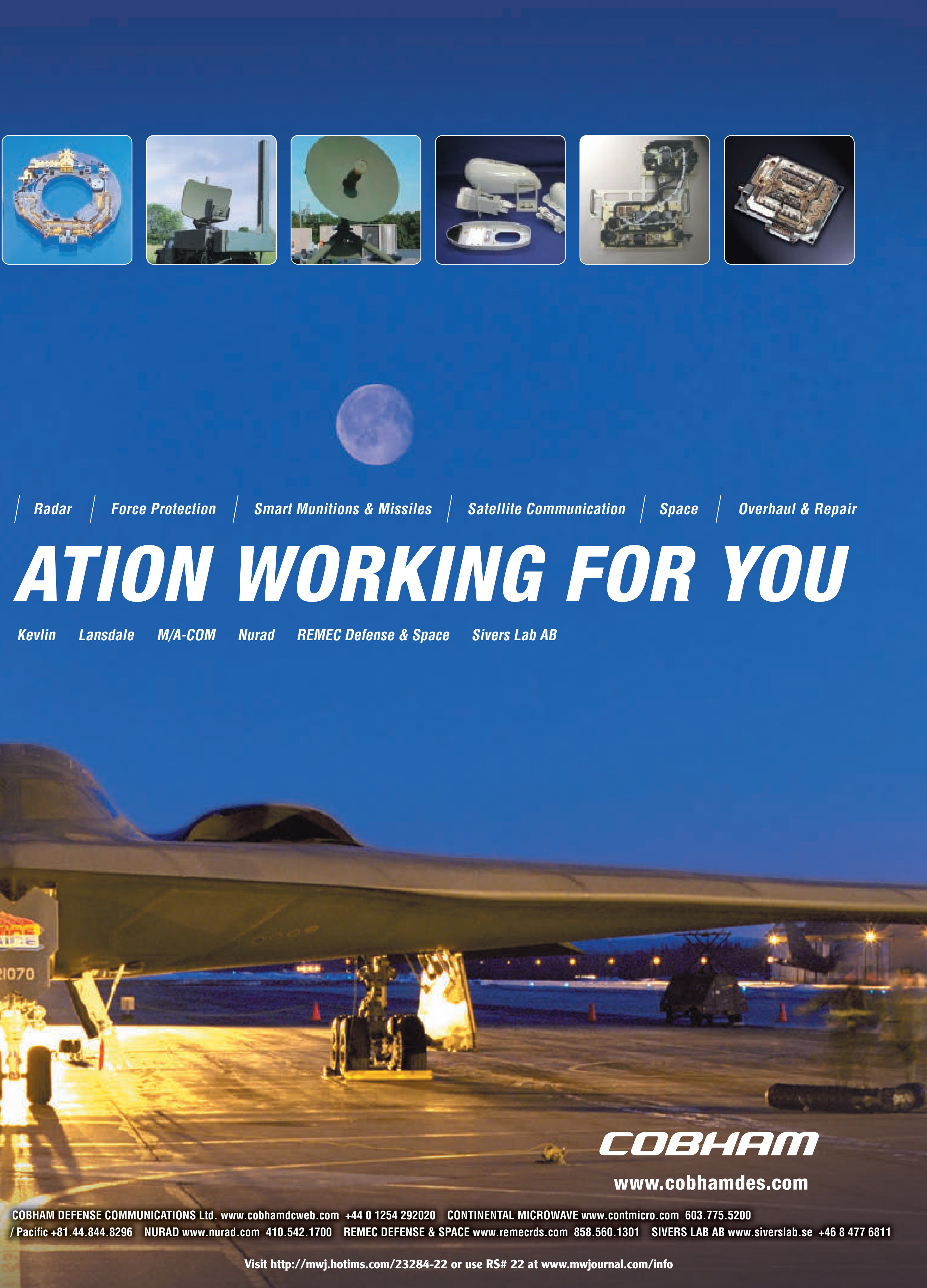

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THE III-V VS. SILICON BATTLE

Power amplifiers are important components in almost all wireless communication systems. They normally consume large amounts of power, and therefore play a critical role in battery life for mobile devices. As a rough estimate, in a typical WiMAX radio, the baseband and transceiver will consume about 600 mW, whereas the power amplifier will consume about 1.3 W.

When designing a power amplifier, there are a large number of options to be considered. One fundamental choice, however, is whether to use Silicon or III-V technology. This article will point out a number of important issues that affect power amplifier design, and will discuss advantages and disadvantages of the various underlying semiconductor technologies in determining who wins the III-V versus Silicon battle.

In recent years, there have been a number of technological changes that have had an impact on power amplifier designs. Technologies that use OFDM, like WiFi, WiMAX and LTE, are probably the most challenging for a power amplifier; they require a high degree of linearity to meet the required SNR targets, but must also handle a large peak-to-average power ratio associated with OFDM.

In addition, the 802.11-based WiFi and 802.16-based WiMAX standards have become some of the fastest growing technologies in use today, so it makes sense to focus on the GaAs versus Silicon debate within the context of low power (<1 W), high linearity OFDM power amplifiers.

Having chosen GaAs or Silicon, the power amplifier designer is then confronted with further options within each technology, and each option has its own set of advantages and disadvantages. In GaAs, one can design with GaAs HBT (bipolar-based), GaAs PHEMT (FET-based), or GaAs BiFET (a mixture of both bipolar and FET technologies).

In Silicon, one can design in CMOS (FET-based), or in higher speed SiGe BiCMOS (a mixture of both bipolar and FET technologies). The main workhorses in OFDM power amplifier design today are GaAs HBT and SiGe BiCMOS. However, CMOS as well as GaAs BiFET and PHEMT devices are also all in use.

To deliver high power with OFDM, GaAs has almost always been used due to a better trade-off between transition frequency, F_t, and breakdown voltage. However, over the past 10 years, Silicon technology has developed to the point where it is becoming harder to choose one technology over the other. A few years ago,

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anything above 2 GHz and/or 50 mW would have been designed in GaAs. Today, SiGe BiCMOS power amplifiers can be used at power levels close to 1 W and they have plenty of available gain even at 10 GHz.

If efficiency is important, GaAs technologies still offer the best performance, especially at higher powers. GaAs technology also offers higher breakdown voltage, which translates into greater robustness. However, circuitry has been developed that can protect lower breakdown Silicon devices. Complicating the picture even more, integrated CMOS PAs are now being considered at 2.4 and 5 GHz in applications where lower output powers (less than 15 dBm) and relatively low efficiencies (about 10 percent) can be tolerated.

COEXISTENCE

Today, many wireless communications technologies exist, and they often operate simultaneously. For example, Bluetooth and cellular radios must both operate when using a Bluetooth headset during a voice call. WiMAX and cellular radios will both be active on mobile devices during handovers from one network to the other. Cellular and GPS radios will both be enabled when GPS is used on a cellular phone.

Coexistence refers to the simultaneous operation of multiple radios within a device. ***Figure 1*** shows a typical example of a dual-mode WiMAX/W-CDMA radio. In this example, a W-CDMA daughter card is placed on top of, and in close proximity to, a WiMAX module. If the WiMAX and W-CDMA radio must operate simultaneously (which would be required during a handover from one network to another), then care must be taken to ensure that the radios do not interfere with one another.

But what does this have to do with power amplifiers? Since W-CDMA and WiMAX radios operate on different frequencies, one might naively expect no issues when both radios are operating at the same time. The problem, of course, is that noise from one radio that is emitted in the passband of the other radio cannot be filtered out at the receiver, and this noise can desensitize the victim receiver. This problem is most severe when two radios are collocated in the same device, as Figure 1 illustrates, since signals from one radio arrive virtually unattenuated at the receiver of the other radio.

An example is useful to illustrate this problem. Consider a WiMAX radio operating from 2.5 to 2.7 GHz transmitting at 23 dBm, while a victim W-CDMA radio is attempting to receive a signal at 2.17 GHz. The task is to determine what the maximum noise level is that the W-CDMA radio can tolerate so that its sensitivity (i.e. the smallest signal it can detect) is degraded by less than 0.1 dB when the WiMAX radio is operating.

W-CDMA has a 3.84 MHz channel bandwidth and the standard requires a sensitivity of –117 dBm for a coded CDMA signal. Assuming a 21 dB coding gain (128 chip code length), the sensitivity will be –96 dBm/3.84 MHz, or –161.8 dBm/Hz. Based on this, the noise at the W-CDMA antenna would need to be below –170.9 dBm/Hz to result in 0.1 dB degradation in sensitivity (–178.1 dBm + –161.8 dBm results in a net noise of –161.7 dBm).

Of course, the noise power emitted from the WiMAX PA will be reduced as the signal travels from the WiMAX Tx antenna to the W-CDMA Rx antenna. Since the two radios are located very close together, however, one can only expect approximately 20 dB isolation between the antennas, so the output noise from the WiMAX radio will need to be below –150.9 dBm/Hz.

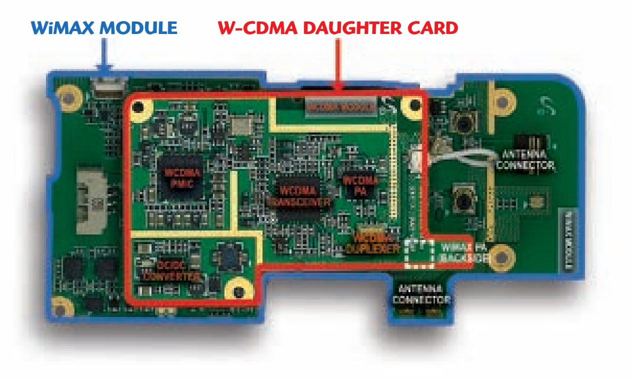


Fig. 1 Dual-mode W-CDMA/WiMAX radio.

Now that the output noise target for the WiMAX radio has been calculated, consider the implications on the power amplifier. Suppose that the input noise to the power amplifier is at the noise floor (–174 dBm/Hz), that the PA has a gain of 30 dB at 2.17 GHz, and has a noise figure of 5 dB. Therefore, the net noise from the PA will be –174 + 30 + 5 = –139 dBm/Hz, requiring 12 dB additional filtering at 2170 MHz in order to degrade sensitivity of the W-CDMA PA by only 0.1 dB.

The most obvious place to put the filter is directly after the PA. This is a bad choice, however, since any losses after the PA result in significant additional power consumption, and this power consumption is manifested as heat that must be dissipated. In addition, the effect of the filter loss is worse as output powers increase. For example, assuming that the coexistence filter has 1.5 dB loss and that the PA has 20 percent efficiency, ***Table 1*** shows the effect of this filter on power consumption and net PA efficiency for different output powers. At an output power of 18 dBm, the 1.5 dB filter loss results in about 130 mW extra DC power consumption. Some of this power is dissipated in the filter

TABLE I

EFFECT OF POST PA LOSSES ON POWER CONSUMPTION

Desired output power	18	23	26	dBm
Post PA coexistence filter loss	1.5	1.5	1.5	dBm
PAE	20	20	20	%
Required output power	19.5	24.5	27.5	dBm
PA power consumption assuming no post PA losses	315.5	997.6	1990.5	mW
Actual PA power consumption	445.6	1409.2	2811.7	mW
Additional Power Dissipation	130.1	411.6	821.2	mW
Net PAE	14.2	14.2	14.2	%

(26 mW), but most of the additional power (104 mW) is dissipated in the PA, which must be made 1.5 dB larger to overcome the filter losses.

When transmitting at 23 dBm, adding the filter increases power consumption by 411 mW. At 26 dBm, the power consumption increases by 821 mW. One can see that putting a filter after the PA can result in a severe energy penalty (especially at higher output powers), and this results in shorter battery life. In addition, there are resultant cost increases since the PA must be made larger to overcome the filter loss. It is also interesting to note that a 1.5 dB post-PA loss reduces the PA efficiency by the same amount at each output power, from 20 to about 14.2 percent.

In order to reduce power losses, it is preferable to not place the coexistence filter after the PA. However, it should also not be placed in front of the PA, since most of the noise is generated within the PA. Therefore, the filter is optimally placed between the PA stages, internally on the PA die. The next question then is which technologies are best suited for implementing integrated filters?

At first glance, one might expect GaAs-based semiconductor technology to have an advantage because the passives have higher Q due to lower substrate losses. However, Silicon processes have evolved, and it is now possible to fabricate passive devices on insulating SiO_2, and their performance can be as good as it is on lower-loss GaAs substrates.

There is an additional consideration, however. Modern foundry production tolerances make it very difficult to control the capacitance and inductance of passive devices to the accuracy required for demanding coexistence filters. In order to meet coexistence noise requirements, some form of post-production tuning is required. It is much more convenient to tune devices if one has access to digital control lines. The ability to integrate analog or digital control in tuning sharp filters in SiGe BiCMOS or Si-CMOS technology gives Silicon technology an advantage in this area.

PREDISTORTION

Moore's Law is bringing down the price of digital hardware, and this makes digital adaptive predistortion (DAPD) more attractive every year. In a DAPD system, shown in ***Figure 2***, the output from the power amplifier is sampled, downconverted to baseband, and is then compared with the input signal. Phase and amplitude distortion created by the power amplifier are detected, and the baseband signal is adjusted to exactly counteract these distortions. This technique can be used to improve the overall PA efficiency.

Predistortion comes at a cost, however. Additional power is required to downconvert the RF output signal and to carry out the appropriate signal processing. One must always ensure that the improvement in efficiency outweighs the cost of implementing the additional functionality. However, DAPD overhead is typically fairly low, since updates to the lookup table can occur quite infrequently and the DAPD blocks are powered off most of the time.

Where does DAPD have the biggest impact? It will probably have the biggest impact when used with PAs developed in highly nonlinear processes. It also has the most significant impact on larger amplifiers, where the power required by the predistorter is dwarfed by the power used by the amplifier.

For example, integrated CMOS PAs are now being seen in low power WiFi handset devices. These CMOS PAs have very low F_t, and would need to operate at very high current densities to achieve the linearity required to meet WiFi EVM specifications.

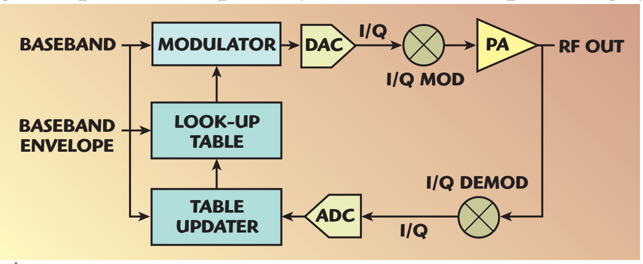


Fig. 2 Block diagram of a digital adaptive predistortion system.

When these devices are operated at lower current levels, they become very nonlinear and DAPD is a necessity for WiFi devices that use integrated CMOS PAs. Even with predistortion, the efficiency of integrated CMOS PAs is quite low, typically less than 10 percent. However, since these devices are operating at relatively low output powers (typically less than 40 mW), the efficiency is not that critical, and DAPD is used to ensure adequate linearity.

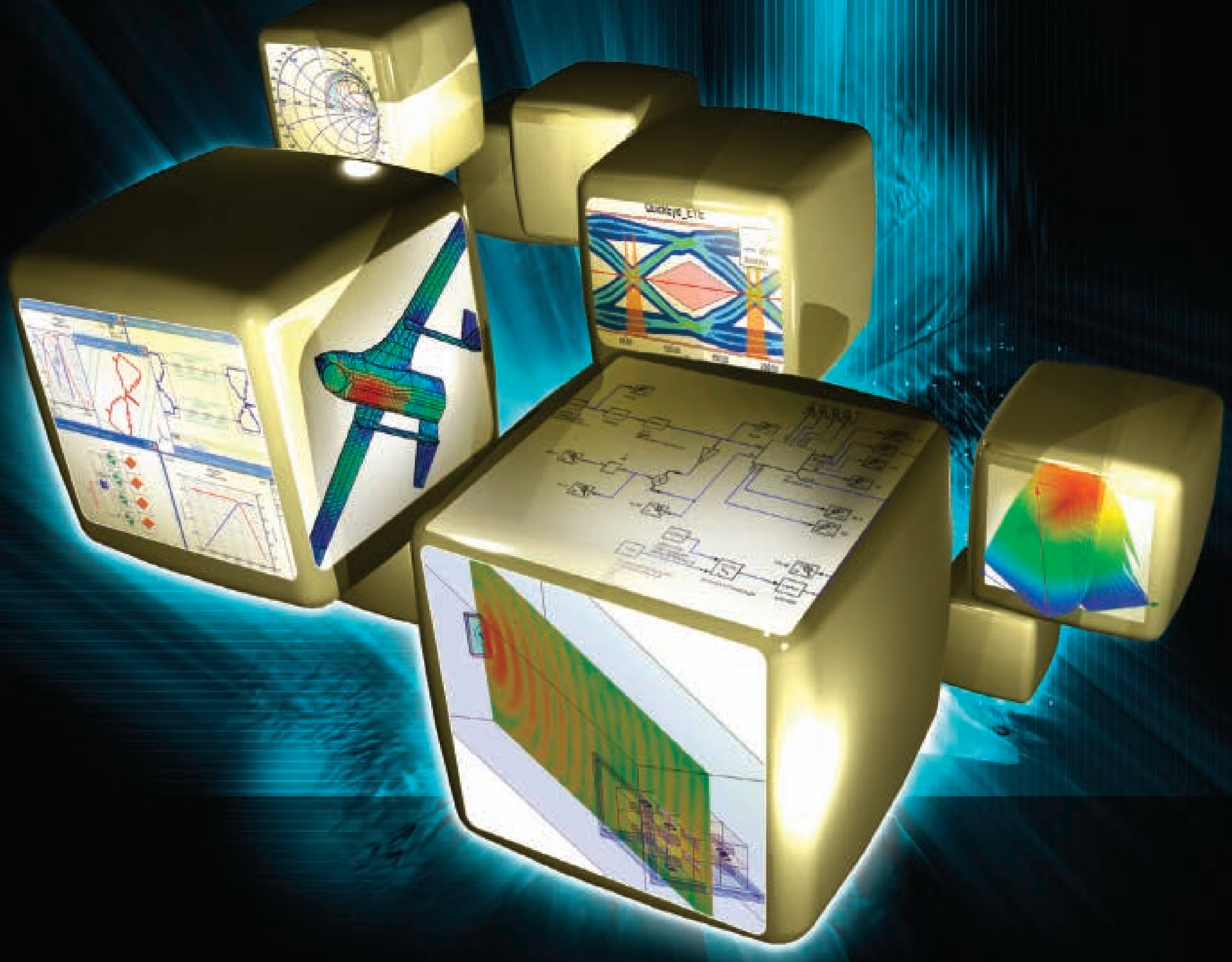
In contrast to CMOS only devices, the linearity of GaAs and SiGe transistors reduces the need for predistortion. However, predistortion can be used to improve performance, as it can improve both EVM and spectral mask.

For optimal performance with DAPD, it is best to use a PA that has been designed for maximum efficiency and not maximum linearity. In addition, by optimizing the feedback, one can tune the predistortion to apply more correction to EVM or mask. This can be important. For example, as output power increases, WiFi PAs become significantly mask limited because the out-of-band emissions limits specify a maximum absolute emission level. However, other systems like Japan's new xgPHS system employ 256QAM modulation, and one would want to optimize the DAPD for EVM correction.

There is not really a preferred technology for DAPD. Predistortion is not a necessity for GaAs or BiCMOS PAs, but it can certainly help, and will improve efficiency, especially at higher output powers. For CMOS PAs, predistortion is a requirement due to the relatively low efficiency of this technology.

QUIESCENT CURRENT

Most often, power amplifiers are specified in terms of current consumption at their rated output power, and power added efficiency (PAE) is normally specified at full power. When the output power is reduced, the current drawn by the PA is reduced. However, the current drawn is not linear with output power. For example, if the output power drops



by 50 percent (3 dB), the current typically drops by only about 20 percent. In addition, when output power is backed off so that it approaches zero, the current does not drop to zero, but instead saturates at the PA quiescent current, I_{cq}, due to the bias currents drawn by the PA.

In many applications, quiescent current is of no concern at all. For example, if a power amplifier will be operating at close to maximum power whenever it is transmitting, the power it consumes when backed off is unimportant, and I_{cq} is irrelevant. This is typically the case for 802.11 WiFi power amplifiers: When data is being transmitted, the PA is on and always operating at maximum power; between transmit bursts it is disabled and consumes only leakage current.

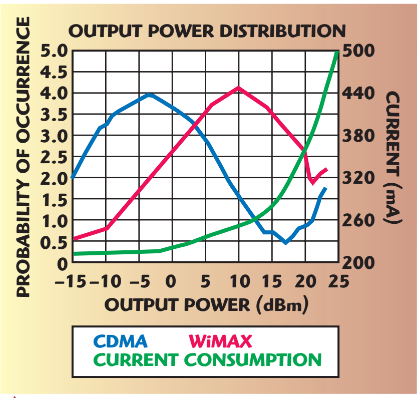
If a PA must be used over a wide range of transmit powers, then power consumption at backed off power levels becomes important, and I_{cq} is important. A good example of this occurs in either CDMA or WiMAX power amplifiers. WiMAX, for example, requires a minimum of 45 dB transmit dynamic range, since power control is intrinsic to the overall network.

Figure 3 shows the expected transmit power distribution for a mobile device in both a CDMA and WiMAX network. For CDMA, one can see that the handset most often transmits at –4 dBm, and it transmits at maximum power relatively infrequently. For WiMAX, handsets will most often transmit at approximately 10 dBm, and again, devices will transmit at maximum power only infrequently.

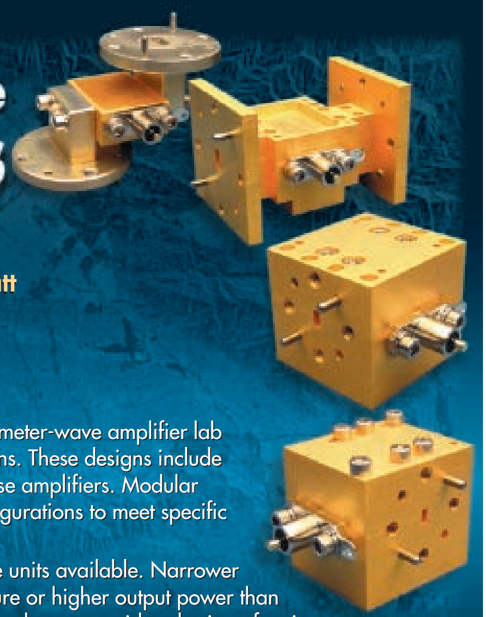
Also overlaid on this graph is current consumption versus output power for a typical power amplifier. Because the PA is often transmitting at low powers, one can see that it is important to minimize current consumption at lower output powers in order to maximize battery life.

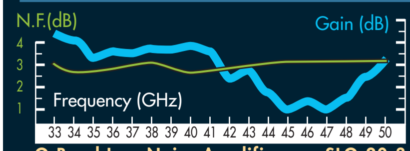
There is probably little advantage of one technology over another in terms of getting good efficiency at backed off powers; they are all equally bad. For example, typical WiMAX PAs have 100 mA I_{cq}. Assuming that the PA draws I_{cq} when delivering 0 dBm, the PA consumes 330 mW and has an efficiency of only 0.3 percent at 0 dBm output power versus an efficiency of about 20 percent at full rated power.

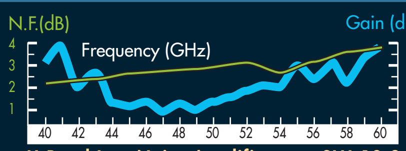
There are a number of techniques that can be used to reduce power consumption at low output powers. A common technique is to bypass the output stage at low output powers, routing the RF energy around the final stage. This drops the gain, and significantly reduces current draw, since the output stage draws no current when it is bypassed.



▲ *Fig. 3 Transmit power distribution for devices in CDMA and WiMAX networks.*







This technique is effective since the output stage is the largest stage, and draws the most current.

Typically, output stage bypass is done with switches. This favors technologies that have FET switches, since FET switches have much lower loss and are more linear. Therefore, PHEMT or GaAs BiFET processes are good choices.

A SiGe BiCMOS process, at first glance, might not seem to be a great choice since the technology makes it difficult to produce high quality, low loss switches due to substrate coupling effects. However, Silicon-on-Insulator (SOI) technology has been developed in recent years, and SOI switches are now becoming available with performance rivaling GaAs switches. Therefore, a SiGe BiCMOS process is also suitable for developing low quiescent current devices.

It is much more difficult to fabricate efficient switches with GaAs HBT or CMOS technology, so these technologies are not suitable for output stage bypass commonly used to achieve ultra low quiescent current.

LEAKAGE CURRENT

In all wireless systems, if there is no data to transmit, the PA is disabled and ideally it consumes no power at all. However, unless a switch is placed in series with the supply voltage driving the PA (which is not attractive because of cost, size and power consumption), the power amplifier will always have a supply voltage applied to the collector (bipolar devices) or drain (FET devices).

While the PA can be ‘turned off’, in practice there is always a small amount of leakage current that flows even when the PA is disabled. This leakage current is a parasitic battery drain, and reduces standby times for mobile devices. Low leakage is often specified as a firm requirement in devices like handsets where standby time is important.

The requirement for low leakage is met with most technologies. GaAs HBT, SiGe HBT and CMOS power amplifiers can all be manufactured with low leakage currents, typically under 10 A. The one technology that may have a problem with leakage current is PHEMT. These devices typically have leakage currents an order of magnitude larger than those manufactured with other technologies. The high leakage current seen with PHEMT PAs is intrinsic to this technology.

Technically speaking, a PHEMT gate looks like a diode, so the threshold voltage needs to be quite low (significantly less than a diode drop). As a result, with 0 V applied to the gate there can be appreciable leakage. Other technologies have insulated gates so threshold voltages are higher and leakage currents are much smaller.

The high leakage current of PHEMT devices is often cited as a reason not to use PHEMT technology for mobile devices. A PHEMT PA turned off and consuming a 100 A leakage current would deplete a typical 1,000 mA-hr battery in 10,000 hours (417 days), and will have a minor impact on the mobile device’s standby time.

While this seems to be a very small contributor, there are a large number of parasitic drains on the battery that all reduce standby time, and phone manufacturers wish to minimize each contributor.

So, for leakage current, the loser appears to be GaAs PHEMT. This is a factor in devices like mobile phones where standby time is important, but will be much less important in devices like laptops.

FRONT-END ICS

As Smartphones incorporating dual-band WiFi, multi-band cellular, GPS, FM and Bluetooth radios grow in popularity, it becomes increasingly difficult to fit everything into the required form factor. The RF front-end, comprising all components between the transceiver and antenna, can contribute significantly to the overall footprint. RF front-end vendors have responded, and the size of RF front-end components in communications devices has been continually shrinking.

Figure 4 shows a timeline giving an example of the degree to which integration has been applied to RF front-ends for WiFi, and one can see that integration has significantly reduced their footprint. In 2002, front-ends comprised unmatched PAs with many discrete devices, and the RF front-end had a size of about 16 x 18 mm. By 2005, front-end laminate-based modules were available incorporating discrete surface-mount components for matching, and the size had been reduced to about 8 x 7 mm. In 2007, many of these discrete matching components had been replaced by integrated passive devices, and one could now achieve the same functionality in a 4 x 4 mm module without the need for a laminate.

The next logical step in this integration process is to develop a front-end integrated circuit (FEIC), shown in the last photo in Figure 4, achieving a 3 x 3 mm form factor. FEICs offer the possibility of much greater levels of integration by integrating PAs, LNAs, switches and filters onto a single chip. Of course, the pattern of progressive integration has been repeated numerous times in the history of Silicon IC development. GaAs PHEMT and BiFET technologies are well suited for FEICs as they can be used to make excellent LNAs, PAs and switches.

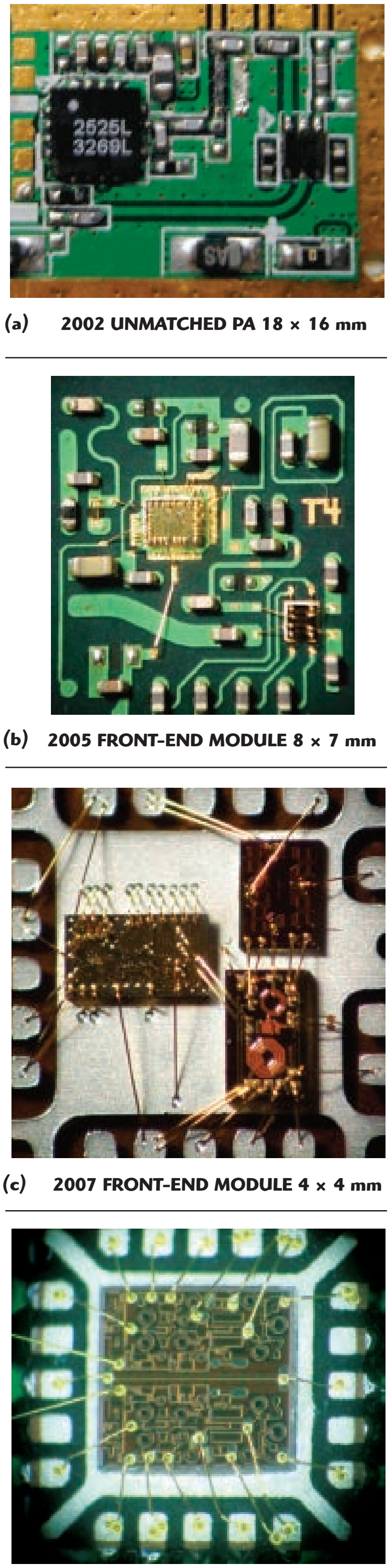
As has been discussed, the SiGe BiCMOS process, at first glance, might not seem to be a great choice, since it is difficult to produce high quality, low loss switches with this technology. However, SOI switches are now available with performance rivaling GaAs switches. As a result, a SiGe BiCMOS process is also a highly suitable platform for FEIC development and one would expect significant growth in this area. In fact, the SiGe BiCMOS platform is even more compelling when considering the possible integration of battery management circuits onto the same die.

To summarize, for front-end IC development, CMOS and GaAs HBTs will not be suitable. GaAs PHEMT and BiFET processes, as well as SiGe BiCMOS processes incorporating SOI technology, are all good choices.

POWER AMPLIFIERS WITH SERIAL INTERFACES

Historically, PAs have been standalone, independent components. Even today, most PAs are controlled with only a single analog enable signal, often requiring precision regulators. In RF front-end modules where power amplifiers, low noise amplifiers and switches are all integrated into a single packaged device, routing the control signals from the baseband chip to the RF module can be very challenging, especially with the advent of multiband and multi-PA MIMO technologies. For example, an 802.11a/b/g MIMO radio will require two 5 GHz PAs, two 5 GHz LNAs, two 2.4 GHz PAs, two 2.4 GHz LNAs, filters and Rx/Tx switches, each of which must be controlled separately.

A new trend that is emerging is to use a serial interface to control the PA and/or components within the RF front-end module. A serial-interface-controlled PA has the potential to revolutionize PA operation, bringing



(a) 2002 UNMATCHED PA 18 × 16 mm

(b) 2005 FRONT-END MODULE 8 × 7 mm

(c) 2007 FRONT-END MODULE 4 × 4 mm

(d) 2008 FRONT-END IC 3 × 3 mm

Fig. 4 Evolution of RF front-end sizes for WiFi radios.

the digital interface one step closer to the antenna. In the context of complex front-end modules, the serial interface can reduce or eliminate control lines, greatly simplifying routing from the baseband chip. One could also use the serial interface to report temperature and detector voltages directly over the serial bus, thereby reducing pin-count and eliminating the need for A/D converters on the baseband chip.

Serial interfaces favor Silicon processes like CMOS and SiGe BiCMOS. Most GaAs processes lack complimentary devices (pFET or PNP transistors). As a result, it is not possible to implement significant logic or logic control like a truth table on a GaAs die. Therefore, HBT, BiFET, or PHEMT-based devices would all require an external CMOS logic die to properly implement a serial interface. Consequently, if serial interface control of PAs or RF front-ends is important, the logical choice is CMOS or SiGe BiCMOS.

CONCLUSION

There have been a number of important issues that have impacted the design of power amplifiers in recent years. This article has summarized several new issues, and has looked at how each affects the choice of technology for the power amplifier, particularly for PAs used with OFDM modulations. CMOS PAs are suitable for lower output powers, and require the use of digital adaptive predistortion to achieve linearity required for operation.

While GaAs HBT technology has traditionally been used for high power and high frequency power amplifiers, high performance SiGe BiCMOS power amplifiers are now competing very effectively with them. SiGe BiCMOS power amplifiers can be preferred to GaAs HBT PAs based on the availability of digital logic for serial interface control, as well as for the high levels of integration possible for front-end IC development. Consequently, GaAs HBT and GaAs PHEMT PAs will be used at progressively higher power levels and in more specialized applications. Slowly but surely, Silicon is progressing in the III-V versus Silicon battle on the power amplifier front. ■

Darcy Poulin holds a BS degree with honors in engineering physics from Queen's University at Kingston, and a PhD degree in applied physics from McMaster University in Hamilton, Ontario, Canada. He brings to SiGe Semiconductor more than 15 years of experience in RF engineering and IC design. He is currently principal engineer, RF Systems and Technical Marketing, and is responsible for RF systems work, standards development, and technical marketing activities for WiFi, WiMAX and LTE.

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

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AML811PN1808	8.5 – 11.0	18	18	-152.5	-157.5	-165.5	-168
AML811PN1508	8.5 – 11.0	15	28	-145.5	-153.5	-158.5	-164.5
AML26PN0904	2.0 – 6.0	9	20	-150	-165	-165	-178
AML26PN1201	2.0 – 6.0	11	15	-155	-160	-160	-175

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AFL30040125	50 – 500	23	28	53	+28V @ 700mA
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*Above 500MHz.

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L0204-44	2 - 4	44	25	42.5	45	14
L0206-40	2 - 6	40	10	38.5	40	8.5
L0208-41	2 - 8	41	12	40	40	17
L0218-32	2 - 18	32	1.4	31	35	5
L0408-43	4 - 8	43	20	41.5	45	17
L0618-43	6 - 18	43	20	41.5	45	22
L0812-46	8 - 12	46	40	45	45	28
Millimeter-Wave Power Amplifiers						
L1826-34	18 - 26	34	2.5	33	35	4
L1840-27	18 - 40	27	0.5	26	30	2
L2240-28	22 - 40	28.5	0.7	27	30	3
L2630-39	26 - 30	39	8.0	38	40	15
L2632-37	26 - 32	37	5.0	36	38	10
L2640-31	26 - 40	31	1.2	30	30	5
L3040-33	30 - 40	33	2.0	32	33	9
L3337-36	33 - 37	36	4.0	35	40	12
L3640-36	36 - 40	36	4.0	35	40	10

High-Power Rack Mount Amplifiers

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

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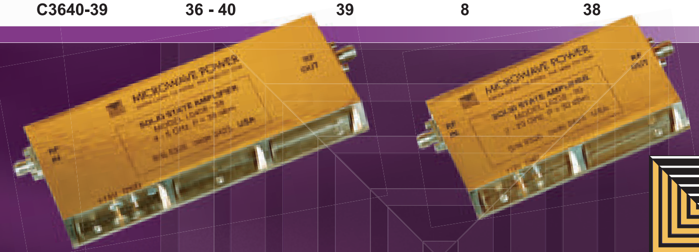

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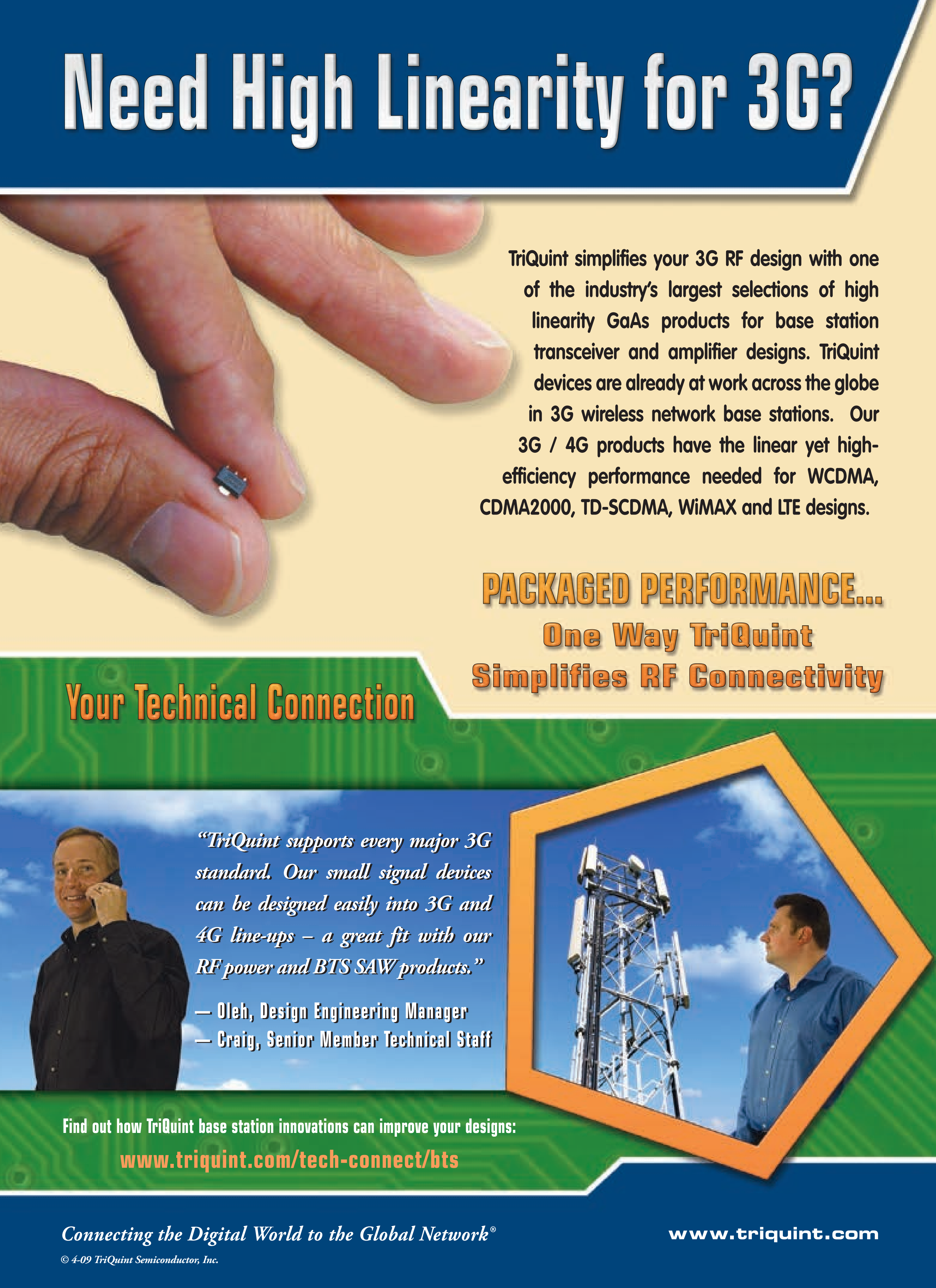

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CA01-2110	0.5-1.0	28	1.0 MAX, 0.7 TYP	+10 MIN	+20 dBm	2.0:1
CA12-2110	1.0-2.0	30	1.0 MAX, 0.7 TYP	+10 MIN	+20 dBm	2.0:1
CA24-2111	2.0-4.0	29	1.1 MAX, 0.95 TYP	+10 MIN	+20 dBm	2.0:1
CA48-2111	4.0-8.0	29	1.3 MAX, 1.0 TYP	+10 MIN	+20 dBm	2.0:1
CA812-3111	8.0-12.0	27	1.6 MAX, 1.4 TYP	+10 MIN	+20 dBm	2.0:1
CA1218-4111	12.0-18.0	25	1.9 MAX, 1.7 TYP	+10 MIN	+20 dBm	2.0:1
CA1826-2110	18.0-26.5	32	3.0 MAX, 2.5 TYP	+10 MIN	+20 dBm	2.0:1

NARROW BAND LOW NOISE AND MEDIUM POWER AMPLIFIERS

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CA01-2111	0.4 - 0.5	28	0.6 MAX, 0.4 TYP	+10 MIN	+20 dBm	2.0:1
CA01-2113	0.8 - 1.0	28	0.6 MAX, 0.4 TYP	+10 MIN	+20 dBm	2.0:1
CA12-3117	1.2 - 1.6	25	0.6 MAX, 0.4 TYP	+10 MIN	+20 dBm	2.0:1
CA23-3111	2.2 - 2.4	30	0.6 MAX, 0.45 TYP	+10 MIN	+20 dBm	2.0:1
CA23-3116	2.7 - 2.9	29	0.7 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA34-2110	3.7 - 4.2	28	1.0 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA56-3110	5.4 - 5.9	40	1.0 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA78-4110	7.25 - 7.75	32	1.2 MAX, 1.0 TYP	+10 MIN	+20 dBm	2.0:1
CA910-3110	9.0 - 10.6	25	1.4 MAX, 1.2 TYP	+10 MIN	+20 dBm	2.0:1
CA1315-3110	13.75 - 15.4	25	1.6 MAX, 1.4 TYP	+10 MIN	+20 dBm	2.0:1
CA12-3114	1.35 - 1.85	30	4.0 MAX, 3.0 TYP	+33 MIN	+41 dBm	2.0:1
CA34-6116	3.1 - 3.5	40	4.5 MAX, 3.5 TYP	+35 MIN	+43 dBm	2.0:1
CA56-5114	5.9 - 6.4	30	5.0 MAX, 4.0 TYP	+30 MIN	+40 dBm	2.0:1
CA812-6115	8.0 - 12.0	30	4.5 MAX, 3.5 TYP	+30 MIN	+40 dBm	2.0:1
CA812-6116	8.0 - 12.0	30	5.0 MAX, 4.0 TYP	+33 MIN	+41 dBm	2.0:1
CA1213-7110	12.2 - 13.25	28	6.0 MAX, 5.5 TYP	+33 MIN	+42 dBm	2.0:1
CA1415-7110	14.0 - 15.0	30	5.0 MAX, 4.0 TYP	+30 MIN	+40 dBm	2.0:1
CA1722-4110	17.0 - 22.0	25	3.5 MAX, 2.8 TYP	+21 MIN	+31 dBm	2.0:1

ULTRA-BROADBAND & MULTI-OCTAVE BAND AMPLIFIERS

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB)	Power-out @ P1-dB	3rd Order ICP	VSWR
CA0102-3111	0.1-2.0	28	1.6 Max, 1.2 TYP	+10 MIN	+20 dBm	2.0:1
CA0106-3111	0.1-6.0	28	1.9 Max, 1.5 TYP	+10 MIN	+20 dBm	2.0:1
CA0108-3110	0.1-8.0	26	2.2 Max, 1.8 TYP	+10 MIN	+20 dBm	2.0:1
CA0108-4112	0.1-8.0	32	3.0 MAX, 1.8 TYP	+22 MIN	+32 dBm	2.0:1
CA02-3112	0.5-2.0	36	4.5 MAX, 2.5 TYP	+30 MIN	+40 dBm	2.0:1
CA26-3110	2.0-6.0	26	2.0 MAX, 1.5 TYP	+10 MIN	+20 dBm	2.0:1
CA26-4114	2.0-6.0	22	5.0 MAX, 3.5 TYP	+30 MIN	+40 dBm	2.0:1
CA618-4112	6.0-18.0	25	5.0 MAX, 3.5 TYP	+23 MIN	+33 dBm	2.0:1
CA618-6114	6.0-18.0	35	5.0 MAX, 3.5 TYP	+30 MIN	+40 dBm	2.0:1
CA218-4116	2.0-18.0	30	3.5 MAX, 2.8 TYP	+10 MIN	+20 dBm	2.0:1
CA218-4110	2.0-18.0	30	5.0 MAX, 3.5 TYP	+20 MIN	+30 dBm	2.0:1
CA218-4112	2.0-18.0	29	5.0 MAX, 3.5 TYP	+24 MIN	+34 dBm	2.0:1

LIMITING AMPLIFIERS

Model No.	Freq (GHz)	Input Dynamic Range	Output Power Range Psat	Power Flatness dB	VSWR
CLA24-4001	2.0 - 4.0	-28 to +10 dBm	+7 to +11 dBm	+/- 1.5 MAX	2.0:1
CLA26-8001	2.0 - 6.0	-50 to +20 dBm	+14 to +18 dBm	+/- 1.5 MAX	2.0:1
CLA712-5001	7.0 - 12.4	-21 to +10 dBm	+14 to +19 dBm	+/- 1.5 MAX	2.0:1
CLA618-1201	6.0 - 18.0	-50 to +20 dBm	+14 to +19 dBm	+/- 1.5 MAX	2.0:1

AMPLIFIERS WITH INTEGRATED GAIN ATTENUATION

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB)	Power-out @ P1-dB	Gain Attenuation Range	VSWR
CA001-2511A	0.025-0.150	21	5.0 MAX, 3.5 TYP	+12 MIN	30 dB MIN	2.0:1
CA05-3110A	0.5-5.5	23	2.5 MAX, 1.5 TYP	+18 MIN	20 dB MIN	2.0:1
CA56-3110A	5.85-6.425	28	2.5 MAX, 1.5 TYP	+16 MIN	22 dB MIN	1.8:1
CA612-4110A	6.0-12.0	24	2.5 MAX, 1.5 TYP	+12 MIN	15 dB MIN	1.9:1
CA1315-4110A	13.75-15.4	25	2.2 MAX, 1.6 TYP	+16 MIN	20 dB MIN	1.8:1
CA1518-4110A	15.0-18.0	30	3.0 MAX, 2.0 TYP	+18 MIN	20 dB MIN	1.85:1

LOW FREQUENCY AMPLIFIERS

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure dB	Power-out @ P1-dB	3rd Order ICP	VSWR
CA001-2110	0.01-0.10	18	4.0 MAX, 2.2 TYP	+10 MIN	+20 dBm	2.0:1
CA001-2211	0.04-0.15	24	3.5 MAX, 2.2 TYP	+13 MIN	+23 dBm	2.0:1
CA001-2215	0.04-0.15	23	4.0 MAX, 2.2 TYP	+23 MIN	+33 dBm	2.0:1
CA001-3113	0.01-1.0	28	4.0 MAX, 2.8 TYP	+17 MIN	+27 dBm	2.0:1
CA002-3114	0.01-2.0	27	4.0 MAX, 2.8 TYP	+20 MIN	+30 dBm	2.0:1
CA003-3116	0.01-3.0	18	4.0 MAX, 2.8 TYP	+25 MIN	+35 dBm	2.0:1
CA004-3112	0.01-4.0	32	4.0 MAX, 2.8 TYP	+15 MIN	+25 dBm	2.0:1

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Northrop Grumman Selected to Develop Wireless Spacecraft Technology

Radios are wireless. Telephones are wireless. Computers are wireless. And in the next step forward in space systems, satellite equipment could become wireless too. Northrop Grumman Corp. is developing a robust, radiation-hardened, wireless spacecraft bus under a $4.1 M, 21-month, first phase contract from the US Air Force Research Laboratory (AFRL). A spacecraft data bus serves as the electrical interface between the spacecraft's equipment and payloads.

"The innovative program will redefine spacecraft of the future," said John Brock, Director of Mission Technology Futures for Northrop Grumman Aerospace Systems. "Wireless technology will allow us to build faster, lower cost and lighter weight spacecraft by reducing the extensive touch labor, risks and complexities associated with integrating heavy, copper wire harnesses." Under the contract, Northrop Grumman will develop a wireless data bus interface that enhances AFRL's innovative electronics architecture for spacecraft called Space Plug-n-Play Avionics or SPA. These electronics have modern features of automatic device recognition and fault detection, much like commercial computer interfaces, to enable addition and removal of equipment without any software or database changes.

The development challenge is to create hardware elements for managing messages and directing communication traffic in an RF-rich micro-environment with hundreds of wireless devices. The initial phase will conclude with a wireless standard, such as Bluetooth, and will establish protocols, design implementation guidelines, and address spacecraft unique features such as security, reliability and electromagnetic emissions management.

Called SPA—Wireless, the interface communication system will upgrade commercial wireless technology for internal spacecraft use. Upgraded space wireless devices will allow new capabilities for spacecraft to:

- Locate and track parts through assembly, integration and rework;
- Detect when tools and assembly aids are inside the spacecraft;
- Automatically assess the connectivity health of a delivered component; and
- Ease reconfiguration and self-examination using commercial off-the-shelf wireless equipment.

"Many functions in a spacecraft that currently need a wire harness are used only once, or only intermittently over the life of a satellite," Brock explained, adding that the company is continuously exploring the use of new technologies to reduce the cost of spacecraft. "These functions, such as deployment limit switches, temperature measurements, and status switches are excellent candidates for wireless."

Lockheed Martin Awarded Contract to Expand Submarine Communications

Lockheed Martin has been awarded a $35.8 M contract by the US Navy to design and produce antenna buoy systems that will significantly expand the communications capabilities of submarines while they are submerged. The Navy's Communications at Speed and Depth (CSD) program will use expendable submarine and air-launched communications buoys to enable submarines operating below periscope depth and at tactical speeds to communicate with surface ships and land-based assets via satellite networks. All classes of US Navy submarines will be equipped with this capability.

Under the contract, a Lockheed Martin-led industry team will develop three types of expendable communications buoys: two submarine-launched tethered buoys that provide real-time chat, data transfer and e-mail capabilities via either Iridium or UHF satellites; and an untethered, acoustic-to-radio frequency gateway buoy that can be launched from a submarine or maritime patrol aircraft to enable two-way data transfer between a submerged submarine and surface assets. The contract also includes production of associated shore and onboard equipment needed to support the systems. If all options are exercised, the cumulative value of the contract is estimated at $177.9 M.

The Lockheed Martin-led team, which includes Ultra Electronics Ocean Systems and ERAPSCO, collectively has more than 50 years of experience in the design and development of expendable devices. Ultra Electronics Ocean Systems Inc., headquartered in Braintree, MA, is a world-leading developer and provider of special purpose expendable devices for US Navy submarines and surface ships as well as major allied navies. ERAPSCO, a joint venture between Sparton Electronics Florida Inc., DeLeon Springs, FL and Ultra Electronics – USSI, Columbia City, IN, is a designer and manufacturer of expendable underwater transducer and sensor products for the US Navy and its allies.

"Having the ability to communicate at speed and depth will truly transform submarine communications," said Captain Dean Richter, Program Manager – PEO C4I / Submarine Integration Program Office (PMW 770). "With this capability, submarines become a fully-integrated fleet asset with on-demand access to the Global Information Grid."

"Delivering this capability eliminates a traditional limitation of submarines by giving them the ability to communicate with maximum tactical flexibility and maneuverability," said Joe Rappisi, Vice President and General Manager of Lockheed Martin's Marion-based business. "We are partnered with the industry's best to give submarines the same access to communication networks as the rest of the US Navy's fleet."

Harris Corp. Demonstrates Highband Networking Radio Systems

Harris Corp.'s new Highband Networking Radio™ (HNR) provided interoperable, long-range backbone communications for stationary, on-the-move and airborne platforms, including the Boeing A160T "Hummingbird" Unmanned Aerial System, at the US Army's C4ISR On-the-Move Event at Fort Dix, NJ. The radio was co-developed with BAE Systems. The event was held last summer and marked the Army's largest-ever Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR) and networking technology demonstration.

The airborne communications layer provided by the A160T Hummingbird unmanned aerial system allowed Harris to demonstrate the system's ability to bridge air/ground communications between two geographically dispersed networks. The Army exercise also demonstrated that the Harris system could operate in both C-band and Ku-band simultaneously within a single, integrated network, thereby providing Brigade-and-above echelon commands with robust communications for tactical operations. During the exercise, 11 C-band and Ku-band HNR systems were demonstrated. Harris intends to support and participate in C4ISR OTM E09 and continue to leverage its relevant environment to further develop and accelerate features and capabilities in the HNR system.

"The performance achieved by the Highband Networking Radio in the C4ISR OTM event was an important milestone in the production of this product and provides continued validation of the capabilities of the Harris-developed Highband Networking Waveform™ in a variety of applications," said Wes Covell, President of Defense Programs for Harris Government Communications Systems.

The Highband Networking Radio integrates directive-beam technology with mobile, ad hoc mesh networking, and achieves burst data rates of up to 54 Mbps. It has been implemented on a variety of fixed-wing rotary-wing and airship platforms, including piloted aircraft and unmanned aircraft systems. Applications of the Highband Networking Waveform and HNR extend to numerous scenarios, including terrestrial tactical communications augmented by air-to-ground and air-to-air nodes, as well as air-and-missile defense missions. The waveform and radio also can be used to extend the battlespace network into the maritime force contingent, connecting expeditionary forces with near-shore support and blue-water platforms. HNR was recently deployed to the US Army 101st Airborne Assault Division's 2nd Brigade Combat Team in Baghdad, Iraq. ■


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EU Keeps Embedded System Developers Interested

The INTEROperable Embedded Systems Tool chain for Enhanced rapid Design, prototyping and code generation (INTERESTED) project has been launched. This new initiative is funded under the European Union's 7th Framework Programme.

INTERESTED is focused on the creation of the first-ever European-wide, integrated and open reference tool chain covering the full spectrum of embedded systems and software development. Its aim is to realise a reference tool chain that is highly dependable, safe and efficient while also reducing the cost of deployment and maintenance by 50 per cent. Delivery of the complete, integrated reference tool chain is expected by the end of 2010.

The project brings together the leading European embedded tool vendors, whose tools form the basis for the integrated reference tool chain, with major European embedded tool users from a variety of industries who will validate the reference tool chain against real-world design requirements and applications. As well as creating a reference tool chain that draws on leading European embedded systems and software tools, the project will also provide interoperability with Commercial Off-the-Shelf (COTS), open source and in-house embedded design solutions.

Using standards-based integration and interoperability solutions, the INTERESTED tool chain will assimilate embedded tools into three distinct design domains—system and software design, networking and execution platform, and timing and code analysis. These design domains cover the full scope of embedded systems and software engineering from system and application software design modelling, verification and code generation through networking and RTOS execution platforms to hardware-dependent software verification and code generation as well as timing analysis and code execution verification.

The INTERESTED reference tool chain is intended primarily for use by companies operating within stringent quality control requirements on the development of complex safety and mission-critical embedded systems. Such companies must generally comply with formal certification processes such as DO-178B for aerospace, IEC 61508 for industry, EN 50128 for railways, IEC 60880 for energy power plants and DEF STD 00-56 for military requirements as well as the forthcoming ISO 26262 automotive safety standard.

NGMN Releases ITDD Document

The Next Generation Mobile Network (NGMN) Alliance has launched the Initial Terminal Device Definition (ITDD) document, which provides the generic definitions required for next generation devices and demonstrates the Alliance's commitment to providing support across the entire next generation marketplace including devices and networks.

A major objective of the NGMN Alliance is to ensure that next generation devices are available when the network is commercially available in 2010. The industry requires complete synchronicity of next generation devices, networks and services for a successful launch. The ITDD project was initiated to determine the requirements for user equipment for delivery in 2010. It defined devices that are enabled to serve common requirements while at the same time providing enough customisation to be regionally useful.

This document has initiated a sequence of Executive Workshops on Devices where all NGMN partners are committed to participate and the alliance continues to put a major focus in its work plan on the critical success factors in the device area including early device availability and capabilities, certification, test cases and IPR matters. The ITDD document can be downloaded at www.bbngmn.org.

C4AS and EADS DS Create Joint Venture

C4 Advanced Solutions (C4AS), a wholly owned subsidiary of the Emirates Advanced Investments group, and EADS Defence & Security (DS) have created a joint venture company in Abu Dhabi to develop and market high-tech solutions in the field of defence and security applications.

This joint venture company will open a long-term relationship between EADS DS and the EAI group and will be dedicated to bringing advanced solutions to its customers. Those solutions will be jointly developed by the two partner companies through the new JV company in close cooperation with customers and end users, thus maximising operational value.

This partnership is also a clear cornerstone of EADS DS and EAI strategy to address efficiently the key importance of transfer of technology to the UAE, as a successful medium for the development and implementation of strategic and nationally sensitive defence and security systems.

Next Generation Backhaul Network for Morocco

North African operator, Wana, has selected Cambridge Broadband Networks' VectaStar Next Generation point-to-multipoint microwave backhaul solution to increase the performance of its backhaul network and support the introduction of mobile broadband services in Morocco. The backhaul solution provides operators with investment protection by enabling them to build cost-effective backhaul networks today with the capacity for their next generation networks tomorrow.

Wana is one of Cambridge Broadband Networks' longest standing customers. It built its first VectaStar network in 2006, which was subsequently extended in 2008 using 10.5 GHz equipment. The new equipment purchased operates at 26 GHz, exceeding the performance and flexibility levels Wana needs to build a cost-effective mobile broadband backhaul network for the future.

Such future-proofing was a key factor in the selection of the solution as Karim ZAZ, CEO of Wana, explained, "VectaStar has served Wana well as a backhaul and access product. The improved performance of VectaStar Next Generation, along with its unique simultaneous IP and TDM support, makes it the ideal technology to backhaul our mixed service mobile broadband network. Its architecture also shortens network deployment time, helping us speed network upgrades to our customers. We see it as an essential element to ensure the continued profitability of Wana."

Thales Wins ESA Contract for LTAS

Thales Alenia Space España has won a €3.8 M contract from the Directorate of Technical and Quality Management of the European Space Agency (ESA) for the development and qualification of an avionics kit to provide Launcher Telemetry Acquisition via Satellite (LTAS). This kit will be used on future missions by Ariane 5, Vega and other European launchers, and is capable of communicating via relay satellites such as the American TDRSS constellation and/or the European Artemis satellite.

As prime contractor, Thales Alenia Space España will be responsible for the design and production of an engineering model, followed by a ground compatibility test using the Artemis satellite. An in-orbit demonstration test currently planned on the second Vega flight, VERTA-1, will follow, with deliveries scheduled for 2010.

The LTAS kit is designed to be installed on a launcher to handle the mission's telemetry transmissions via satellite. The kit will encode the telemetry data from the launcher's avionics, then amplify and transmit this data via the antennas.

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Semiconductor End-use Segments Will Suffer Due to Recession

The current global economic slump will be felt broadly across all semiconductor end-use market segments, reports In-Stat. This slump is unlike the 2001 downturn that was demand-driven and more strongly felt in some segments than in others.

"The automotive segment is expected to experience a 22.7 percent revenue decline in 2009 because of the price sensitivity of consumers and the lack of available credit for many potential buyers," says Jim McGregor, In-Stat analyst. "The consumer segment is also expected to lag the overall semiconductor market in 2009 as consumers cut spending, but the consumer segment should recover relatively quickly due to declining prices and consumers' willingness to spend a few hundred dollars for communications and entertainment devices while still deferring larger-priced purchases. Beginning in 2010, the consumer segment should begin growing as an overall percentage of the semiconductor market once again, reaching 21.4 in 2013."

Recent research by In-Stat found the following:

- Long term, the computer segment will lose share while the consumer and automotive segments gain share.
- The computer segment will remain the largest well beyond 2013 at 40.7 percent of total semiconductor revenue.
- Total semiconductor revenue is expected to drop by 19.6 percent in 2009, but should eclipse 2008 revenue at $265.9 B in 2012.

The research, "Global Semiconductor End-use Forecast: Is Anyone Buying?," covers the worldwide market for semiconductors. It includes:

- Worldwide semiconductor unit, average selling price (ASP) and revenue forecasts
- Worldwide semiconductor revenue forecasts by end-use market segments broken out by region and by major WSTS product category
- Regional semiconductor revenue forecasts broken out by major end-use category
- Semiconductor major product category forecasts broken out by end-use market segments

WiMAX Subscriber Revenue Will Grow in 2009

Any reader who believed all the recent headlines would feel confident that the WiMAX market is being crushed by LTE. Nortel has left the WiMAX market and Alcatel-Lucent has "backed off" from WiMAX; these developments supposedly dealt a blow to Clearwire, which had so far chosen neither as an infrastructure vendor. But that is not quite the whole story.

Nortel exited the mobile WiMAX market because it failed to become competitive and win any significant business. Nortel is staying in the fixed WiMAX market. Alcatel-Lucent did not really back away from mobile WiMAX, but rather views it more as a wireless broadband solution than a fully mobile wireless solution. Alcatel-Lucent moved R&D spending from WiMAX to LTE since WiMAX is productized while LTE is just starting to develop. The lines are very blurred between fixed/portable use of mobile WiMAX and fixed/portable/mobile use of mobile WiMAX. Many deployments will start with fixed and portable services first and may evolve to fully mobile use later.

"Contrary to the popular view, Alcatel-Lucent is still quite involved with mobile WiMAX," says ABI Research principal analyst Philip Solis. "The company has had its 3.5 GHz products certified by the WiMAX Forum; its 'ng Connect' program includes mobile WiMAX; and it is working with Intel on an interoperability program for mobile WiMAX devices. In addition, Alcatel-Lucent ranks first in 2008 market share for mobile WiMAX base station deployments, followed by Alvarion, Motorola and Samsung." WiMAX has many growth opportunities beyond traditional mobile operator networks, including data-centric deployments in both developed and developing regions. "To ignore a growth market in a down economy would be a mistake," adds Solis. Growth will be more modest for WiMAX base stations by themselves for 2009, but 2010 will see healthy expansion.

800,000 Alternative Energy-powered Base Stations in 2009

No one can deny that green and clean agendas are rising to the surface in the mobile communications market. ABI Research forecasts that in 2009 over 800,000 base stations will utilize alternative energy solutions such as wind or solar energy, and that nearly 70 million mobile devices will be ethically disposed of or will be recycled in 2009.

To meet the growing need for detailed market information about these green initiatives, ABI Research has launched a new Clean Telecoms Research Service.

Vice President and Chief Research Officer Stuart Carlaw says, "One only has to look at the splash of solar powered mobile devices at Mobile World Congress 2009 to see that environmentally friendly solutions are becoming increasingly important to mobile consumers, service providers, application developers and OEMs alike. Renewable energy will be a critical aspect in connecting the next two billion subscribers in off-grid and brown power areas. Not only is it environmentally friendly, but it is also extremely cost effective."

The new ABI Research Clean Telecoms Research Service covers important aspects such as energy consumption, renewable energy penetration, manufacturing and materials usage, corporate responsibility, regulatory issues, recycling, and product end-of-life management in the key areas of radio access and core networks, devices and services.

US Consumers Could Drop Spending on Mobile, Broadband and Pay TV Services

US consumer spending on Subscription-TV, Broadband and Mobile Services will be "about the same" for most consumers, but about 15 percent intend to cut back. As a result, In-Stat estimates that consumer spending across these three segments could see nearly a $5 B decrease during the next 12 months. Yet In-Stat's recent survey reveals that broadband service is among the most integral parts of consumers' lives. Over 66 million consumers across demographic categories are using the Internet while camped out on their sofas watching TV.

"Some male age groups had 40 to 50 percent of respondents using a PC while watching TV, and about 30 percent of females under the age of 40 are also using a PC while watching TV," says Gerry Kaufhold, In-Stat analyst. "New approaches using online web portals synchronized to a TV program will continue to develop, because they present no new costs. Cable TV operators also face increasing competition from lightweight services that deliver popular cable programming, supplemented by content delivered via broadband."

Recent research by In-Stat found the following:

- Consumer multitasking while watching TV varies significantly depending on demographic characteristics.
- Several companies are identifying new opportunities to "marry" TV to people simultaneously viewing a related website, and transform the World Wide Web into a "lean back" experience.
- Low-cost Netbook PCs could represent a $2.4 B opportunity.
- The biggest decrease in spending on mobile, broadband and subscription TV services will come from households with income below $35 K.

The research, "US TV Viewers Response to Economic Turmoil," covers TV viewing habits in the US. It includes:

- Analysis of impact of current economic downturn on consumer behavior regarding TV viewing, broadband use, and spending across mobile, broadband and subscription TV.
- Results and analysis of a late 2008 US consumer survey on TV viewing, Internet usage habits and multitasking while watching TV.
- Examination of consumers' interest in Internet TV services.


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INDUSTRY NEWS

■ **IEEE**, the world's largest technical professional society, signed a merger agreement with the honor society **Eta Kappa Nu** (HKN), a nonprofit, public-service organization comprising nearly 200 university chapters. The merger, which will go into effect by mid-2009 pending final approval, will make HKN the official honor society of IEEE, recognizing scholarship and academic excellence and identifying student leaders, young professionals and eminent scholars in the IEEE's technical fields of interest. Under the agreement, HKN will become an organizational unit of IEEE, governed by the new IEEE-HKN Board of Governors. A restricted endowment will be created in the IEEE Foundation to support HKN's educational, societal and recognition activities. In addition to holding HKN's current assets, the new endowment will receive an initial donation of US$1.2 M from IEEE.

■ **The Vitec Group**, a worldwide provider of a wide range of equipment and services to the broadcasting, entertainment and photographic industries, announced the establishment of **RF Extreme LLC**, a new business unit within the company that comprises leading digital and analog video microwave brands, Nucomm, RF Central and Microwave Service Co. (MSC).

■ The **Lumexis** Fiber To The Screen (FTTS™) system is airborne with the assistance of **Tyco Electronics**. This new system brings weight savings and unprecedented capability to the commercial airline industry as demonstrated during the maiden flight of the US Airways A320 launched February 3, 2009. The products supplied by Tyco Electronics aided a problem-free installation for the first US Airways A320 aircraft in Rome, NY. As an example of its commitment to customer satisfaction, Tyco Electronics closely assisted in the installation process, contributing to the successful delivery.

■ Based upon the success of the recent Tech Tours held in Bangalore and Chennai, India, **ETS-Lindgren** and **Agilent Technologies** announced plans to add three new cities in India to the Tech Tour™ schedule for 2009. Newly added locations include Delhi, Pune and Hyderabad—all coming in June, 2009.

■ **AWR**, an innovation leader in high frequency electronic design automation (EDA), and **Anritsu Co.**, a global provider of test and measurement solutions, announced AWR Connected™ for Anritsu, which makes Microwave Office high frequency design software a standard component of Anritsu's new VectorStar MS4640A vector network analyzer (VNA). AWR Connected for Anritsu makes the MS4640A the first microwave instrument to physically integrate a full suite of design tools within its firmware. Microwave Office software provides all the tools necessary for high frequency IC, printed circuit board, and module design, including linear circuit simulators, electromagnetic (EM) analysis tools, and integrated schematic and layout, without leaving the measurement environment.

■ **Visible Assets Inc.** announced that the Institute of Electrical and Electronics Engineers (IEEE) has approved RuBee®, a long-wavelength, packet-based, magnetic transceiver protocol, as a new international standard designated IEEE 1902.1. Visible Assets and **Seiko Epson Corp.** sponsored creation of the standard and the workgroup and are responsible for its development.

■ **Freescale Semiconductor**, a supplier of 802.15.4 chipsets, announced it has shipped more than seven million IEEE® 802.15.4 and ZigBee® units in 2008 for the wireless sensor networks used in smart energy, industrial control and home entertainment applications.

■ **VXI Technology Inc.** announced that it has changed its name to **VTI Instruments Corp.** to more completely represent the applications and markets that it serves. VTI Instruments develops precision instrumentation for electronic signal distribution, data acquisition and monitoring on several open architecture platforms, including VXI, VME and LXI, which the company co-founded in 2004.

■ **Elcoteq SE**, an electronics manufacturing services (EMS) company in the communications technology industry, marks the 10-year anniversaries of its Dongguan high volume manufacturing plant and its Hong Kong management support office in China. Elcoteq was one of the first EMS companies to recognize Chinese customer demand for local manufacturing and support services, establishing Elcoteq Dongguan and Elcoteq Asia Ltd. in 1999. Elcoteq factories in China manufacture communications technology products such as wireless communications terminal products, home communications products and network equipment.

■ **L-com Global Connectivity Inc.** has announced that its Boca Raton, FL facility has been ISO 9001-2008 certified. This location houses engineering, sales and manufacturing for L-com's HyperLink brand wireless products.

■ **Laird Technologies Inc.**, a global leader in the design and supply of customized, performance-critical components and systems for advanced electronics and wireless products, was chosen in a global selection as one of the Top 100 M2M companies for 2009 by *M2M Magazine*.

CONTRACTS

■ **Herley Industries Inc.** announced that it has received an option award exceeding $4.7 M to supply Tactical Instrument Landing Systems (TILS) for both the F/A-18E/F/G and E-2D Naval aircraft. The AN/ARA-63 TILS is a microwave landing system that provides precise elevation and azimuth guidance information necessary for critical aircraft carrier landings.

■ **Elcom Technologies Inc.** announced receipt of orders totaling $2.4 M for Elcom's UFS and IBS lines of frequency synthesizers. The orders reflect Elcom's growing market share in threat simulation and antenna test, respectively.

Elcom believes the orders reflect an increasing need by defense contractors and defense departments around the world to more accurately emulate aggressor capabilities as combat aircraft are exposed to increasingly sophisticated hostile environments. Elcom was selected due to its leading fast switching speed capabilities, low phase noise, high frequency agility, fine frequency resolution and flexible modulation & attenuation.

■ **RF Industries Ltd.** announced that its **RadioMobile** division has received a $76,000 follow-on purchase order to provide IQ Mobile systems to a major California County Fire Agency.

■ **RF Micro Devices Inc.** (RFMD), a designer and manufacturer of high performance semiconductor components, announced the company's RF7168 dual-band GSM/GPRS transmit module (TxM) has been selected to support multiple **MediaTek** GSM/GPRS handset platforms based on MediaTek's MT6139 and Othello®-G transceivers. MediaTek is a provider of GSM/GPRS cellular platforms and accounts for the majority of GSM/GPRS handsets produced by handset manufacturers in China.

■ The US Air Force recently announced that it has selected **KOR Electronics** to design, build and deliver three of its latest generation Radio Frequency Target Generators (RFTG). Designed specifically to handle a broad spectrum of radar, RF and target generation applications, the RFTG designs will integrate highly sophisticated software and state-of-the-art microwave components to orchestrate solutions to overcome some of the most challenging problems in high fidelity RF signal generation.

■ **TriQuint Semiconductor**, an RF product manufacturer and foundry services provider, announced that it has fulfilled initial production orders from **Northrop Grumman Corp**. to support the F-35 Lightning II fire control radar system. The F-35, also referred to as the Joint Strike Fighter (JSF), is being developed by Lockheed Martin Corp. with primary partners Northrop Grumman and BAE Systems. The program is forecast to deliver several thousand aircraft by the mid-2030s.

FINANCIAL NEWS

■ **Exalt Communications**, a provider of high performance licensed and license-exempt microwave radio systems for wireless backhaul applications, announced that it has raised $15 M in Series C funding. InterWest Partners led the financing, joining existing investors Velocity Interactive Group and Trinity Ventures, who were full participants in the round, on the company's board of directors. Exalt will use the funds to accelerate international growth, expand marketing and sales to carriers, governments and enterprises, strengthen its presence in North America and continue expanding its product portfolio.

■ **Wavesat Inc.**, a supplier of broadband wireless semiconductor solutions, announced the company has secured its latest round of funding, raising $11.7 M CAD. Existing investors led by BDR Capital, BDC Capital and Multiple Capital participated in the round. Proceeds will be used to further strengthen the company's leadership position in the 4G Broadband market.

NEW MARKET ENTRIES

■ **RF Connections**, a woman owned small business, is a new concept in business representation and technical consulting. President and founder of RF Connections, Ruth Fawson, worked alongside some of the pioneers of the RF connector industry for more than 40 years and has extensive experience with RF connector and cable assembly design. Fawson represented her former company's interests at military and industry connector meetings and spearheaded QPL programs as project manager and design engineer. RF Connections offers manufacturer representation at key military accounts. Technical consulting includes creation and implementation of custom training modules, research reports applicable to the defense market and technical design services. RF Connections is also an independent woman owned, small business distributer of custom and difficult to find microwave product. For more information, visit www.rf-connections.com.

■ **DKN Research**, a research and engineering firm in Haverhill, MA, and **NY Industries**, a circuit board manufacturer in Ohtsu, Japan, launched a prototype and engineering service for Printable Electronics. The firms utilize state-of-the-art facilities and offer a broad range of experience with printing technologies for microelectronics and packaging. For more information, visit www.dknresearch.com.

PERSONNEL

■ **Yoichiro Kega** has been appointed president for ALPS Electric Europe GmbH. Based at the European headquarters in Düsseldorf, Germany, he will be responsible for further strategic developments and the successful implementation of the company's products in the European market. Kega has worked for ALPS for almost 25 years in different positions including European sales manager and domestic sales senior manager at the headquarters in Japan and as business planning manager at ALPS Peripheral Division.

▲ *Yoichiro Kega*

■ Crane Aerospace & Electronics, a segment of Crane Co., has announced the appointment of **Charles "Bud" Jewett** as business development director for the Electronics Group. Jewett will be responsible for strategic business relationships, partnerships and new business development. He will be based in Annapolis, MD. Prior to joining Crane, Jewett worked in business development with Harris Government Communications Systems where his focus included US Naval communications, data links and networking solutions. Jewett is a retired US Navy Captain with 30 years of experience as a Naval Flight Officer and a leader in acquisition and systems engineering at the Naval Air Systems Command.

▲ *Charles "Bud" Jewett*

■ Lark Engineering announced the appointment of **Paul Courville**, Design Engineering Operations, whose responsibilities include R&D, designing and implementing into production new multi-function microwave designs. Previously, Courville worked for REMEC Defense & Space, 147th Combat Communication Squadron and Cohu Electronics.

■ Sabritec, a custom connecting devices manufacturer, announced the addition of **Robert Fake** to its sales and marketing staff as western regional sales manager. Fake brings a great deal of insight and experience into the company's organization working for over 20 years in OEM sales and product marketing management primarily within the engineering interconnect industry. Most recently, Fake was the business development manager with a major military cable solution provider. His knowledge in a wide variety of connector products will provide the necessary support to all of the company's product lines in support of its rapidly growing business. Fake will be based out of Orange County, CA, and be focused on business development, market expansion, sales rep and major account management for the western region of the US.

▲ *Robert Fake*

REP APPOINTMENTS

■ **San-tron Inc.**, a manufacturer of RF coaxial connectors and cable assemblies, has announced the hiring of a new field sales representative to handle customer relationships in Istanbul, Turkey. **IMCA Elektronik** is a knowledge-based marketing company specializing in generating demand in the electronic components and semiconductors industry. Located in Istanbul, Turkey, IMCA will be servicing accounts for customers throughout the country. They can be reached by phone at +90 212 483 39 12, e-mail info@imca.com.tr, or on the web at www.imca.com.tr.

■ **Modelithics Inc.** announced that **ICON Design Automation Pvt. Ltd.** will be the company's representative in India. Modelithics and ICON Design Automation have signed a comprehensive agreement designed to support India's market for high accuracy RF and microwave simulation models and characterization services.

■ **Mouser Electronics Inc.** announced it reached a worldwide distribution agreement with **Vectron International**, an industry leader in precision frequency control products. Mouser's stock includes Vectron's crystal oscillators and surface acoustic wave (SAW) products.

■ **XMA** welcomes **NW Sales LP** as the company's manufacturer representative for the TX, AR, OK, LA territory. Established in 1972, NW Sales is a well-respected manufacturers' representative firm serving the leading OEMs in the commercial, defense and petrochemical markets in the four-state territory of Texas, Oklahoma, Louisiana and Arkansas.

A CUSTOM III-V HETEROJUNCTION BIPOLAR TRANSISTOR MODEL

Communication systems today comprise the major use of GaAs technology with the highest volumes found in the cellular handset front-end. Here, heterojunction bipolar transistor (HBT) power amplifiers (PA) and Pseudomorphic High Electron Mobility Transistor (PHEMT) switches enjoy a comfortable market share. In this environment, the demands of production design require a robust CAD system with accurate and verified compact models for both active and passive devices. In this paper, we will outline some of the work done at RFMD® to develop and support scalable HBT models suitable for handset power amplifier design.

In the first section, a brief outline is given of the evolution of a custom HBT model from a basic Gummel-Poon formulation to one encompassing more GaAs physics. It is written in Verilog-A and and runs in multiple environments. In the second section, a model of a single device is shown that can be scaled to simulate the behavior of large output arrays. This will include both electrical and thermal aspects. Finally, we will present validation data to illustrate the performance of the model.

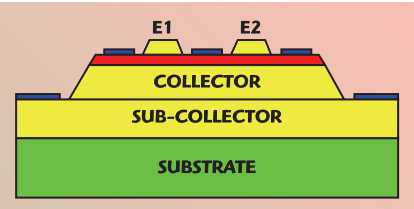


Fig. 1 Cross-section of two-finger HBT (not to scale).

A cross-section of a simple two-finger HBT is shown in ***Figure 1***. In these devices, the emitter is made of a wider bandgap material such as AlGaAs or InGaP while the base has a narrower bandgap, typically GaAs. In a single-heterojunction device, the base, collector and sub-collector will all be of the same material, while in a double-heterojunction bipolar transistor (DHBT) the collector will use a wider material. The energy band diagram for the more general DHBT is shown in ***Figure 2***. In these systems, the potential barrier seen by base holes in the valence band is higher than that seen by emitter electrons in the conduction band. This results in higher emitter injection efficiency, leading to higher gain. In a conventional homojunction bipolar junction transistor (BJT), high injection efficiency requires a highly doped emitter and a thicker, lower doped base, increasing the base resistance and base transit time. The theory behind this dates back to the early days of the transistor.[1]

SONJA R. NEDELJKOVIC, JOHN R. MCMACKEN, PAUL J. PARTYKA AND JOSEPH M. GERING
RFMD, Greensboro, NC

THE HBT MODEL

DC Operation

The large-signal equivalent circuit used in the model is shown in ***Figure 3***. In typical fashion, we divide the device into intrinsic and extrinsic sections. To characterize the DC behavior, we need to develop expressions for the emitter-collector transport current (I_{CE}) and the two base diodes that create it (I_{BE}, I_{BCi}). We begin with the Gummel-Poon formulation for the forward current[2] (due to injection across the base-emitter junction).

$$I_{CF} = \frac{I_{SF}}{q_B}\left[e^{\frac{V_{BE}}{N_F V_T}} - 1\right] \tag{1}$$

Here, q_B is the hole charge in the base normalized to its equilibrium value (i.e., $q_B = Q_B/Q_{B0}$.) Thus, at zero bias q_B=1. Similarly, the reverse transport current is written as

$$I_{CR} = \frac{I_{SR}}{q_B}\left[e^{\frac{V_{BC}}{N_R V_T}} - 1\right] \tag{2}$$

and the total current is simply the difference between the two: $I_{CE}=I_{CF}-I_{CR}$. Note that we have used separate saturation currents (I_{SF}, I_{SR}) and ideality factors (N_F, N_R) for forward and reverse operation. In conventional silicon homojunction devices this is not necessary since the reciprocity principle ensures that both currents are equal for equal bias. In HBTs, however, the presence of conduction band spikes at the junctions can give rise to additional transport mechanisms such as thermionic emission and tunneling. If these are significant, we need the flexibility of the additional parameters. To illustrate this, consider the forward and reverse Gummel plot for a single-heterojunction AlGaAs/GaAs device, as shown in ***Figure 4 (a)***. In this technology, the emitter/base interface was graded to minimize the conduction band spike. The slope and intercept of the "ideal" part of the current is the same and could be modeled using one I_S and N. ***Figure 4 (b)***, on the other hand, shows the same measurements for an InP DHBT. With conduction band spikes at both the emitter-base and base-collector junctions, the additional parameters are necessary.

Similar flexibility is required in modeling the base current. The DC current gain of an HBT is nonlinear and cannot be written as the transport current divided by some beta parameter. Consider the plots of DC beta (forward and reverse) versus current shown in ***Figures 5 (a)*** and ***(b)***. Not only is there a large variation in gain, but the forward and reverse beta differs by two orders of magnitude. Thus, we use separate saturation currents and ideality factors for both ideal and leakage components:

$$I_{BE} = I_{SH}\left[e^{\frac{V_{BE}}{N_H V_T}} - 1\right] + I_{SE}\left[e^{\frac{V_{BE}}{N_E V_T}} - 1\right] \tag{3}$$

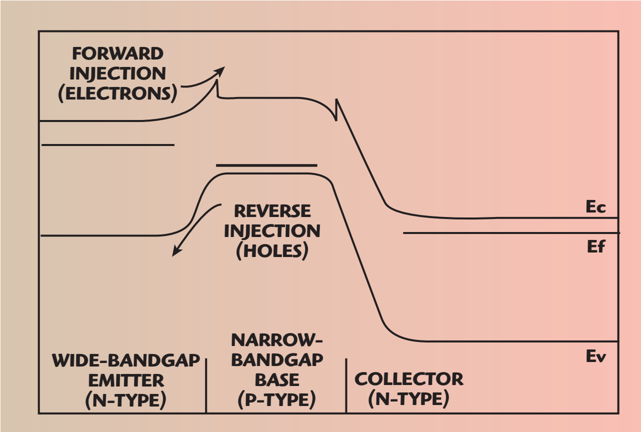


Fig. 2 Energy band diagram of a HBT.

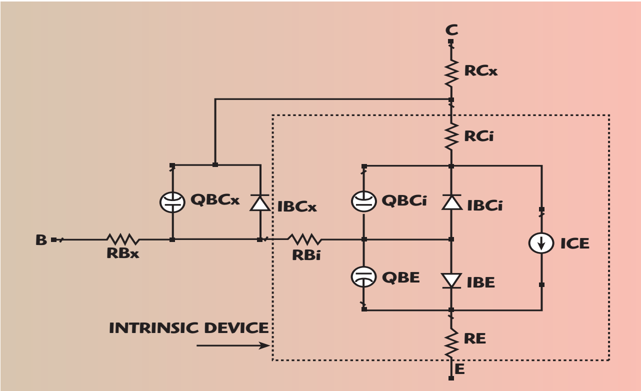


Fig. 3 Large-signal equivalent circuit for RFMD HBT model.

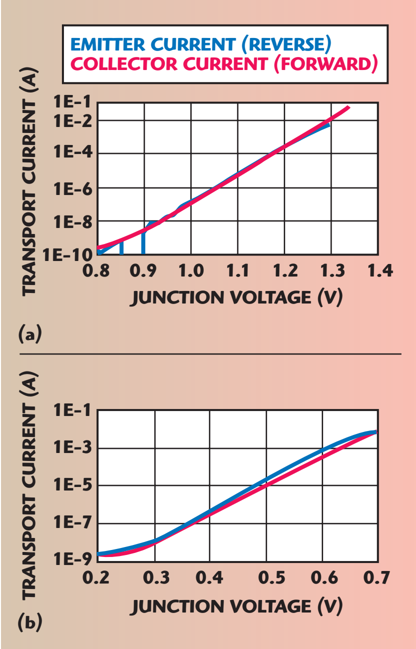


Fig. 4 Forward and reverse collector-emitter current for a graded AlGaAs/GaAs single heterojunction (a) and an InP double heterojunction (b) transistor.

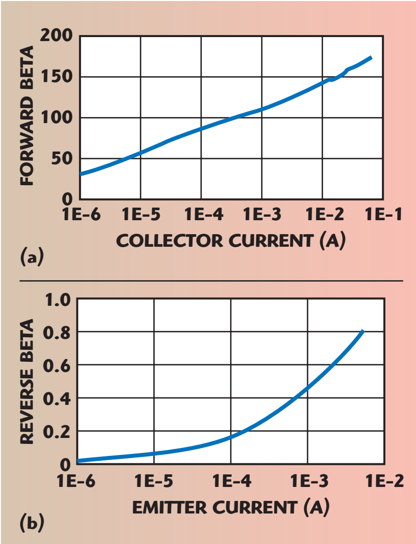


Fig. 5 Forward beta-IC/IB (a) and reverse beta-IE/IB (b) for an AlGaAs HBT.

$$I_{BC} = I_{SRH}\left[e^{\frac{V_{BC}}{N_{RH}V_T}} - 1\right] + I_{SC}\left[e^{\frac{V_{BC}}{N_C V_T}} - 1\right] \qquad (4)$$

Next we consider the normalized hole charge q_B. In the standard Gummel-Poon method, two effects are normally considered that will change the hole charge from its equilibrium value. The first is the Early effect[3] in which the width of the un-depleted base changes with bias (Equation 6). The second is the high-current Kirk effect[4] in which the base region can push out into the collector (Equation 7). The two effects are combined into Equation 5.

$$q_B = \frac{q_1}{2} + \sqrt{\frac{q_1^2}{4} + q_2} \qquad (5)$$

where

$$q_1 = 1 + \frac{V_{BE}}{V_R} + \frac{V_{BC}}{V_F}, \text{ and}$$

$$q_2 = \frac{I_S}{I_{KF}}\left[e^{\frac{V_{BE}}{V_T}} - 1\right] + \frac{I_S}{I_{KR}}\left[e^{\frac{V_{BC}}{V_T}} - 1\right] \qquad (6)$$

In HBTs with their highly-doped bases, the Early effect is not significant but we have left the parameters in mainly for nostalgia. There are, however, a variety of high-current effects. Using this formulation, the high current limit of I_{CE} tends to

$$I_{CE} \approx \sqrt{I_S I_{KF}}\; e^{\frac{V_{BE}}{2V_T}} \qquad (7)$$

(i.e., a fixed ideality factor of 2.0). For HBTs we need more flexibility and thus we add an additional expression to q_B, similar to the one used in the Agilent HBT model.[5]

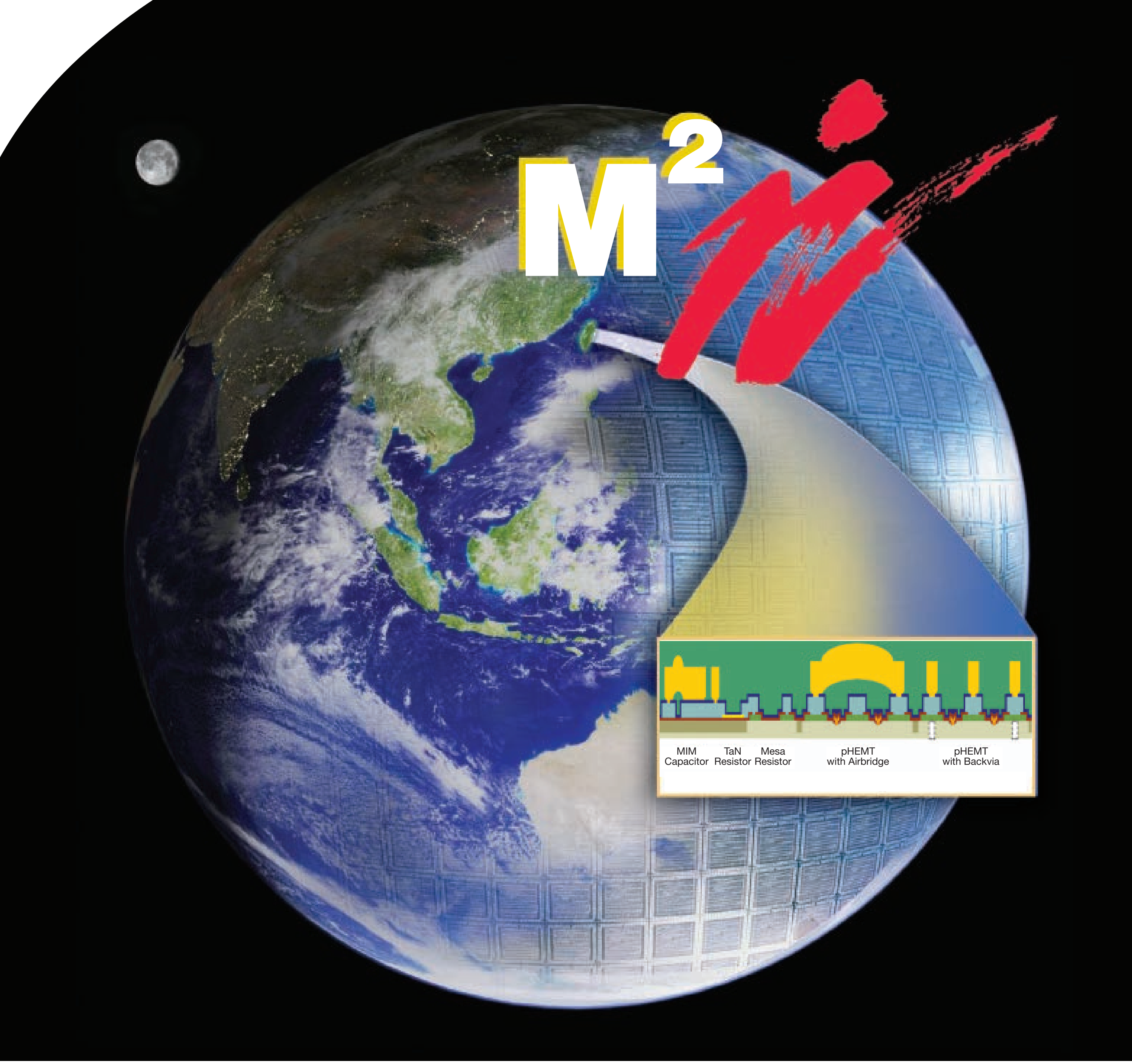
$$q_B = \frac{q_1}{2} + \sqrt{\frac{q_1^2}{4} + q_2} + \frac{I_S}{I_{SA}} e^{\frac{V_{BE}}{N_A V_T}} + \frac{I_S}{I_{SB}} e^{\frac{V_{BC}}{N_B V_T}} \qquad (8)$$

TEMPERATURE MODELING

The most common approach to temperature modeling is to make some subset of the parameters functions of either a ratio or difference of the junction temperature to some reference temperature, e.g., $X(T)=f(T/T_{NOM})$ or $X(T)=f(T-T_{NOM})$. Some can be physics-based while others are purely phenomenological expressions. For example, the variation of saturation current is usually modeled as

$$I_s(T) = I_S(T_{nom})\left(\frac{T}{T_{nom}}\right)^{XTI} e^{\left[\frac{E_g(T_{nom})}{kT_{nom}} - \frac{E_g(T)}{kT}\right]} \qquad (9)$$

This equation can be derived from the power law temperature variation of the conduction and valence band effective density of states. In contrast, the ideality factors are written simply as


M2
MIM
Capacitor
TaN
Resistor
Mesa
Resistor
pHEMT
with Airbridge
pHEMT
with Backvia

$$N_X(T) = N_X + TN_X(T - T_{NOM}) \tag{10}$$

And parasitic resistances is written as

$$R_X(T) = R_X\left(\frac{T}{T_{NOM}}\right)^{TR_X} \tag{11}$$

CHARGE EXPRESSIONS – Q_{BE}

All capacitances in our model are written as charge expressions and implemented using the Verilog-A ddt() operator. The base-emitter junction has three terms associated with it: The depletion region junction capacitance, a diffusion capacitance associated with the base transit time and a charge to account for the high-current Kirk effect.

The junction capacitance is modeled using the usual expression

$$C_{BE} = \frac{C_{BEO}}{(1 - V_{BE}/V_{JBE})^{M_{JBE}}} \tag{12}$$

where the corresponding charge is just the integral over voltage.

$$Q_{JBE} = C_{BE0}\frac{V_{JBE} - V_{BE}}{(m-1)\left[1 - V_{BE}/V_{JBE}\right]^{M_{JBE}}} \tag{13}$$

The narrow, highly doped base of an HBT allows us to model the diffusion charge simply as a constant transit time multiplied by the forward transport current:

$$Q_B = T_B \cdot I_{CF} \tag{14}$$

Finally, the Kirk effect is modeling using a power-law-based transit time

$$Q_{TK} = T_{TK}\left[\frac{I_{CF}}{I_{TK}}\right]^{G_{TK}} I_{CF} \tag{15}$$

The resulting base-emitter charge term is simply the sum of all three effects

$$Q_{BE} = Q_{JBE} + Q_B + Q_{TK} \tag{16}$$

CHARGE EXPRESSIONS – Q_{BC}

In the base-collection junction, the reverse-bias depletion capacitance is limited by the width of the collector, as the depletion region width will not change significantly once it reaches the sub-collector. To account for this effect, Equation 12 needs to be modified in some way. In our work, we have adopted the approach used in HICUM Level 0, as it is simple to implement and simple to extract.[6]

The time constant associated with the collector delay has a forward current dependence that is modeled with a hyperbolic tangent function after Iwamoto[7]

$$T_f = \frac{1}{2}TFC0\left(1 + \tanh\left(\frac{ITC\left(1 - \frac{V_{BC}}{VTC}\right) - Icf}{ITC2\left(1 - \frac{V_{BC}}{VTC2}\right)}\right)\right) \tag{17}$$

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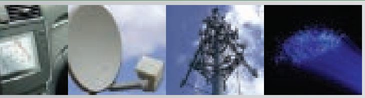

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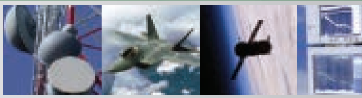

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- ♦ +29.5 dBm OIP3
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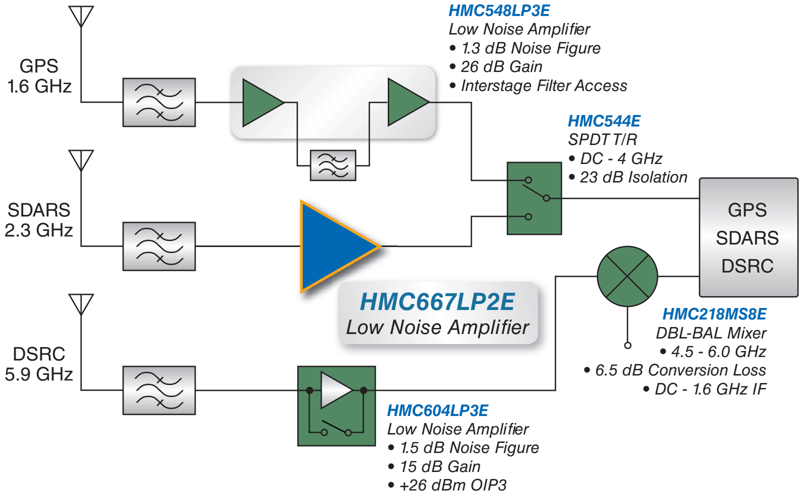

A Selection of In-Stock LNAs Including 4 New Products

	Frequency (GHz)	Function	Gain (dB)	OIP3 (dBm)	NF (dB)	P1dB (dBm)	Bias Supply	Package	Part Number
	0.05 - 0.96	Low Noise, 75 Ohm	14	39	2.2	19	+5V @ 120 mA	ST89	**HMC599ST89E**
	0.175 - 0.66	Low Noise	24	37	0.5	19	+5V @ 90mA	LP3	**HMC616LP3E**
NEW!	0.175 - 0.66	Low Noise, Dual Channel	24	37	0.5	19	+5V @ 93mA	LP4	**HMC816LP4E**
	0.2 - 4.0	Low Noise, High IP3	13	38	2.3	22	+5V @ 110mA	ST89	**HMC639ST89E**
	0.2 - 4.0	Low Noise, High IP3	13	40	2.2	22	+5V @ 155mA	ST89	**HMC636ST89E**
	0.35 - 0.55	Low Noise	17	38	1	21	+5V @ 104mA	LP3	**HMC356LP3E**
	0.55 - 1.2	Low Noise	16	37	0.5	21	+5V @ 88mA	LP3	**HMC617LP3E**
NEW!	0.55 - 1.2	Low Noise, Dual Channel	16	37	0.5	21	+5V @ 88mA	LP4	**HMC817LP4E**
	0.7 - 1.2	Low Noise, Failsafe Bypass	16	33	0.9	13	+5V @ 57mA	LP3	**HMC668LP3E**
NEW!	0.7 - 2.2	Low Noise	22	36	1.7	24	+5V @ 227mA	LP3	**HMC758LP3E**
	1.7 - 2.2	Low Noise, Failsafe Bypass	17	29	1.4	12	+5V @ 86mA	LP3	**HMC669LP3E**
	1.7 - 2.2	Low Noise	19	36	0.75	20	+5V @ 117mA	LP3	**HMC618LP3E**
NEW!	2.1 - 2.9	Low Noise	19	33	0.9	19	+5V @ 95mA	LP3	**HMC715LP3E**
	2.3 - 2.7	Low Noise	19	29.5	0.75	16.5	+5V @ 59mA	LP2	**HMC667LP2E**
	2.3 - 2.7	Low Noise w/ Bypass	20	31	1.1	17	+5V @ 74mA	LP3	**HMC605LP3E**
NEW!	3.1 - 3.9	Low Noise	18	33	1	19	+5V @ 65mA	LP3	**HMC716LP3E**
	3.3 - 3.8	Low Noise w/ Bypass	19	29	1.2	16	+5V @ 40mA	LP3	**HMC593LP3E**
	4.8 - 6.0	Low Noise w/ Bypass	15	26	1.5	14	+5V @ 42mA	LP3	**HMC604LP3E**
NEW!	4.8 - 6.0	Low Noise	16.5	31.5	1.1	18.5	+5V @ 73mA	LP3	**HMC717LP3E**

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A base diffusion capacitance is also incorporated due to the reverse transport current and writes the base-collector charge as a sum of these terms:

$$Q_{BC} = Q_{JBC} + T_f I_{CF} + T_r I_{CR} \tag{18}$$

HBT SELF-HEATING

HBTs used in PA applications are run at relatively high power densities. Thus, the Joule heating in the device can lead to a significant temperature rise. This is illustrated in ***Figure 6***. The DC beta of an AlGaAs/GaAs device decreases at higher temperatures, and this drop can be seen in the forward IV curve, especially in the regions where power dissipation is high. We model this effect in the most common way, which is to approximate the various thermal time constants in the structure by a two-pole lumped element circuit driven by a current source. The value of the current is set equal to the power dissipated in the device (usually dominated by the drop across the base-collector junction). The voltage developed across the current source is equal to the device temperature rise that is fed back into the temperature model to solve for the device current in a consistent manner until the electrical simulation converges. We provide external pins for both sides of the thermal circuit. The "bottom" pin can be connected to an external thermal network that represents a package while the upper node can be attached to another network to simulate thermal coupling. The resulting five-terminal equivalent circuit is shown in ***Figure 7***. In the thermal network of Figure 7, C_{th}, R_{th2} and C_{th2} are constant parameters of the model, while the R_{th} element is temperature dependent.

In early works, the thermal resistance of an HBT

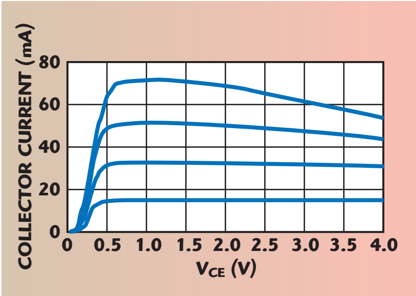

Fig. 6 Forward I-V measurement of an AlGaAs/GaAs HBT showing the effects of self-heating.

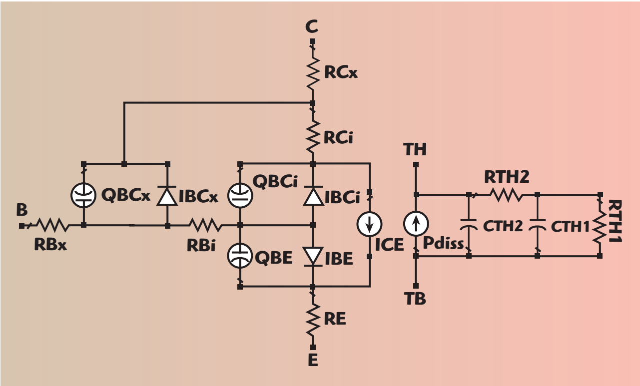

Fig. 7 Five-terminal large-signal equivalent circuit incorporating two-pole self-heating.

was constant and most commonly extracted with Dawson's procedure.[10] Yeats[11] provided a more rigorous expression for thermal resistance as a function of ambient temperature and dissipated power. This approach is necessary to account for the temperature-dependant thermal conductivity of GaAs; however, there was a concern over potential numerical issues as Yeats' parameter n is close to 1, and (n-1) is in a denominator. Yeats' parameter n comes from the expression for the temperature dependence of thermal conductivity.

$$\kappa(T) = \kappa_{300K}\left(\frac{300K}{T}\right)^n \tag{19}$$

Since n is typically close to 1, this implies that the thermal resistively is approximately linear in temperature. Therefore, we adopted a linear-temperature dependence in the expression for thermal resistance.

$$R_{th} = R_{th0} + R_{th1}(T_j - T_{nom}) + R_{th1}(T_{base} - T_{nom}) \tag{20}$$

The model parameters are R_{th0} and R_{th1}; T_j, T_{base} and T_{nom} are the junction, device-base and nominal-model temperatures, respectively. The formula in Equation 20 makes the thermal resistance in effect dependent on the thermal gradient from the junction to the base of the transistor (node TB in Figure 7). It is worth noting that we investigated separate parameters for the T_j and T_{base} contributions in Equation 20, but found that it had no practical benefit.

Akin to the approaches in References 10 and 11, the thermal resistance parameters are determined by fitting the base-emitter voltage versus dissipated power at a constant emitter current, Equation 20 coupled with the following:

$$V_{be} = V_{b0} + V_{b1}(T_j - T_{nom}) \tag{21}$$

$$T_j = T_{base} + R_{th}P_{diss} \tag{22}$$

Figure 8 shows the fit of the thermal resistance model to measurements on a standard transistor cell. This same data set was fitted to Yeats' thermal resistance equation in Reference 11. ***Figure 9*** compares the thermal resistance of our model to that of Yeats' formula versus junction temperature with a 25°C base temperature. The agreement is quite good over the junction temperature range expected in normal operation (in this case less than 100°C) and shows that the simplification of the model provides sufficient accuracy while avoiding potential stability or convergence problems. Lastly, it should be noted that some other models do have temperature-dependent thermal resistances.[8,9] Unfortunately, these models only take into account the junction temperature, thus ignoring the effect of any thermal gradient in the device substrate.

Returning to the four elements of the thermal circuit (R_{th2}, C_{th2}, R_{th} and C_{th}), typically R_{th2} and C_{th2} are set to small, negligible values. R_{th} and C_{th} are extracted based on the methods presented in References 10 and 12 and the discussion of the previous paragraph. The thermal resistance extraction methods assume that if a constant emitter current (high enough to observe significant power dissipation) is forced through the device then the variation in base-emitter voltage is only due to the variation in junction temperature. Measurements are conducted over a wide range of temperatures to account for the temperature dependence of thermal resistance. The thermal capacitance is extracted from pulsed I-V measurements using the normalized difference unit (NDU) method.[12] The method is based on the comparison of pulsed I-V measurements of different pulse lengths to static I-V measurements. The thermal time constant is defined as the time after a step in P_{diss} when 63.2 percent of the resulting change in the junction temperature has occurred. From the NDU versus pulse length plot, the thermal time constant (tau) is extracted (see ***Figure 10***) and the thermal capacitance is calculated as

$$C_{th} = tau / R_{th} \tag{23}$$

Unlike the thermal resistance, the thermal capacitance is assumed to be temperature independent.

Single Cell Model Validation

Once extracted, a transistor model should be validated in multiple ways. Our HBT model is fully checked against DC measurements and S-parameter measurements over a wide range of biases and temperatures. This verifies that the model plays back the types of measurements used in the model extraction. Once the extracted model shows good agreement with this first-step validation, a second level of validation is performed with on-wafer large-signal measurements such as 50 Ω power sweeps,[13] source/load-pull measurements and waveform measurements.

The 50 Ω power sweep is performed with a commercial vector network analyzer (VNA), which is calibrated to measure vector S_{11} and S_{21} as well as the power at second and

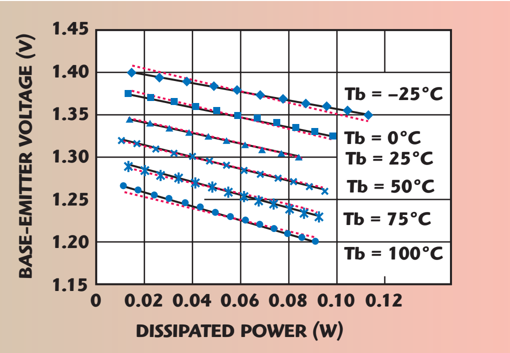

Fig. 8 Measured (symbols), modeled per this article (solid lines) and modeled with constant thermal resistance value (dashed lines) base-emitter voltage vs. dissipated power for a single-cell HBT (32 mA).

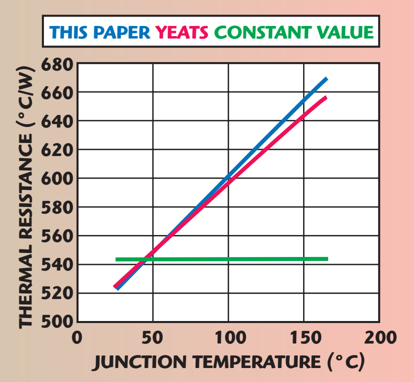

Fig. 9 Calculated thermal resistance vs. junction temperature for various models.

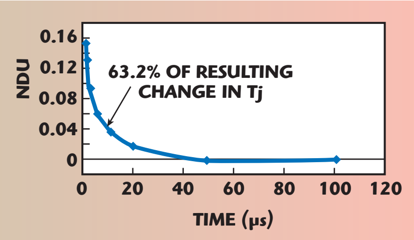

Fig. 10 Extraction of the thermal time constant from the NDU vs. pulse length.

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XC0900P-03	0.80–1.0	25
XC0900E-03	0.80–1.0	75
XC0900A-03	0.811–1.0	225
XC0900L-03	0.8–1.0	225
XC1400P-03S	1.2–1.6	30
C1720J5003A00*	1.7–2.0	4
1P503	1.7–2.0	30
XC1900E-03	1.7–2.0	120
XC1900A-03	1.7–2.0	225

Part Number	Frequency (GHz)	Power (W)
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JP503	2.0–2.3	25
XC2100E-03	2.0–2.3	100
XC2100A-03	2.0–2.3	145
C2327J5003A00*	2.3–2.7	4
1P603	2.3–2.7	25
XC2500E-03	2.3–2.7	80
XC2500A-03	2.3–2.7	150
C3337J5003A00*	3.3–3.7	4
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third harmonics. Measurements in the 50 Ω power sweep setup are done over bias and temperature. Even though the load-line for this measurement is 50 Ω, through a combination of biases and power levels, the device is effectively exercised over its full I-V plane. Since this measurement can be easily integrated into the same measurement stand that performs on-wafer, DC and S-parameter measurements, it is a valuable first-step in large-signal validation. ***Figures 11 (a)*** and ***(b)*** show a comparison of the measured and simulated output power at the fundamental, second harmonic and third harmonic from 50 Ω power sweeps at a Class A and Class AB bias point, respectively. Because of the flexibility to cover multiple test conditions with the 50 Ω power sweep, we have devised a metric (discussed in Reference 13) that gauges the relative error between the simulation and the measurement. This metric has been very helpful in judging the improvements in the model as it evolved to its present form.

Waveform measurements are also performed on-wafer at ambient temperature, and for this measurement we use a commercial large-signal network analyzer (LSNA). The spectral components of the base and collector voltages and currents are measured at the transistor reference plane, and the time domain waveforms are calculated. The system is configured to vary bias and RF drive power as well as the input and output impedances using mechanical tuners. ***Figures 12 (a)*** and ***(b)*** show the base and collector waveforms at a Class AB bias point for nominal 50 Ω source and load terminations.

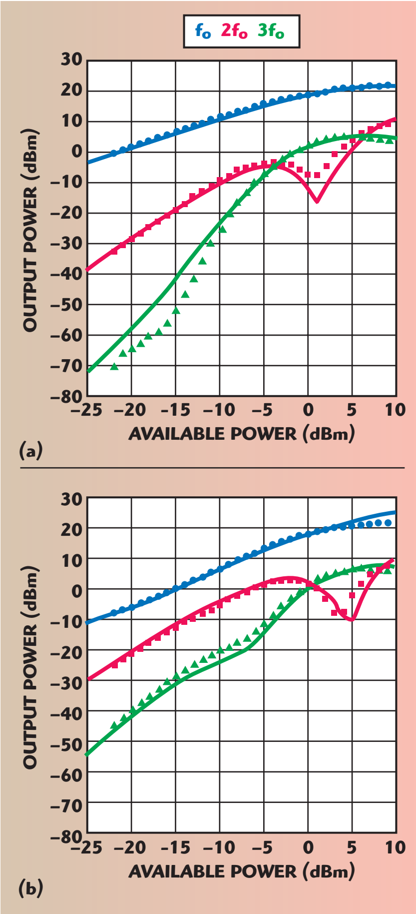

Fig. 11 Measured (symbols) and simulated (solid lines) output powers at f_0, $2f_0$ and $3f_0$ from a 50 Ω power sweep on a single HBT at V_c = 3.5 V and I_{cq} = 20 mA (a) and I_{cq} = 2 mA (b).

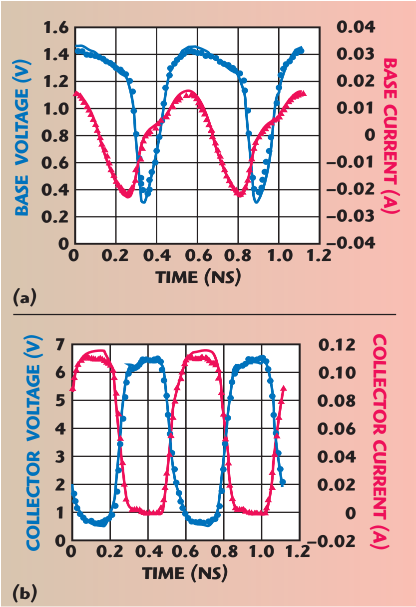

Fig. 12 Measured (symbols) and simulated (solid line) base (a) and collector (b) voltage and current waveforms with nominal 50 Ω loading (V_c = 3.5 V, I_{cq} = 2 mA and P_{avs} = 5 dBm).

MULTI-CELL ARRAY MODELING

In PA applications, scaling the model from a single device to large arrays is necessary. Using a simple multiplication factor is not sufficient, as the parasitic interconnect and thermal behavior of an array will be quite different from the single cell transistor used to extract the model.

Our approach for multi-cell array modeling involves a combination of EM simulations of the interconnect manifolds and scaling of the thermal impedances[14] to account for the increase in operating temperature due to the proximity of devices in the array. While the manifold modeling is handled using EM simulation,[14] thermal modeling of the arrays is implemented in two different ways:

- Deriving a custom thermal impedance scaling equation in the Verilog-A code that is capable of predicting the average junction temperature for various array layouts, and
- Adding thermal coupling networks between the thermal nodes (utilizing the TH and TB pins of Figure 5 (b)) of neighboring devices without altering the internal thermal resistance.

A custom thermal scaling equation or a thermal coupling network can be generated in many different ways;[15-20] for example, by using a finite-difference numerical thermal simulation,[21,22] by using a 3-D finite-element steady-state thermal solver[23,24] or by optimizing to achieve a best fit with measured data (I-V curves).[15,17]

For the first approach where it is necessary to derive a thermal scaling equation that provides an average temperature for a variety of layouts, we started from electrical measurements extracting effective, average thermal resistances for arrays with different numbers of cells and cell-to-cell separations. The equation consists of the thermal resistance of a single cell and a correction function to account for the number of cells and the cell-to-cell separation.

$$Rth\_cell = Rth\_nom * f(N, y) \quad (24)$$

Rth_nom is the thermal resistance of a single cell device, N is the number of cells and y is the device pitch. The function, $f(N,y)$, simply modifies the thermal resistance function of an isolated device, scaling it by an array-specific factor. The unit-cell thermal resistance in Equation 24 is already temperature-dependent and is separately scalable with respect to within-cell geometry. The function, $f(N,y)$, is derived empirically for arrays of selected unit cells by curve-fitting to the measured DC data until the best fit to the overall array I-V characteristics is achieved. The thermal scaling equation is then validated against TCAD simulations at low- and medium-power dissipations (see ***Figure 13***).

To extend the scaling equation to arrays of a larger variety of unit cells, TCAD simulations were employed. TCAD simulations of array temperatures provide a low-cost, efficient

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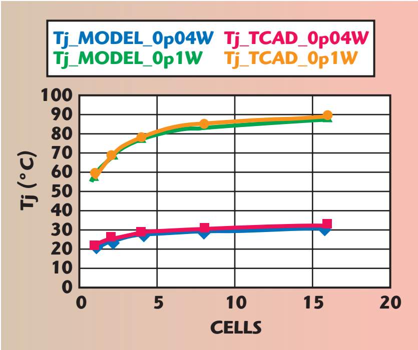
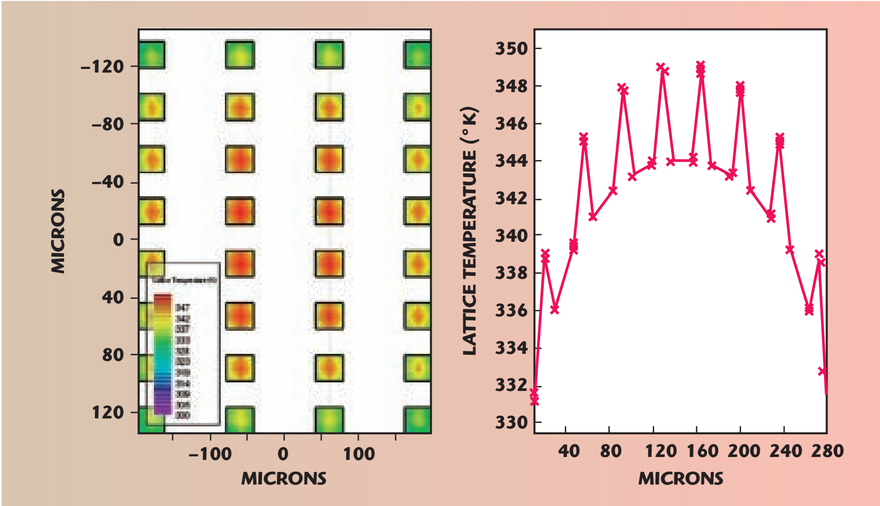


▲ *Fig. 13 Comparison of modeled and TCAD-simulated Tj as a function of cell number (P_{diss} = 0.04 and 0.1 w/cell).*



▲ *Fig. 14 Layout generated TCAD with temperature imbalance in an array.*

alternative to generating data from electrical measurements on real arrays. After the initial calibration of the simulation to measured results, TCAD is used to generate a large set of thermal data from which we derive the scaling function for each unit cell type. Because the TCAD input decks are typically text files, it is straightforward to write a script that automatically generates input decks for arbitrary arrays of unit-cell power sources arranged in a regular grid. This automated deck generation along with the short TCAD simulation times allowed for the efficient creation of large sets of thermal data (see ***Figure 14***).

In this first implementation of Rth modification for arrays, the array is represented as a collection of identical parallel HBTs where each device has an "average" thermal resistance that yields the effective array temperature at a given power dissipation. Thus, there is no temperature or electrical variation from cell to cell within the array. Instead, each device has a modified thermal resistance that effectively increases the device temperature at a given P_{diss} compared to an isolated device running at the same P_{diss}. Since this approach provides an average junction temperature, it cannot be used to analyze the "hot spots" in the array caused by any thermal imbalance. Although this approach does not provide information about the temperature distribution in the array, in many cases it is desirable to use this simplification as it results in shorter simulation times and improved robustness due to fewer electrical nodes without impacting simulation accuracy.

The second approach for the thermal modeling of multi-cell arrays is based on creating a network of thermal resistances connecting adjacent devices. This allows devices within an array to have distinct temperatures, thus giving a more accurate prediction of the temperature distribution in the array at the expense of simulation time and complexity. Thermal resistors are used to connect the thermal nodes of the five-terminal model for adjacent devices, as shown in ***Figure 15***. The heat paths represented by the resistive network are shown in ***Figure 16***.

In our approach, we adopt a simplified pi-network where the resistances are extracted using a test structure,

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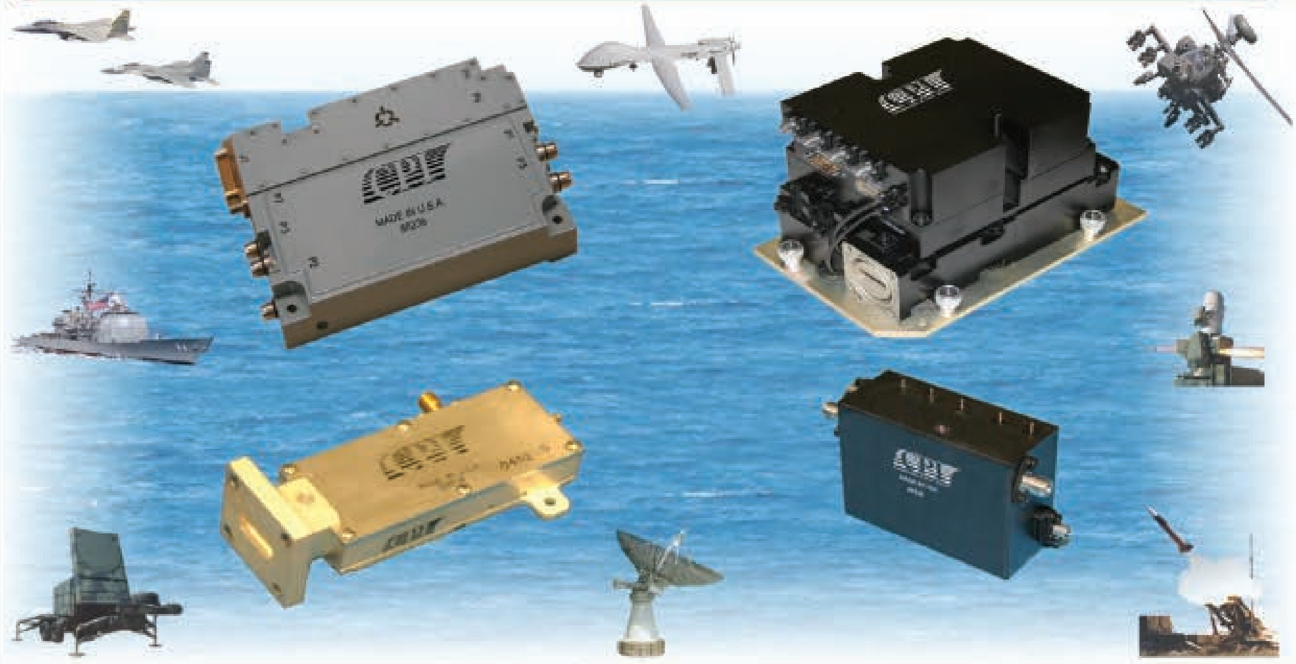

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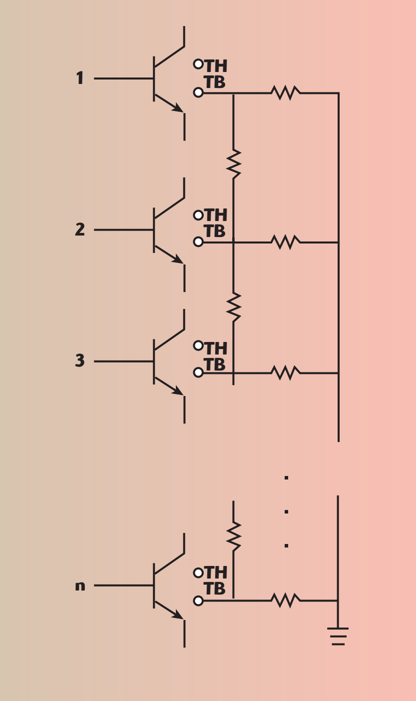
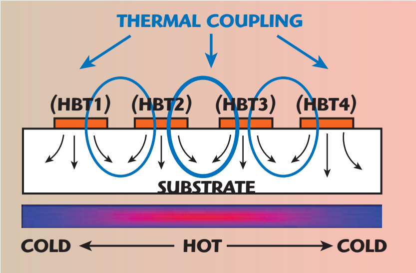
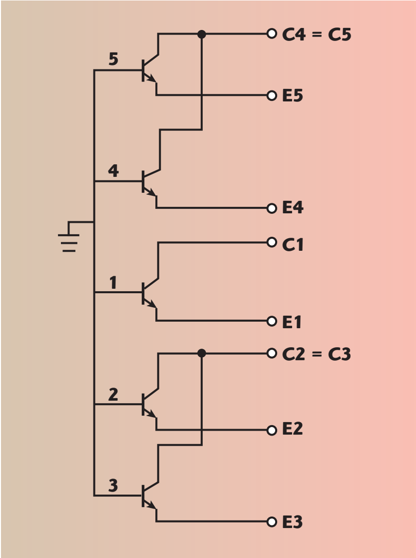


▲ *Fig. 15 Thermal coupling network to account for thermal imbalance in an array.*



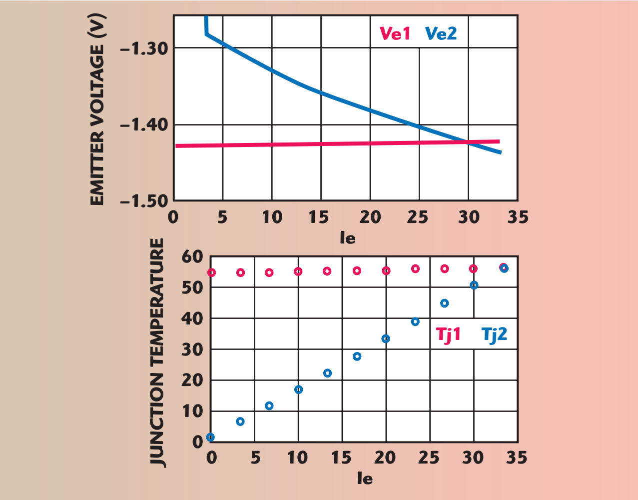
▲ *Fig. 16 Heat dissipation in multi-cell device.*



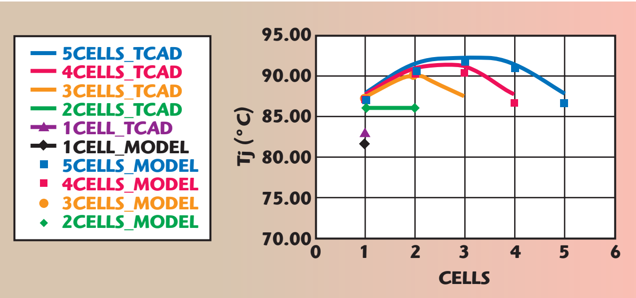
▲ *Fig. 17 Test structure used to evaluate neighbor heating for the thermal coupling network.*

as shown in ***Figure 17***. The values of the thermal resistors used to connect adjacent devices can be derived from electrical measurements that represent a change in an individual device's temperature as its neighbor devices are individually powered on (see ***Figure 18***). This is again based on the Vbe thermometer method, inferring a temperature rise in a given device as a neighbor heats it from the change in V_{be} needed to produce a constant emitter current. Test data shows that the temperature rise due to thermal coupling is proportional to the power dissipated in the neighboring transistors and depends on the proximity of the neighbor transistors with the device under test. Results were validated by comparing the electrical simulation of a two-cell through five-cell array with thermal coupling networks to TCAD simulation (see ***Figure 19***). Utilizing the results from this test, we were able to generate thermal coupling networks for larger arrays using the principle of superposition, where the thermal resistors are calculated from a device's temperature rise attributed to power dissipated by its nearest neighbors. The approach was tested for a variety of device spacing, array configurations and cell numbers. It is important to note that the thermal coupling networks are extracted from measurements done at room temperature, relying on the fact that intrinsic thermal resistance is temperature-dependent. If higher accuracy is desired over a wide temperature range, it would be necessary to assign temperature-dependence to the elements in the thermal network.

For the full validation of a multi-cell array model, we consider a more practical example, a typical 32-cell array. While either approach for the thermal modeling can be used, the first approach described above has been used for this example. The results are shown in ***Figures 20*** and ***21***, where the measured data is marked by circles with the simulation by a solid line. ***Figure 21 (a)*** and ***(b)*** indicate a reasonable match to Γ_{IN} with the power gain within 0.7 dB over 6 dB

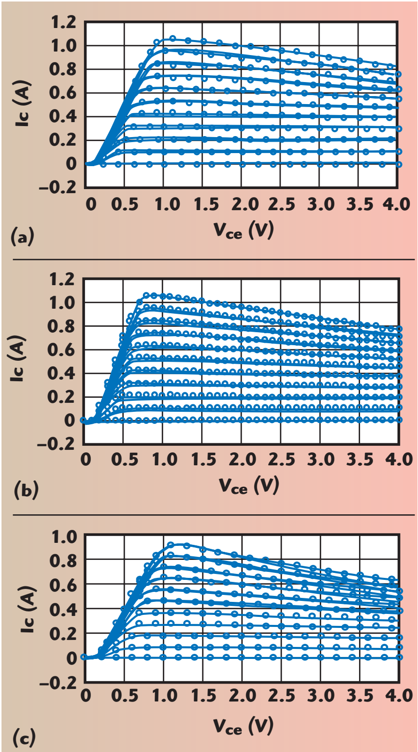


▲ *Fig. 18 Modeled (symbols) and measured (solid lines) emitter voltage and junction temperature of a two-cell device (device 1 is turned on while device 2 emitter current is swept).*



▲ *Fig. 19 TCAD (lines) and model (symbols) simulations of Tj (P_{diss} = 0.1 w/cell, T_{amb} = 25°C).*

into compression. ***Figure 21 (c)*** shows the power added efficiency (PAE) with less than 5 percent error. Finally, the measured versus simulated dynamic load line is shown in ***Figure 21 (d)***.



▲ *Fig. 20 I-V curves for large arrays generated using a principal of superposition at –25°C (a), 25°C (b) and 85°C (c).*

CONCLUSION

We have discussed the salient features of a custom III-V HBT model and its scaling for cellular PA applications. While this custom model is similar in basic accuracy at the unit-cell level to some commercially available models, we have found the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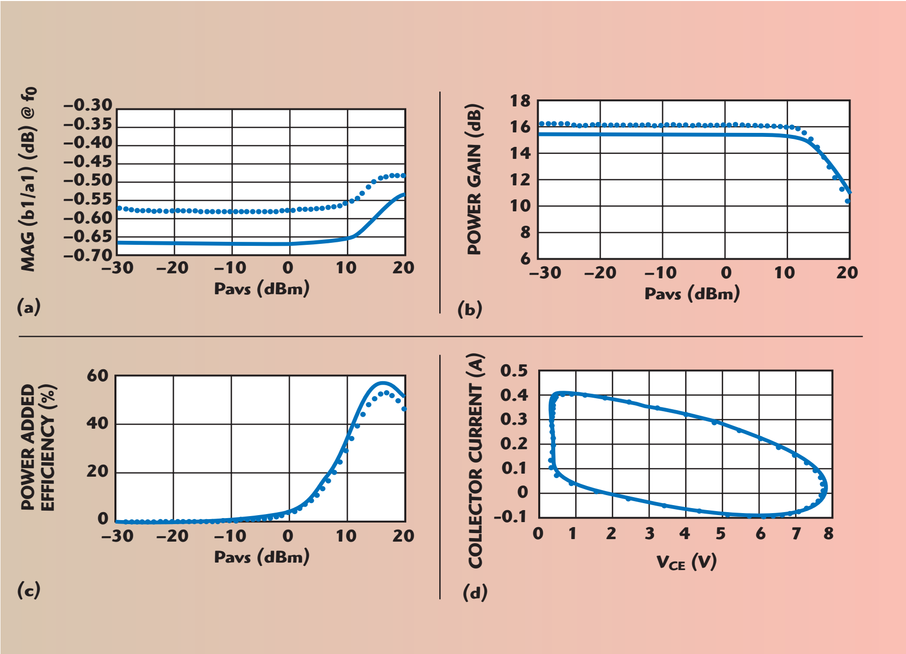

Fig. 21 Thirty-two-cell model validation: Input Gamma vs. available power (a), power gain vs. available power (b), PAE vs. available power (c) and dynamic load line (d).

flexibility to tailor a custom model to an application space beneficial to scaling the model to multi-cell arrays used in product designs without degrading array-level accuracy or simulation time.

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References

1. H. Kroemer, "Theory of a Wide-gap Emitter for Transistors," *Proceedings of the IRE*, Vol. 45, No. 11, 1957, pp. 1535-1537.
2. H.K. Gummel and H.C. Poon, "An Integral Charge Control Model of Bipolar Transistors," *Bell System Technical Journal*, Vol. 49, 1970, p. 827.
3. J.M Early, "Effects of Space-charge Layer Widening in Junction Transistors," *Proceedings of the IRE*, v40, 1952, p. 1401.
4. C.T. Kirk, "A Theory of Transistor Cutoff Frequency


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(fT) Falloff at High Current Densities," *IRE Transactions on Electron Devices*, v9, n2, 1962, pp. 164-174.
5. Agilent Heterojunction Bipolar Transistor Model, Agilent Advanced Design System Documentation 2008, Nonlinear Devices Chapter 2, pp. 4-33.
6. M. Schroter, S. Lehmann, H. Jiang and S. Komarow, "HICUM/Level0 – A Simplified Compact Bipolar Transistor Model," *IEEE Proceedings of the 2002 Bipolar/BiCMOS Circuits and Technology Meeting*, 2002, pp. 112-115.
7. M. Iwamoto, D.E. Root, J.B. Scott, A. Cognata, P.M. Asbeck, B. Hughes and D.C. D'Avanzo, "Large-signal HBT Model with Improved Collector Transit Time Formulation for GaAs and InP Technologies," *IEEE International Microwave Symposium Digest*, 2003, pp. 635-638.
8. Agilent Heterojunction Bipolar Transistor Model, Non-Linear Devices, Agilent ADS Documentation v2005A, Chapter 2, 2005, pp. 4-42.
9. UCSD HBT Model, http://hbt.ucsd.edu.
10. D.E. Dawson, A.K. Gupta and M.L. Salib, "CW Measurement of HBT Thermal Resistance," *IEEE Transactions on Electron Devices*, Vol. 39, No. 10, October 1992, pp. 2235-2239.
11. B. Yeats, "Inclusion of Topside Heat Spreading in theDetermination of HBT Temperatures by Electrical and Geometrical Methods," *21st Annual Gallium Arsenide Integrated Circuit Symposium Digest*, October 1999, pp. 59-62.
12. C. Baylis, L. Dunleavy and J. Daniel, "Direct Measurement of Thermal Circuit Parameters Using Pulsed IV and Normalized Difference Unit," *Microwave Symposium Digest, 2004 IEEE MTT-S International, Volume 2*, June 2004, pp. 1233-1236.
13. J. Gering, S. Nedeljkovic, F. Kharabi, J. McMacken and D. Halchin, "Transistor Model Validation through 50 Ohm, Vector Network Analyzer Power Sweeps," *70th ARFTG Conference.*
14. S. Nedeljkovic, J. McMacken, J. Gering and D. Halchin, "A Scalable Compact Model for III-V Heterojunction Bipolar Transistors," *Microwave Symposium Digest, 2008 IEEE MTT-S International*, June 2008, pp. 479-482.
15. H. Beckrich, S. Ortolland, D. Pache, D. Celi, D. Gloria and T. Zimmer, "Impact of Neighbor Components Heating on Power Transistor Electrical Behavior," *Microelectronic Test Structures, 2006 IEEE International Conference*, March 2006, pp. 205-210.
16. D. Walkey, T.J. Smy, D. Celo, T.W. MacElwee and

M.C. Maliepaard, "Compact, Netlist-based Representation of Thermal Transient Coupling Using Controlled Sources," *IEEE Transactions on Computer-Aided Design of Integrated Circuits and Systems*, Vol. 23, No. 11, November 2004, pp. 1593-1596.
17. P. Dai, P. Zampardi, K. Kwok, C. Cismaru and R. Ramanathan, "Study of Thermal Coupling Effect in GaAs Heterojunction Bipolar Transistor by Using Simple Mirror Circuit," *GaAs ManTech 2005*.
18. D. Walkey, T.J. Smy and D. Celo, "Prediction of Maximum Temperature Rise in Multi-finger Transistor Structures Using Normalization," *GaAs ManTech 2002*.
19. P. Baurelis, "Electrothermal Modeling of Multi-emitter Heterojunction Bipolar Transistors (HBT)," *Integrated Nonlinear Microwave and Millimeter-wave Circuits Third International Workshop*, October 1994, pp. 145-148.
20. M. Schubler, V. Krozer, J.G. de la Fuente and H.L. Hartnagel, "Thermal Coupling in Multi-finger Heterojunction Bipolar Devices," *27th European Microwave Conference and Exhibition*, September 1997, pp. 104-108.
21. D. Denis, C.M. Snowden and I.C. Hunter, "Coupled Electrothermal, Electromagnetic and Physical Modeling of Microwave Power FETs," *Microwave Theory and Techniques, IEEE Transactions*, Vol. 54, Vol. 6, June 2006, pp. 2465-2470.
22. M. Rudolph, F. Schnieder and W. Heinrich, "Investigation of Thermal Crunching Effects in Fishbone-type Layout Power GaAs-HBTs," *Gallium Arsenide Applications Symposium GaAs 2004*, October 2004, Amsterdam, The Netherlands.
23. H. Beckrich, T. Schwartzmann, D. Celif and T. Zimmer, "A Spice Model for Predicting Static Thermal Coupling Between Bipolar Transistors," *Research in Microelectronics and Electronics*, 2005 PhD, Vol. 2, July 2005, pp. 75-78.
24. D. Lopez, R. Sommet and R. Quéré, "Spice Thermal Subcircuit of Multi-finger HBT Derived from Ritz Vector Reduction Technique of 3D Thermal Simulation for Electrothermal Modeling," *Gallium Arsenide Applications Symposium GaAs 2001*, 24-28 September 2001, London, England.
25. A. Cidronali, G. Collodi, C. Accillaro, C. Toccafondi, G. Vannini, A. Santarelli and G. Manes, "A Scalable PHEMT Model Taking into Account Electromagnetic and Electro-thermal Effects," *Gallium Arsenide Applications Symposium GaAs 2003*, 6-10 October 2003, Munich, Germany.

MANAGING CRYSTAL OSCILLATOR ACCELERATION SENSITIVITY IN MOBILE APPLICATIONS

All quartz crystal oscillators are affected by acceleration. While for many applications the effects are negligible, in those where frequency stability is critical and the environment is physically demanding (high shock or vibration), the effects can be significant. Even devices that are operated in relatively benign locations are under the influence of gravity and possibly low level vibration. If they are rotated or moved, a small shift in the operating frequency will occur. ***Figure 1*** shows a precision quartz resonator mounted in a four-point holder.

The acceleration sensitivity characteristic of a quartz crystal, commonly referred to as Gamma ($\vec{\Gamma}$), is vectorial in nature. The frequency shift that will be exhibited by a crystal experiencing an acceleration is therefore dependent on the direction and magnitude of the applied force as well as the magnitude and orientation of the inherent acceleration or "g-sensitivity" vector.[1] The fractional frequency change $\frac{\Delta f}{f_0}$ of the oscillator under an acceleration $\vec{a}$ is given by the inner product of $\vec{\Gamma}$ and $\vec{a}$, that is

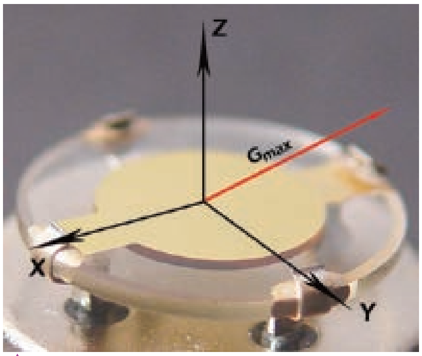

Fig. 1 Four-point mount crystal blank.

$$\frac{\Delta f}{f_0} = \vec{\Gamma} \cdot \vec{a} \quad (1)$$

The acceleration sensitivity vector $\vec{\Gamma}$ can be determined by measuring the frequency change under acceleration in three linearly independent directions (e.g. three orthogonal directions) that are aligned with the faces of the oscillator or crystal package. A frame of reference is therefore defined. The magnitude $|\vec{\Gamma}|$ of $\vec{\Gamma}$ is given by the square-root of the sum of the squares of its components (Γ_x, Γ_y, Γ_z)

$$\left|\vec{\Gamma}\right| = \sqrt{\Gamma_x^2 + \Gamma_y^2 + \Gamma_z^2} \quad (2)$$

It can be seen that the fractional frequency change is maximally positive when $\vec{a}$ is parallel to $\vec{\Gamma}$; it is maximally negative when $\vec{a}$ is antiparallel to $\vec{\Gamma}$, and approaches zero when $\vec{a}$ is perpendicular to $\vec{\Gamma}$. This relationship is illustrated in ***Figure 2***. The direction of $\vec{\Gamma}$ relative to the measurement frame as shown in ***Figure 3*** may then be determined.[4]

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

* Octave band.

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$$\Phi = \cos^{-1}\left(\frac{\Gamma_x}{\sqrt{\Gamma_x^2 + \Gamma_y^2}}\right) \qquad (3)$$

$$\theta = \sin^{-1}\left(\frac{\Gamma_z}{\vec{\Gamma}}\right) \qquad (4)$$

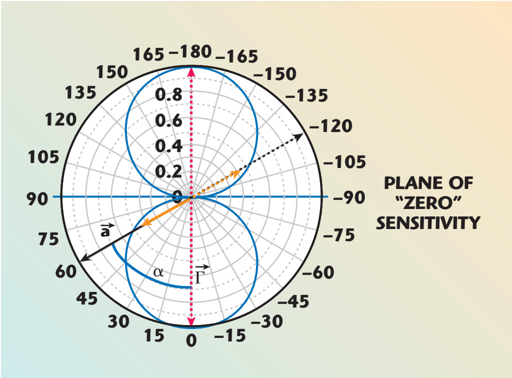
Normally the dominant source of the oscillator's acceleration sensitivity is the quartz crystal resonator. Depending on the construction, a given group of crystals may exhibit substantial variation in both the direction and magnitude of $\vec{\Gamma}$. It is therefore necessary to measure each crystal in order to be assured of its individual characteristic.

The acceleration sensitivity of a quartz crystal is caused primarily by non-uniform stresses induced within the active area of the quartz blank by the acceleration. The active area of a crystal resonator is in the center of the blank, between the plated electrodes. Conventional crystals are typically mounted at two points in a flat holder such as an HC-43 or HC-45. Round holders such as the HC-35 or HC-37 (TO-05 or TO-08 size) mount the crystal horizontally at three or four points. The resonant frequency of any mechanical body is inherently sensitive to stresses and strains that cause the resonant frequency to change. An applied acceleration in any direction will impart a stress to the quartz that is non-uniform in some manner due to the mounts. Typical crystal acceleration sensitivities will range from about 1 x 10^{-10} per g for specially constructed precision SC-cut and AT-cut resonators to the order of 10^{-7} per g for tuning fork resonators.[2]

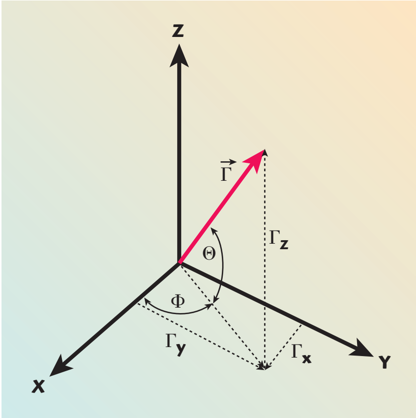
With the drive to continually reduce the package size of crystal oscillators for new systems and applications, improvements have been made in the performance of miniature strip crystals. These resonators use small rectangular quartz blanks instead of the round wafers found in conventional holders, as shown in ***Figure 4***.[5] Although these crystals have been used for some time in low cost oscillators, recent advances in their design and processing have provided resonators for some precision applications that are just as good or even better in some respects than the much larger conventional holders. The blanks are mounted at one end and suspended in a cantilever fashion. The low mass of the quartz and the isolation of the active area from the stress of the mount can provide a design with low acceleration sensitivity with some being better than 1x10^{-9} per g.

ENVIRONMENTAL EFFECTS

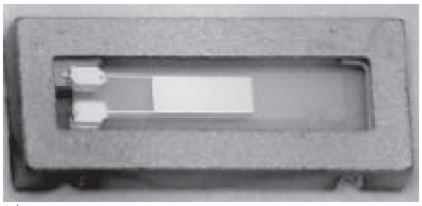
The type of acceleration that the crystal is exposed to will determine how the frequency will respond. It is common for an oscillator to experience mechanical shocks due to routine handling of equipment or movements in the vicinity of the oscillator. These types of shocks will cause a



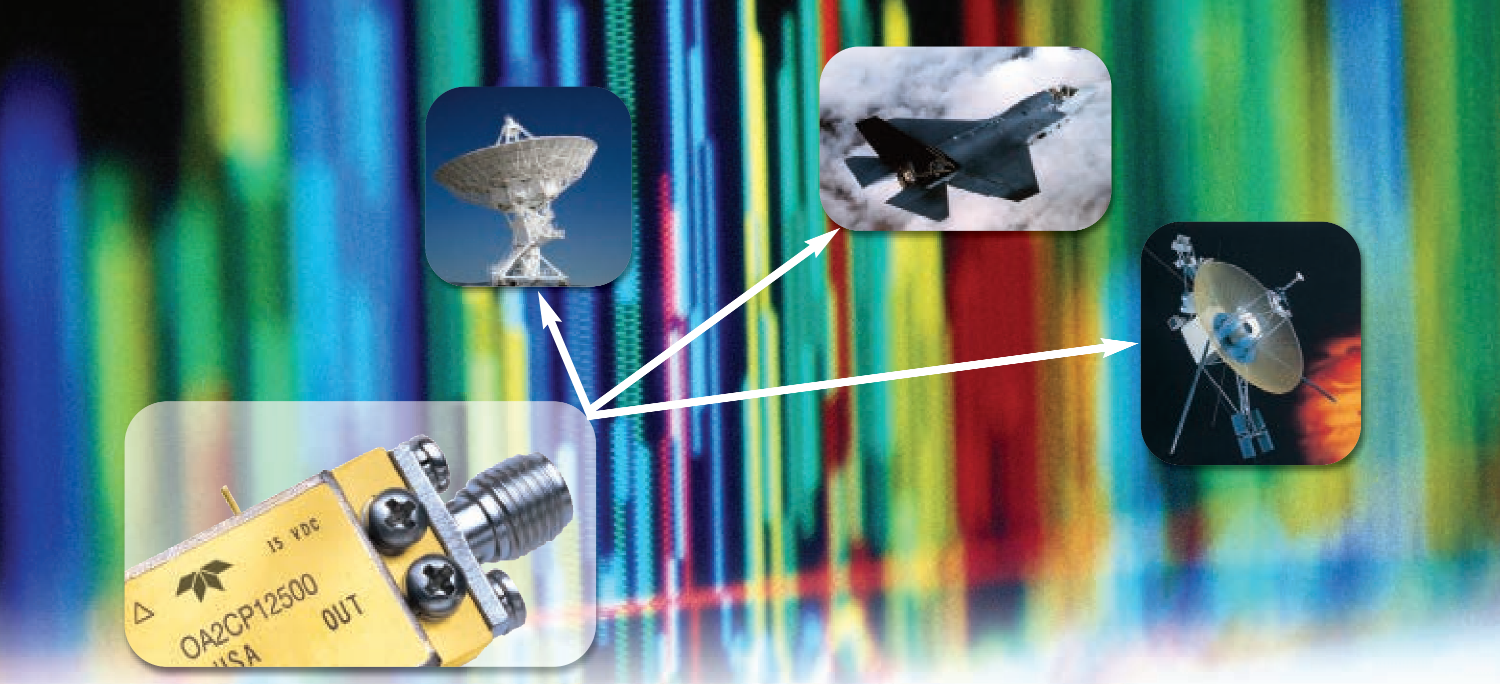
▲ *Fig. 2 Relative frequency shift as a result of applied acceleration.*



▲ *Fig. 3 Gamma vector measurement frame.*



▲ *Fig. 4 Internal view of crystal strip mount.*



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Model	Freq. Range (MHz)	Tuning Voltage Range (Volts)	Output Power/ Variation (dBm/ ±dB)	Typical Phase Noise Offset at 10kHz/100kHz (dBc/Hz)	Nominal Modulation Sensitivity Min.-Max. (MHz/V)	Typical Harmonic Suppression (dBc)	D.C. Bias Voltage (Volts)	D.C. Bias Current (mA)
Oscillator with internal MMIC amplifier available in SMTO-8 or CougarPak™								
OAS5100	4300-5100	0-15	13.0/2.0	-84/-108	50-85	-22	5.0	94
OAS7700	5700-7700	0-15	10.0/2.0	-75/-100	70-250	-30	5.0	95
OAS8900	6900-8900	0-15	10.0/2.0	-70/-95	100-270	-30	5.0	95
Oscillator available in SMTO-8 or CougarPak™								
OS6700	5400-6700	0-15	0/2.0	-75/-100	80-180	-17	5.0	25
OS7700	5700-7700	0-15	2.0/2.0	-75/-100	70-250	-17	5.0	25
OS8900	6900-8900	0-15	1.0/2.0	-70/-95	100-270	-25	5.0	24
Oscillator available in TO-8, SMTO-8 or CougarPak™								
OC1000	500-1000	0-20	10.0/2.0	-90/-105	15-55	-10	15.0	35
OC3400	2700-3400	0-15	10.0/2.0	-80/-105	75-115	-12	15.0	60
OC4500	3500-4500	0-15	8.0/2.0	-75/-100	50-150	-10	15.0	60
Oscillator, Amp, Filter and Voltage Regulator in 2- and 3-Stage CougarPak™								
OA2CP2001	1000-2000	0-(-15)	15.0/2.0	-70/-100	50-150	-15	15.0	250
OA2CP12500	9000-12500	0-(-12)	15.0/2.0	-65/-95	150-450	-25	15.0	250
OA3CP18001	12000-18000	0-(-12)	15.0/2.0	-55/-85	150-750	-15	15.0	350

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

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temporary perturbation in the frequency that could disturb the operation of circuitry such as narrowband phase-locked loops. Reducing these effects requires either attenuation of the applied shock or improving the acceleration sensitivity of the oscillator.

Oscillators that are deployed in a mobile environment such as a vehicular application may experience significant levels of vibration. Through the acceleration sensitivity of the oscillator, this vibration modulates the output frequency. Random vibration on some airborne platforms can reach extremely high levels. This wideband mechanical vibration leads to wideband phase noise degradation in the oscillator. Periodic vibrations from an engine, rotating machinery or even a cooling fan can induce discrete sidebands on the output signal. The levels of the sidebands will be determined by the magnitude and frequency of the vibration as well as the acceleration sensitivity component of the crystal in the direction of the force.[1]

Another influence that affects all oscillators is the constant acceleration due to gravity. All bodies at rest on the surface of the earth experience an acceleration $\vec{a}$ of 1 g directed upward. Rotating an oscillator around a horizontal axis will change the angle between $\vec{\Gamma}$ and $\vec{a}$. Through Equation 1 it can be seen that a frequency change will occur. For many applications this change is negligible, but for those requiring stability on the order of 1 ppb or better, this amount of frequency shift can be significant.

ACCELERATION SENSITIVITY MEASUREMENT METHODS

There are several methods that can be used to measure the acceleration sensitivity $\vec{\Gamma}$ of an oscillator. Here we discuss the simple 2-g tipover test and the vibration induced sideband methods.

A technique that uses the constant gravitational acceleration of the earth to cause a measurable frequency shift in an oscillator is known as the "2-g tipover test". A set of orthogonal axes relative to the oscillator case is defined. The oscillator is oriented so that one axis ($\hat{x}$) points upwards and the frequency is measured. The oscillator is then rotated 180° so that this axis points downwards and the frequency is measured in this orientation. From the point of view of the oscillator, this is as though the acceleration changed from

$$\vec{a} = (1g)\hat{x} \text{ to } \vec{a} = -(1g)\hat{x}$$

so the resultant frequency difference between the two configurations would be given by

$$\frac{\Delta f}{f_0} = \Gamma_x(1g) - \Gamma_x(-1g) = \Gamma_x(2g) \qquad (5)$$

There is a net 2 g change in the acceleration so $\vec{\Gamma}_x$ is one half of the fractional frequency change (in units per g). Repeating this for the other two axes gives all three components of $\vec{\Gamma}$ and hence $\vec{\Gamma}$ is defined. This method requires a relatively stable oscillator in order to see the gravitational induced shifts above the short-term noise and thermal drift of the oscillator. Several cycles may be needed to separate the g sensitivity from these effects.

An accurate method for measuring the acceleration sensitivity of any oscillator uses mechanical vibration to modulate the output frequency of the oscillator through the acceleration sensitivity effect (see ***Figure 5***). The effect on the output signal can then be observed with a spectrum analyzer. Sinusoidal vibrations are used to characterize the sensitivity at a specific frequency. Under sinusoidal vibration, discrete sidebands will be induced on the oscillator output signal offset from the carrier f_0 by the vibration frequency f_v. Since the sinusoidal vibration essentially FM modulates the carrier, the level of the sidebands will be predicted by FM modulation theory. For a signal whose frequency has a peak change of Δf at a modulating frequency f_m, the measured sideband levels at frequency $f_0 \pm f_m$ will have good approximation to the modulation index formula for a small index of <0.1.[2]

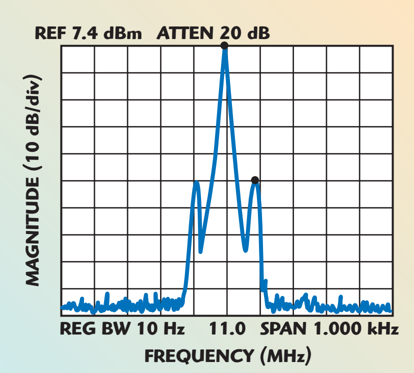

Fig. 5 Oscillator spectrum under sine vibration.


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$$\text{Sideband Level(dBc)} = 20\log\left(\frac{\Delta f}{2f_m}\right) \quad (6)$$

The amount of frequency shift is given by $\Delta f = |\vec{\Gamma}\cdot\vec{a}| f_0$ and the modulation frequency is the frequency of the sinusoidal vibration f_v so that the formula for the level of the vibration induced sidebands becomes:

$$L(f_v) = 20\log\left(\frac{|\vec{\Gamma}\cdot\vec{a}|\, f_0}{2f_v}\right) \quad (7)$$

By rearranging the formula, the measured sideband level in dBc can be converted to the corresponding g-sensitivity in the direction being vibrated, d, given the known vibration g-level α_d and nominal frequency f_o.

$$\left|\Gamma_d\right| = \frac{2f_v}{\alpha_d \cdot f_o}\cdot 10^{\frac{SB(dB)}{20}} \quad (8)$$

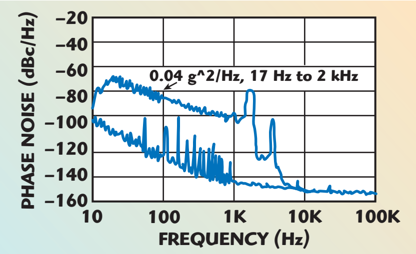
The acceleration sensitivity is fairly constant with frequency as long as the vibration frequency is below the lowest mechanical mode of the resonator. This could be as high as two or three kHz for a strip crystal or a stiff four-point mount or as low as 100 Hz for a large crystal using a spring type mount. The frequency shift is also linearly proportional to the applied g level up to about 50 g's. For screening purposes a vibration frequency and acceleration level are chosen that give easily measurable sidebands.

EFFECTS OF RANDOM VIBRATION

Under random vibrations the oscillator will experience accelerations over a wide range of frequencies and various magnitudes. Even a moderate amount of random vibration can cause a significant degradation of an oscillator's phase noise performance (see ***Figure 6***). Similar modulation index arguments are used to calculate the vibration induced noise at a frequency offset, f_r. These random motions are characterized by the power spectral density of the vibration profile. The formula for approximating the induced noise at offset f_r becomes:

$$L(f_r) = 20\log\left(\frac{\vec{\Gamma}\cdot f_0\cdot\sqrt{2PSD}}{2f_r}\right) \quad (9)$$

When the phase noise of the oscillator is measured while vibrating, it is then possible to calculate the g-sensitivity at any frequency within the spectrum. Care must be taken to ensure that fixture resonances and cable sensitivities are accounted for when evaluating the results.



▲ *Fig. 6 Phase noise degradation due to random vibration.*

SCREENING FOR ACCELERATION SENSITIVITY

There are some applications where the performance of the crystal oscillator under vibration or shock is a critical parameter that must be guaranteed 100 percent to a stringent level. Although robust crystal designs and well controlled production processes can produce crystals with high yields, screening is still necessary to ensure some specifications. A typical screening system would consist of a vibration table and controller, fixturing for securing the crystals in an oscillator and a narrow-band spectrum analyzer or other instrument for evaluating the levels of vibration induced sidebands. A vibration level and frequency are selected that will produce measureable sideband levels, but are convenient to work with. A level of 10 g's at a frequency of 90 Hz is a typical choice. ***Figure 7*** shows the results of screening a group of 20 MHz TCXOs that use AT strip crystals.

METHODS FOR REDUCING SENSITIVITY

There are methods and techniques that can be employed to improve the acceleration performance of a crystal oscillator. For example, if the acceleration sensitivity vector $\vec{\Gamma}$ is reasonably consistent in direction and if the accelerations occur primarily in one direction, then aligning the oscillator so that the accelerations are perpendicular to $\vec{\Gamma}$ can result in as much as a 10-fold reduction in frequency changes compared to a worst case alignment.

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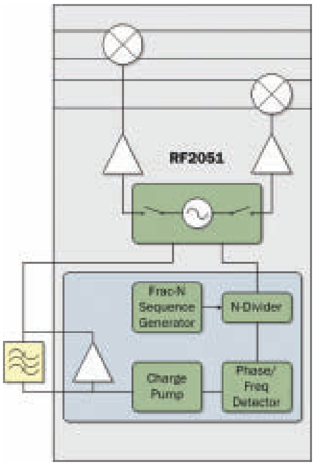

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205x SERIES SPECIFICATIONS

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On-chip VCOs		Yes	Yes	No
RF mixers		2	1	1
DC Parameters				
Supply voltage	V	3.0	3.0	3.0
Supply current (low-current setting)	mA	55	55	55
VCO and Synthesizer				
Input reference frequency	**MHz**		**10 to 104**	
LO frequency	MHz	300 to 2400	300 to 2400	-
Open loop VCO phase noise at 500 MHz LO frequency	dBc/Hz	-140	-140	-
RF Mixer				
RF and IF port frequency range	**MHz**		**50 to 2500**	
Noise figure (low-current setting)	dB	-	9.5	-
Input IP3 (high-linearity setting)	dBm	-	20	-

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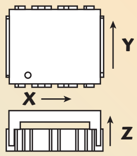
accelerometer with feedback to the oscillator circuit. This closed loop system is then accurately calibrated to offset the frequency of the oscillator proportional to the sensed acceleration and cancel out the frequency shifts caused by the acceleration. This technique can work well at lower frequencies up through a few hundred Hz, but it requires a relatively complex circuit to sense acceleration in all three axes, scale the correction signal properly and account for frequency dependent phase shifts in the circuitry. Close attention to the mechanical details of the design is also required.

ACCELERATION SENSITIVITY



Fo = 20000000 Hz
Vib Lvl. 10 g
Vib FREQ = 90 Hz
dF/F per g = ((2*Fv)/(Fo*Glevel))*10^(dBc/20)

	MEASURED (dBc)			dF/F per g			
S/N	X	Y	Z	X	Y	Z	GAMMA
6	–84.1	–85.5	–85.6	5.61E-11	4.78E-11	4.72E-11	8.76E-11
3	–81.9	–86.3	–81.8	7.23E-11	4.36E-11	7.32E-11	1.12E-10
10	–82.7	–85.4	–81.2	6.60E-11	4.83E-11	7.84E-11	1.13E-10
15	–85.5	–85.6	–76.4	4.78E-11	4.72E-11	1.36E-10	1.52E-10
24	–83.0	–86.6	–69.7	6.37E-11	4.21E-11	2.95E-10	3.04E-10
2	–82.6	–86.2	–70.5	6.67E-11	4.41E-11	2.69E-10	2.80E-10
8	–86.1	–85.6	–65.0	4.46E-11	4.72E-11	5.06E-10	5.10E-10
21	–81.6	–85.7	–63.9	7.49E-11	4.67E-11	5.74E-10	5.81E-10
14	–82.2	–85.7	–63.6	6.99E-11	4.67E-11	5.95E-10	6.01E-10
5	–85.4	–85.2	–62.1	4.83E-11	4.95E-11	7.07E-10	7.10E-10
13	–83.6	–85.5	–61.7	5.95E-11	4.78E-11	7.40E-10	7.44E-10
16	–85.9	–85.8	–59.1	4.56E-11	4.62E-11	9.98E-10	1.00E-09

▲ *Fig. 7 Screening results for a group of 20 MHz TCXOs.*

Another type of compensation involves using multiple crystals with their acceleration sensitivity vectors aligned so that they are pointing in opposite directions in an anti-parallel arrangement.[3] The crystals are then connected to the oscillator circuit either in a parallel or series configuration where the composite combination operates as a single crystal with modified motional parameters. The two $\vec{\Gamma}$ vectors then essentially cancel the effect of each other. This method can be quite effective if the crystals are similar and are characterized and aligned properly in the assembly. With a solid mechanical design, cancellation will occur up through several kHz and can provide a significant improvement in phase noise performance during random vibration.

Some systems designed for severe environments or very sensitive installations can effectively use vibration and shock isolators to mechanically attenuate the force that is transmitted to the oscillator. Vibration isolators are only effective in reducing levels above the natural resonant frequency of the system. Obtaining a low resonant frequency below a few hundred Hz is difficult with a small, light component such as a miniature oscillator and it may be necessary to add weight to the assembly depending on the stiffness of the isolator. There is a region near the resonant frequency where the force is actually amplified by some amount depending on the damping characteristics of the materials. Care must be taken to ensure sufficient sway room to allow for movement of the assembly, especially if excited near the resonant frequency. An isolation system that is not properly designed can make the overall performance worse rather than better.

While acceleration forces are unavoidable, by understanding their effects on oscillator performance and the methods that may be used to mitigate these effects, acceptable performance can be achieved in most application environments. Advancements in crystal technology continue, but the "zero g-sensitivity" oscillator is not yet a reality so dealing with the effects of acceleration will be necessary for the foreseeable future. ■

References

1. R.L. Filler, "The Acceleration Sensitivity of Quartz Crystal Oscillators: A Review," *IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control*, Vol. 35, No. 3, May 1988, pp. 297-305.
2. J.R. Vig, "Quartz Crystal Resonators and Oscillators for Frequency Control and Timing Applications: A Tutorial," Rev. 8.5.3.0, February, 2005, AD-M001251(revised).
3. R.L. Filler, "Acceleration Resistant Crystal Resonator," *U.S. Patent No. 4,410,822*, 1983.
4. J.M. Przyjemski, "Improvement in System Performance Using a Crystal Oscillator Compensated for Acceleration Sensitivity," *Proc. 32^{nd} Annual Frequency Control Symposium*, pp. 426-431, 1978.
5. Statek Corp., Technical Note 28, "An Ultra-miniature Low Profile at Quartz Resonator."

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LDMOS RUGGEDNESS RELIABILITY

An overview of the 28-42-50 V LDMOS technologies is given and the ruggedness reliability is discussed, in addition to the RF performance. Various ruggedness tests are presented such as pulsed snapback measurements, VSWR and video bandwidth tests.

RF power amplifiers are key components in base stations, broadcast transmitters, ISM applications and microwave applications. They can handle a wide range of signal types such as GSM, EDGE, W-CDMA, WiMAX and DVB-T. RF laterally diffused MOS (LDMOS) transistors have been the technology of choice for these power amplifiers for more than a decade, because of their excellent power capabilities, gain, efficiency, cost and reliability.

Ruggedness is one of the most important reliability parameters for RF power transistors. Ruggedness is the ability to withstand a stress condition without degradation or failure. One way to characterize ruggedness is by measuring the voltage standing wave ratio (VSWR) in an RF test fixture with a defined mismatch at the output. The design of the test fixture and the matching of the transistor are critical for the result of the VSWR test. LDMOS transistors are optimized to withstand a certain power and voltage, and the process is engineered for the best trade-off between RF performance and ruggedness.

In this article, RF LDMOS devices are shown, which combine very good ruggedness with state-of-the-art RF performance. Ruggedness tests, which have been developed to meet today's product ruggedness criteria, will be described.

RF LDMOS TECHNOLOGIES (28-42-50 V)

NXP Semiconductors has developed a base station RF LDMOS technology[1,2] and high voltage RF LDMOS technologies.[3] The base station technology operates at supply voltages of approximately 28 V, while the high voltage technology can be used at 42 and 50 V. Both LDMOS types are processed in an 8-inch CMOS-fabrication environment, capable of lithography down to 0.14 μm, where the LDMOS process is derived from the C075 CMOS (0.35 μm gate) process with LOCOS isolation. Additions to this C075 process are the source sinker to the substrate, $CoSi_2$ gate silicidation, tungsten shield and mushroom-type drain structure with thick multi-layer AlCu metallization. A schematic

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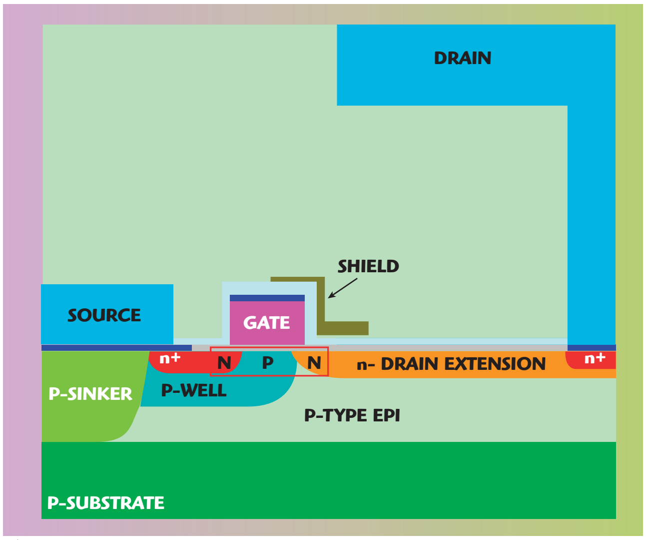
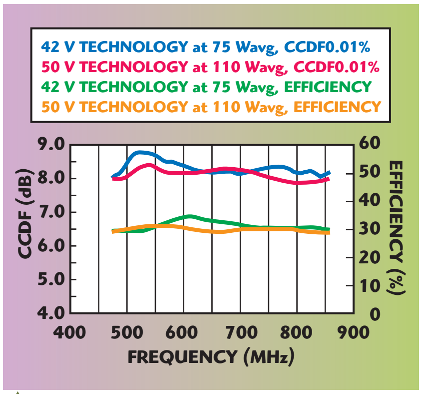
picture of the LDMOS is shown in ***Figure 1***, where the inherently present NPN parasitic bipolar transistor is indicated by the red rectangle.

The RF performance of the base station LDMOS is state-of-the-art and is used in a wide range of applications like GSM, W-CDMA and WiMAX.[1] Recently, high voltage (42 to 50 V) LDMOS technologies[3] have been developed for high power devices at frequencies below 1 GHz. Typical RF performance of the high voltage technology at 470 to 860 MHz (UHF) and 225 MHz (VHF) is shown in ***Figures 2*** and ***3***, respectively. The UHF device delivers 75 to 110 Wavg at 42 and 50 V, respectively. The broadband gain is 19 dB and the efficiency is 30 to 32 percent with a Complementary Cumulative Distribution Function (CCDF) of 8 dB. The VHF device delivers 1300 W power (P1dB) at 50 V with a peak efficiency of over 70 percent and a gain of 24 dB.

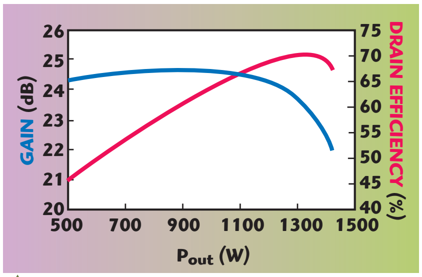
Both devices have been tested to be very rugged and capable of handling high voltage and high power over a wide band of extreme mismatch conditions. In general, at low frequencies, more ruggedness is required of devices. This is partly due to the higher harmonic content at frequencies much lower than the cut-off frequency. Also, the signal type is important for ruggedness, sharply varying pulse signals with a steep rise time being more severe for ruggedness. For this reason, LDMOS technologies have been hardened under the most stringent ruggedness tests during development, and in particular the 50 V high voltage technology.



▲ *Fig. 1 Schematic picture of LDMOS technology.*



▲ *Fig. 2 RF performance of the 42 V and 50 V LDMOS technology devices at 470 to 860 MHz for an 8k DVB-T signal.*



▲ *Fig. 3 RF performance of a 50 V LDMOS device (BLF-578) at 225 MHz.*

PARASITIC BIPOLAR TRANSISTOR

Inherent to the LDMOS device is the presence of a parasitic bipolar transistor. This NPN bipolar transistor is indicated in the schematic picture of the device. The corresponding electrical schematic is given in ***Figure 4***, showing, in addition to the LDMOS, the presence of the parasitic NPN bipolar transistor and the drain-substrate diode. The drain-source diode clamps the voltage across the LDMOS and the parasitic bipolar and sinks the excess current to the substrate. For large sink currents, however, the drain-source voltage exceeds the diode breakdown voltage and the parasitic bipolar transistor can be triggered.

This triggering of the parasitic bipolar transistor is essential for the occurrence of a ruggedness failure. To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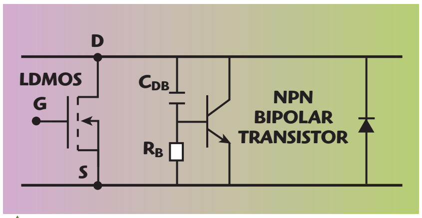


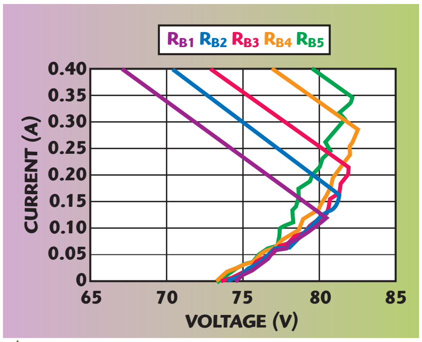
▲ *Fig. 4 Electrical representation of the LDMOS and the inherently present parasitic bipolar transistor and drain-substrate diode.*

make the bipolar transistor robust for a triggering event, the bipolar of the LDMOS has been characterized and optimized. Important transistor parameters for triggering are the base resistance (R_B), the gain of the bipolar and the amplitude of the base current. As a characterization tool for the triggering of this bipolar, a short pulse (50 to 200 ns) is used in the measurement of the current-voltage characteristics. An impedance transmission line is used as a pulse source to create a rectangular pulse. The desired voltage is applied via a DC power supply and then quickly discharged with a low inductance switch. The current and voltage are measured with a memory scope during the discharge. The snapback in the I-V curve is measured, which gives insight in the device properties of the DUT. The characterization is done on a wafer with small (test) devices in a 50 Ω commercially available set-up. Power RF devices cannot be used, since the setup is not able to generate enough current. This is a fast and adequate evaluation of device and process changes on ruggedness without the influence of test circuits and matching conditions.

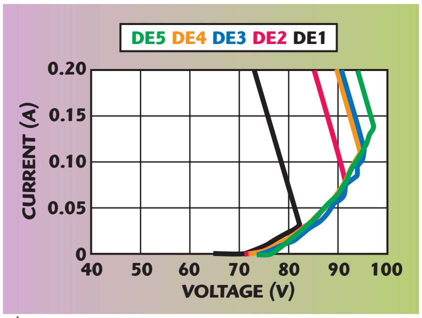
RUGGEDNESS CHARACTERIZATION

During the development of RF-LDMOS processes, the intrinsic ruggedness of the parasitic bipolar transistor of the RF power LDMOS devices has been continuously improved.

The base resistance is important for ruggedness as can be seen from the electrical representation of the LDMOS. In the processing, the base resistance of the parasitic bipolar transistor has been varied to lower the voltage drop between base and emitter. In ***Figure 5***, the pulsed current-voltage characteristic of base station RF LDMOS devices is shown for different base resistances. Around the (diode) breakdown voltage of the transistor



▲ *Fig. 5 Pulsed current voltage characterization of several devices with different base resistance.*



▲ *Fig. 6 Characterization of devices with different drain engineering variants at V_{gs} = 0 V.*

(in this example at approximately 73 V), the drain current starts to increase and at 82 V a snapback occurs. This snapback voltage and snapback current are the two parameters that are a measure for the intrinsic RF ruggedness. By process optimizing the base resistance, the snapback current has been successfully doubled, resulting in a better VSWR of the corresponding power devices.

Furthermore, the capacitance between the base of the bipolar and the drain (CDB) has been optimized by engineering the drain extension of the LDMOS. ***Figure 6*** shows measurements for different drain engineering (DE) variants. At 83 to 98 V, the parasitic bipolar of the device is triggered, causing a snapback in the curve. This snapback is improved by DE variation, resulting in a more rugged device. This is confirmed by VSWR measurements done on power devices. The best devices can tolerate a 10 V higher supply voltage for the same power level and a VSWR of 10:1.

From this rugged base station LDMOS technology, a super-rugged high voltage (42 to 50 V) RF LDMOS technology has been derived for broadcast applications up to 1 GHz and for VHF and ISM applications, where the most stringent reliability criteria are

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ZHL-10W-2G	800-2000	43	+40	+41	7.0	+50	24	5.0	1295.00
• ZHL-20W-13	20-1000	50	+41	+43	3.5	+50	24	2.8	1395.00
ZHL-30W-252+	700-2500	50	+44	+46	5.5	+52	28	6.3	2995.00
• ZHL-50W-52	50-500	50	+46	+48	4.0	+55	24	9.3	1395.00
• ZHL-100W-52	50-500	50	+47	+48.5	6.5	+57	24	10.5	1995.00
○ ***Without Heat Sink/Fan***									
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LZY-2X+	500-1000	46	+45	-	8.0	+54	28	8.0	1895.00
ZHL-5W-2GX	800-2000	45	+37	+38	8.0	+44	24	2.0	945.00
ZHL-10W-2GX	800-2000	43	+40	+41	7.0	+50	24	5.0	1220.00
• ZHL-20W-13X	20-1000	50	+41	+43	3.5	+50	24	2.8	1320.00
ZHL-30W-252X+	700-2500	50	+44	+46	5.5	+52	28	6.0	2920.00
• ZHL-50W-52X	50-500	50	+46	+48	4.0	+55	24	9.3	1320.00
• ZHL-100W-52X	50-500	50	+47	+48.5	6.5	+57	24	10.2	1920.00

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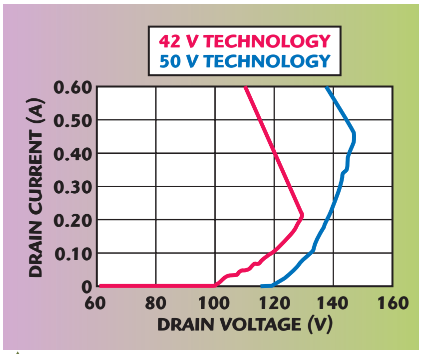
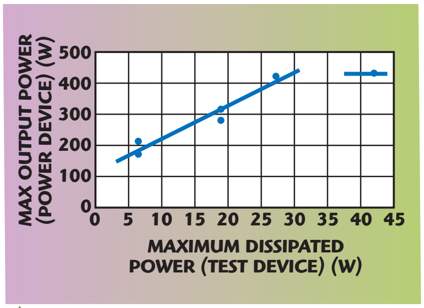
demanded. ***Figure 7*** shows that the breakdown voltage of these high voltage technologies is increased, compared to the 28 V base station technology. More importantly, the snapback voltage is also significantly larger, resulting in values of 130 and 150 V. Simultaneously, the snapback current is more than doubled compared to the base station technology, shown previously. High voltage power devices have been measured for a VSWR of 10:1 at the nominal supply voltage of 42 to 50 V, but they can even withstand values up to 60 to 70 V, as expected from the figure. This ruggedness has been achieved by engineering of the drain extension, epi layer thickness and shield construction.

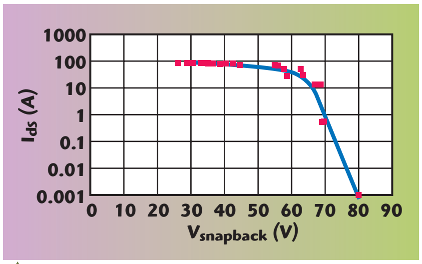
From the snapback current and voltage, the maximum dissipated power before failure is calculated. This power is an indication for the quality of the ruggedness of a power device, as shown in ***Figure 8*** for 42 V development devices. The power at which a power device fails (applying a VSWR of 10:1 with a DVB-T signal) is plotted versus the power at which an on-wafer test device fails (pulsed current voltage sweep). A linear relation is found between the power and on-wafer test device, which indicates this on-wafer test is a good predictor for the ruggedness of a power device. For large powers, there is a deviation from the linear trend. It is speculated that this is due to thermal aspects and circuitry matching.



▲ *Fig. 7 Pulsed current-voltage measurements of the high-voltage broadcast LDMOS for different epi thickness.*



▲ *Fig. 8 Correlation between the peak power at which a power device fails (VSWR = 10:1, 8k DVB-T, 9.5 dB PAR) and the power dissipated at snapback of a corresponding test device.*



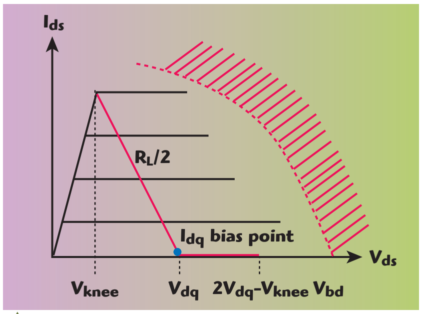
▲ *Fig. 9 Constructed safe operation area of the parasitic bipolar transistor as derived from on-wafer pulsed I-V measurements for NXP base station RF LDMOS.*

RUGGEDNESS SAFE OPERATION AREA

In the application, not only a drain voltage is applied but also a gate voltage. If the applied gate voltage is above the threshold voltage, a current will flow in the transistor and in the base. This base current in combination with a high drain voltage will more easily trigger the parasitic bipolar transistor. The failures of devices have been measured for a wide range of current-voltage settings to construct a parasitic bipolar safe operation area (PB-SOA). The constructed PB-SOA curve is shown in ***Figure 9***.

This PB-SOA curve resembles the theoretical safe operation area curve (see ***Figure 10***), as is known for CMOS devices for instance. A few I-V characteristics and the class AB load line have been added.

The load line approached the edge of the SOA at its two extremes: at high drain current and at high drain voltage. For high current, the triggering of the bipolar is thermally induced, while at high drain voltage the triggering is electrically induced. By engineering the snapback characteristic, the LDMOS devices are optimized to prevent the occurrence of the electrically induced triggering, since this mechanism is the most frequent cause for ruggedness failures, as determined from the occurrence of a random damage pattern. Also, the thermal behavior of LDMOS is part of the continuous improvement.



▲ *Fig. 10 Schematic picture of the safe operation area.*

TABLE I

VBW MEASUREMENT AT VARIOUS SUPPLY VOLTAGES AROUND A CENTER FREQUENCY OF 2 GHz FOR A TONE SPACING OF 80 MHz. P_{OUT} IS THE POWER FOR A SINGLE TONE.

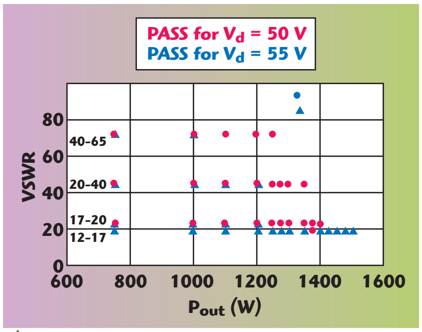
Pout (dBm)	Vd 32 V	33 V	35 V
41.5	Pass	Pass	Pass
42.0	Pass	Pass	Pass
42.5	Pass	Pass	Pass
43.0	Pass	Pass	Pass

RUGGEDNESS IN APPLICATIONS

After the on-wafer pulsed current voltage ruggedness measurements, several ruggedness tests are performed in the application circuitry, the most common one being a measurement of the VSWR. In data sheets, a VSWR of 10:1 is typically specified under nominal power conditions.

A wider bandwidth operation is required for more complex signals like W-CDMA. This puts heavier constraints to the broadband decoupling of circuits. The LDMOS device has to withstand signal deformations due to a non-ideal decoupling. To test the wideband ruggedness, a video bandwidth (VBW) measurement is performed. In a VBW test, a signal with 2 tones in compression is applied, with a tone spacing of Δf. The tone spacing is increased until the device fails. Such a VBW test is shown in ***Table 1*** for the base station LDMOS technology with a Δf of 80 MHz. This is a typical bandwidth for multi-slot W-CDMA amplifiers. Usually the LDMOS is operated at 32 V, but the devices pass up to 35 V supply voltage with this 80 MHz tone spacing as shown in the table.

Extremely rugged devices are in the high voltage technology families. These devices operate at 42 to 50 V at UHF or VHF frequencies, low frequencies where the most ruggedness demands exist. In ***Figure 11***, the VSWR versus output power is plotted for drain supplies of 50 and 55 V applied to a BLF578 device for a signal at 225 MHz with a 20 percent duty cycle. As predicted by the on-wafer tests (discussed in the ruggedness characterization section), the device can easily tolerate 55 V drain voltage in combination with a VSWR of 20 and a power of 1.4 kW, values far above the nominal operation settings.



▲ *Fig. 11 VSWR ruggedness measurement at various output power for a pulsed CW (with 20% duty cycle) signal at 225 MHz.*

CONCLUSION

Various ruggedness reliability tests have been described for RF power transistors. Pulsed on-wafer snapback measurements during the development and VSWR and video bandwidth tests in the application circuitry are used to optimize the ruggedness of 28-42-50 V LDMOS technologies. Extremely rugged devices have been developed in combination with state-of-the-art RF performance. ■

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References

1. F. van Rijs and S.J.C.H. Theeuwen, "Efficiency Improvement of LDMOS Transistors for Base Stations: Towards the Theoretical Limit," *2006 International Electron Devices Meeting Digest*, pp. 205-208.
2. S.J.C.H. Theeuwen and H. Mollee, "LDMOS Transistors in Power Microwave Applications," December 2008 White Paper at *Microwave Journal* website, http://www.mwjournal.com/search/article.asp?HH_ID=AR_6871.
3. S.J.C.H. Theeuwen, W.J.A.M. Sneijers, J.G.E. Klappe and J.A.M. de Boet, "High Voltage RF LDMOS Technology for Broadcast Applications," *Proceedings of the Third European Microwave Integrated Circuits Conference*, 2008, EuMIC02-2, pp. 24-27.

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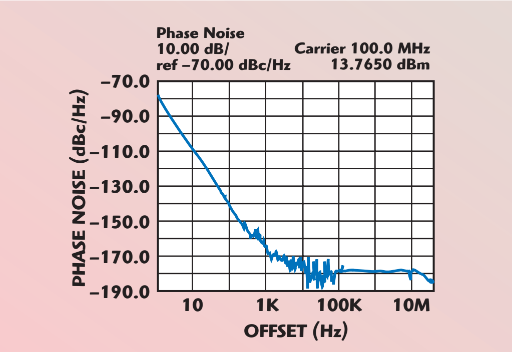
Over the past 50 years crystal oscillators have become ubiquitous wherever a stable reference is needed in RF systems. Oven-controlled Crystal Oscillators (OCXO) in the 5 to 10 MHz range are typically used to provide very stable frequency references, or where ultra-low phase noise is required very close to carrier, at offsets up to about 10 Hz. Also, the high Q of the crystal (typically >10^6 for 3rd-overtone SC-cut) exerts extremely tight control over the oscillator circuit, and crystals with very low phase noise are available.



▲ *Fig. 1 Standard Pascall 100 MHz OCXO phase noise.*

Applications such as phase noise measurement systems, high performance radars and frequency synthesizers generally need low phase noise floors at offsets in the tens to hundreds of kHz region. It is not possible to achieve the required performance by direct multiplication or PLL synthesis from 10 MHz OCXOs because of the 20log(N) relationship which applies when a frequency is multiplied by N. For example, deriving a 1.6 GHz signal from 10 MHz will increase the phase noise by 44 dB. Even if the 10 MHz oscillator has a very low phase noise floor of -175 dBc/Hz, for example, the lowest possible floor at 1.6 GHz is -131 dBc/Hz, even before the noise added by the multiplier or PLL is taken into account.

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VHF OCXOs can provide low close-to-carrier phase noise at the same time as offering an improvement of 20 dB or more in noise floor when used as a reference for multipliers or synthesizers. The standard Pascall OCXO offers best-in-class close-in phase noise combined with a very low noise floor. ***Figure 1*** shows a phase noise plot of a 100 MHz level E OCXO, which has a guaranteed specification of -137 dBc/Hz at 100 Hz offset.

However, enquiries from customers, together with a desire to enhance the performance of Pascall's synthesizer products, suggested that there would be useful benefits for the most demanding applications if the OCXO's noise floor could be reduced. This prompted the development of the new F-series OCXO, which has a lower noise floor while preserving the good close-to-carrier phase noise of the original oscillator.

DEVELOPMENT CONSIDERATIONS

When developing the F-series OCXO it was important to understand and take into account the many mechanisms that can make an oscillator unexpectedly noisy and some of them are extremely subtle. For instance, put simply, a tuned oscillator is a feedback system in which the phase shift round the loop is a whole number of cycles at the operating frequency. The primary frequency control mechanism involves a tuned circuit or resonator. At low offsets this acts as a frequency discriminator, converting frequency variation into phase shift. The oscillator operates at a frequency at which the resonator's phase shift compensates for that of the maintaining circuit.

Also, in addition to the phase shift criterion, the magnitude of the loop gain must be unity. This is generally achieved either by limiting within the oscillator circuit or by an ALC loop.

Because the combined phase shift of the resonator and the maintaining circuit is a whole number of cycles at the operating frequency, any phase perturbation originating within the maintaining circuit requires a compensatory phase change in the resonator. This results in a corresponding frequency shift. In this way, when an amplifier with flat phase noise is used in an oscillator, it will produce a signal with flat FM noise. As ΦM sideband amplitude is proportional to phase modulation and phase is the integral of frequency with respect to time, this leads to the characteristic 20 dB/decade slope seen round the carrier frequency.

Higher-Q resonators give more phase shift for a given change in frequency. In an oscillator this mechanism is used in reverse, so less frequency change is incurred for a given phase perturbation, leading to lower phase noise. This applies equally whether the phase disturbance originates from within the oscillator circuit or externally, from load variation or power supply noise. Hence, high Q is a good thing.

At lower offsets, various mechanisms cause the maintaining circuit to produce flicker phase modulation which the oscillator loop converts to flicker FM noise, giving a 30 dB/decade slope close to carrier.

The phase noise floor depends on both the signal level within the oscillator and the way the output is extracted from it. Compromises often have to be reached between load pulling, noise floor and close-in phase noise.

This description doesn't cover AM noise, though. In a well-designed oscillator, however, it is generally much lower than the phase noise close to carrier, and typically falls to a similar floor at large offsets, so it isn't normally a significant problem.

On the other hand crystal oscillators generally have much worse phase noise than would be predicted from the circuit noise and the resonator Q. This is because the crystals themselves exhibit 1/f FM noise, which translates to $1/f^3$ phase noise. In low noise oscillator designs, the close-to-carrier noise is generally dominated by the crystal's noise rather than its loaded Q or the circuit noise. Therefore, crystal selection is essential if low phase noise is important, as there can be more than 20 dB variation even within a single batch of crystals.

High Q is still important, as it reduces the oscillator circuit's contribution to close-in noise, and minimizes supply pushing and load pulling. At frequencies around 100 MHz, 5th-overtone SC-cut crystals offer the best combination of low noise and high Q,

together with a flat frequency/temperature characteristic at their turnover point, typically about 80°C.

DESIGN CONSIDERATIONS

All of these factors are of importance, but practical oscillator design almost always involves compromises and trade-offs. The F-series OCXO aims to provide the lowest possible phase noise within a relatively compact 2 x 2 x 0.75 inch package.

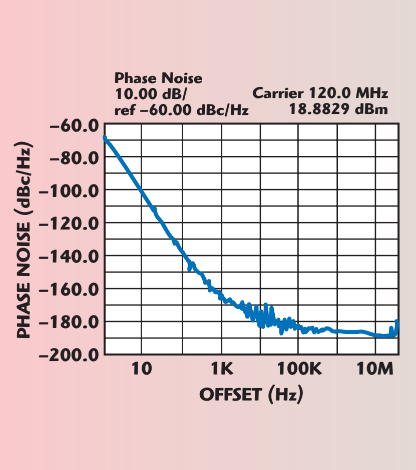
The OCXO incorporates a low noise regulator followed by further filtering to maximize rejection of external supply noise and ripple. In particular, careful attention is paid to ground paths, in order to prevent oven current noise affecting the oscillator's performance. The oscillator is based very closely on the company's standard OCXO design, with the active devices operated linearly because nonlinear operation generally increases the transistors' flicker noise and also increases modulation of the signal by power supply noise and ripple. The degree of degradation tends to vary with factors such as crystal motional resistance, temperature, etc. Linear operation also gives more predictable RF operating conditions, which helps when tuning the oscillator on either side of the crystal's series resonance.

The extra-low noise floor of the F-series OCXO is achieved by maintaining high signal levels within the output amplifier. The signal is taken from the oscillator in a way that maximizes the power into the amplifier while using the resonator to reduce far-from-carrier noise.

TABLE I

F-SERIES OCXO PERFORMANCE AT 100 MHz

Parameter	Value
Tuning range	$\pm\geq 6\times10^{-6}$
Tune voltage	0 to +10 V; positive slope
Temperature stability	$\pm\leq 2\times10^{-7}$ w. r. t. 25°C;-30 to +70°C
Output power	18 dBm ± 2 dB
Harmonics	≤-30 dBc
Phase noise (guaranteed)	
10 Hz offset	≤-102 dBc/Hz
100 Hz offset	≤-137 dBc/Hz
1 kHz offset	≤-164 dBc/Hz
10 kHz offset	≤-178 dBc/Hz
≥100 kHz offset	≤-182 dBc/Hz
Supply voltage	+12 V ±0.5%
Warm-up power	≤ 6 W
Steady-state power	≤3.5 W at 25°C



▲ *Fig. 2 Pascall F-series 120 MHz phase noise.*

PERFORMANCE

The F-series has the same close-in phase noise as the standard Pascall OCXO, together with improved noise floor and higher output power. ***Table 1*** summarizes the performance offered at 100 MHz. Note that the phase noise is guaranteed minimum performance, not typical figures.

The first application for the new OCXO design was at 120 MHz. ***Figure 2*** shows a phase noise plot. The phase noise of crystals rises fairly rapidly with increasing frequency, so it is not possible to achieve the same close-in performance at 120 MHz as at 100 MHz. However, the plot clearly shows the improved phase noise floor.

Measurement of very low phase noise floor presents a serious challenge, and needs cross-correlation to push the test system's added noise below that of the DUT. In this instance, the indicated performance in the 10 to 70 kHz range is probably limited by the test set.

APPLICATIONS

With its exceptionally low phase noise floor, the F-series OCXO is ideally suited for driving ultra-low-noise frequency multipliers, phase detectors and mixers. Its high output power means that an additional drive am-

plifier will not normally be needed, thereby eliminating another source of noise.

For applications that do not require such a low noise floor, the standard OCXO may be a more appropriate choice as it has lower power consumption but still offers the same close-to-carrier performance. However, the extra-low far-from-carrier noise of the F-series can help designers to achieve real performance improvements in state-of-the-art systems such as high performance radars, ultra-low noise frequency synthesizers and phase noise test systems.

CONCLUSION

The new F-series OCXO combines the close-in phase noise performance of the company's standard OCXO with an even lower noise floor and higher output power, offering designers a new tool to improve system performance in the most demanding applications. The oscillator has an ample electrical tuning range of $\pm \geq 6 \times 10^{-6}$, with mechanical tuning available as an alternative, and is in a standard 2 x 2 x 0.75 inch package size.

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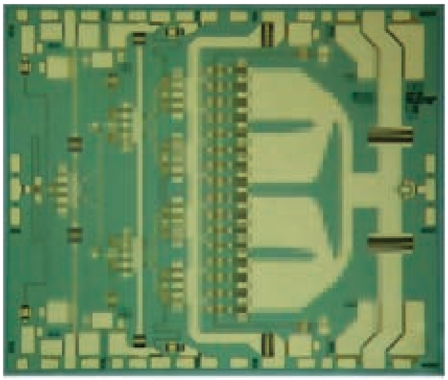


MILLIMETER-WAVE MMICS DELIVER KA-BAND POWER

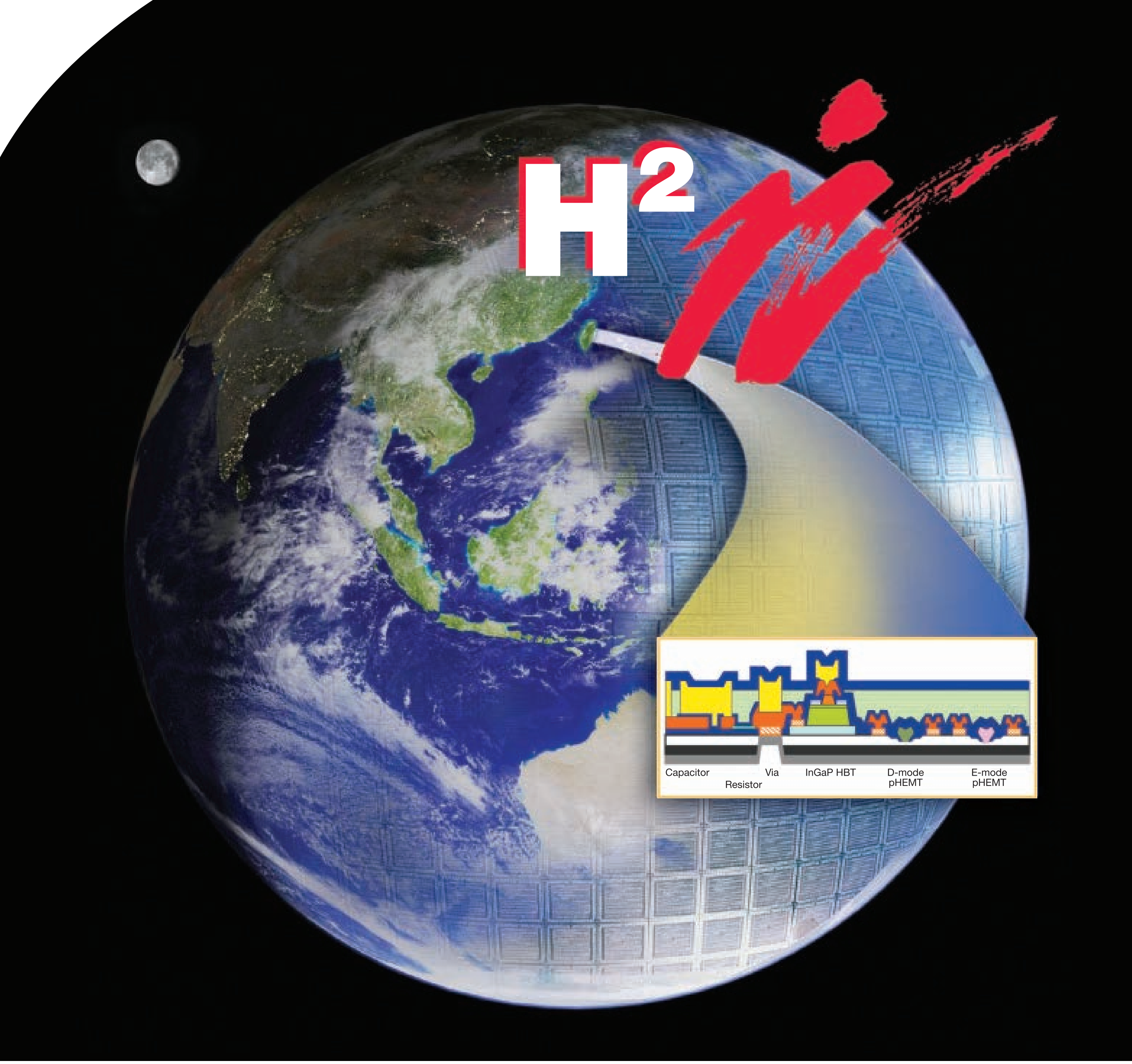
High speed MMICs were historically developed for the United States military and included systems for high data rate network-centric communications, anti-jamming and low detection/interception warfare communications. The millimeter-wave frequency range provides benefits such as broader bandwidth, smaller antennas and greater security. Recently, military millimeter-wave activity has been overshadowed by the growth of commercial sector applications, such as point-to-point and point-to-multipoint radios, VSAT terminals, automotive radar, high speed digital communication networks, sensors and direct broadcast satellite television applications. With this shift, however, still comes a need for high volume Ka-band transmitters to address emerging and traditional military applications.

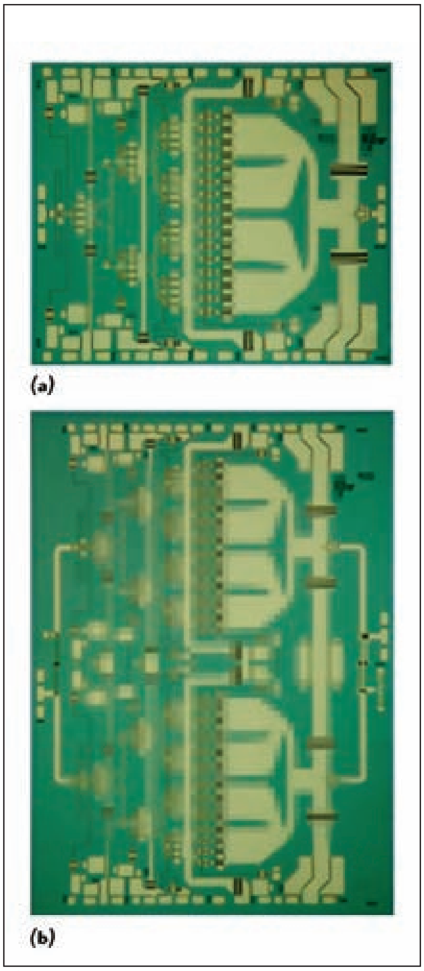
Mimix Broadband has developed two power amplifiers based on a new four-stage 34 to 37 GHz MMIC design. These power amplifiers utilize the company's GaAs PHEMT device technology and electron beam lithography to ensure the highest level of repeatability and uniformity needed for both commercial and military applications. Robust thermal performance and standard 4 mil die thickness also make the device useful in both manual and automated assembly operations. The XP1072-BD multi-stage amplifier, ***Figure 1a***, delivers over 35 dBm of pulsed saturated output power and 22 dB small-signal gain (see ***Figure 2a***). The XP1073-BD device, ***Figure 1b***, is a balanced amplifier version that provides over 37 dBm of pulsed saturated output power and 22 dB small-signal gain (see ***Figure 2b***).

PERFORMANCE

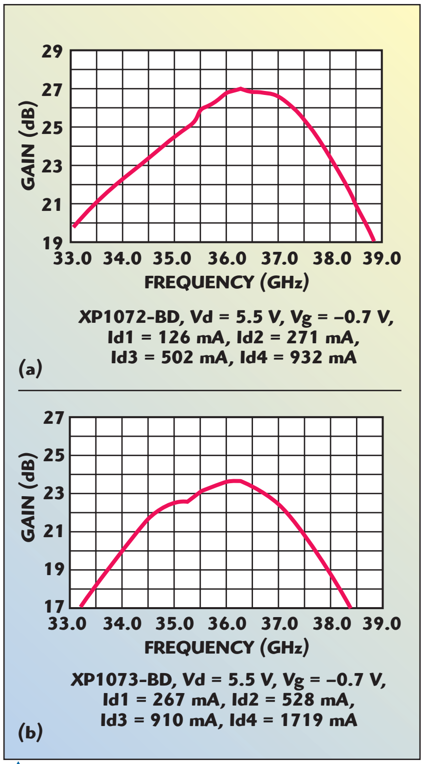
The XP1072-BD operates on a recommended drain voltage of 5.5 V DC and a nominal –0.7 V DC on the gates. Separate biasing of the stages within the amplifier is recommended if the amplifier is to be used in a linear application or at high levels of saturation, where gate rectification will alter the effective

MIMIX BROADBAND INC.
Houston, TX


H2
Capacitor
Resistor
Via
InGaP HBT
D-mode pHEMT
E-mode pHEMT



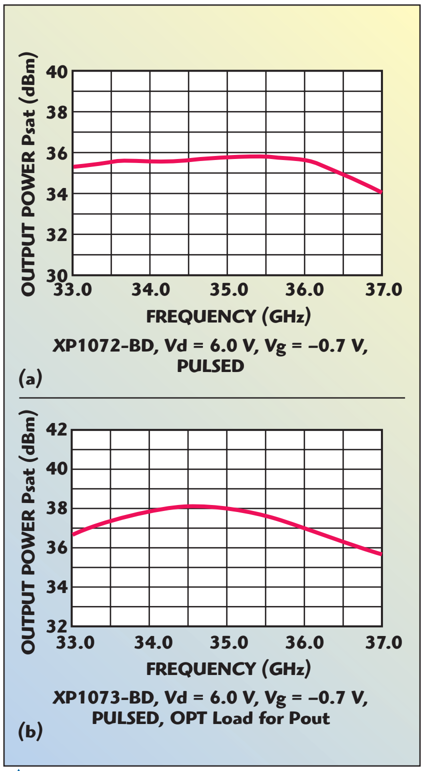
▲ *Fig. 1 Photo of XP1072-BD (a) and XP1073-BD (b).*



▲ *Fig. 2 XP1072-BD (a) and XP1073-BD (b) measured on-wafer gain.*

gate control voltage. For non-critical applications it is possible to parallel all stages and adjust the common gate voltage for a total drain current Id (total) = 2400 mA (maximum 3.0 amps). The power added efficiency for the single die version is 25 percent and 24 percent for the balanced version. The rated operating temperature of the device is between –55° and +85°C.

For applications such as radar, where the amplifier RF output power is saturated, the optimum drain current will vary with RF drive and each amplifier stage is best operated at a constant gate voltage. Significant gate currents will flow at saturation and bias circuitry must allow for drain current growth under this condition to achieve the best RF output power and power added efficiency. Additionally, if the input RF power level varies significantly, a more negative gate voltage will result in less die heating at lower RF input drive levels where



▲ *Fig. 3 XP1072-BD (a) and XP1073-BD (b) output power.*

the absence of RF cooling becomes significant. Note under this bias condition, gain will then vary with RF

MINIATURE C-BAND & X-BAND VCO'S

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MICROWAVE CORPORATION

Model	Frequency Range (MHz)	Tuning Voltage (VDC)	DC Bias VDC @ I [Typ.]	Phase Noise @ 10 kHz (dBc/Hz) [Typ.]	Size (Inch)
DCO Series					
DCO1198-8	1198.4 - 1198.7	0.5 - 7.5	+8 @ 30 mA	-116	[illegible]
DCO170340-5	**1700 - 3400**	**0.5 - 24**	**+5 @ 24 mA**	**-90**	[illegible]
DCO200400-5 **DCO200400-3**	**2000 - 4000**	**0.5 - 18**	**+5 @ 35 mA** **+3 @ 35 mA**	**-90** **-89**	**0.3 x [illegible] 0.1**
DCO300600-5 **DCO300600-3**	**3000 - 6000**	**0.5 - 18**	**+5 @ 35 mA** **+3 @ 35 mA**	**-80** **-78**	**0.3 x 0.3 x 0.1**
DCO400800-5 **DCO400800-3**	**4000 - 8000**	**0.5 - 18**	**+5 @ 35 mA** **+3 @ 35 mA**	**-78** **-76**	**0.3 x 0.3 x 0.1**
DCO432493-5 DCO432493-3	4325 - 4950	0.5 - 11	+5 @ 17 mA +3 @ 17 mA	-88 -86	0.3 x 0.3 x 0.1
DCO473542-5 DCO473542-3	4730 - 5420	0.5 - 22	+5 @ 20 mA +3 @ 20 mA	-88 -86	0.3 x 0.3 x 0.1
DCO490517-5 DCO490517-3	4900 - 5175	0.5 - 5	+5 @ 22 mA +3 @ 22 mA	-88 -86	0.3 x 0.3 x 0.1
DCO495550-5 DCO495550-3	4950 - 5500	0.5 - 12	+5 @ 22 mA +3 @ 22 mA	-87 -85	0.3 x 0.3 x 0.1
DCO608634-5 DCO608634-3	6080 - 6340	0.5 - 5	+5 @ 22 mA +3 @ 22 mA	-86 -84	0.3 x 0.3 x 0.1
DCO615712-5 DCO615712-3	6150 - 7120	0.5 - 18	+5 @ 22 mA +3 @ 22 mA	-85 -83	0.3 x 0.3 x 0.1
DXO Series					
DXO810900-5 DXO810900-3	8100 - 8800	0.5 - 16	+5 @ 22 mA +3 @ 22 mA	-82 -80	0.3 x 0.3 x 0.1
DXO900965-5 DXO900965-3	9000 - 9650	0.5 - 16	+5 @ 22 mA +3 @ 22 mA	-80 -78	0.3 x 0.3 x 0.1

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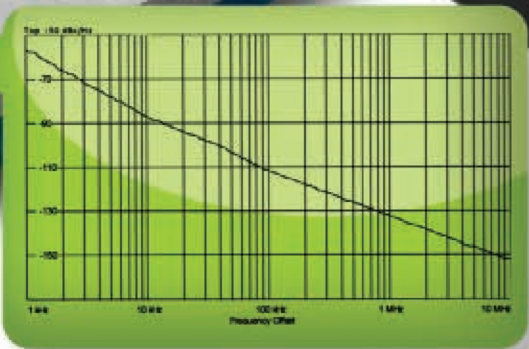

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drive. Output power as a function of frequency is shown for both devices in ***Figure 3***, demonstrating the amplifier's performance.

For linear applications where optimum IM3 (Third-Order Intermod) performance is required at more than 5 dB below P1dB, active gate biasing can be implemented to keep the drain currents constant as the RF power and temperature vary. Active biasing of the gates gives the best performance and most reproducible results. Depending on the supply voltage available and the power dissipation constraints, the bias circuit may be a single transistor or a low power operational amplifier, with a low value resistor in series with the drain supply used to sense the current. The gate voltage of the PHEMT is controlled to maintain the desired drain current and provides an indirect form of temperature compensation.

APPLICATIONS

These amplifiers focus on serving market applications where performance (saturated power and PAE), compact size and extreme ruggedness are primary drivers. While new applications are emerging, RADAR is probably the most closely targeted application, using FMCW on missiles and munitions. Another likely defense application is Ka-band for battlefield resource tracking and management. Airborne applications include landing systems for commercial fixed wing aircraft and precision altimeters for rotary craft on the military side. In many cases, these parts will reside behind small antenna elements or arrays on small platforms and therefore the devices are offered in die form as preferred by most of the system integrators working at these frequencies and power levels.

While lower power MMIC solutions are currently available, these devices are limited to power levels that in the past required 2 or 4 way combining to achieve the required output power. Due to circuit losses, combining lower power devices leads to diminished performance, hurting overall power and efficiency while increasing the substrate footprint. Conversely, combining with this device raises the ceiling of what was thought possible with solid-state amplifiers. Multiple die combined in an array provide a solid-state solution for RADAR applications. Multiple gain stages eliminate drivers, and the balanced design offers better VSWR and greater power from a single part. Power combining naturally becomes more painful as you go up in frequency. This device eliminates or reduces the need to combine die in many applications. With a reduced part count, using these MMICs to design high power solid-state amplifiers offers the benefits of lower complexity and simpler assembly, leading to higher yield and optimal results.

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Papers should first be submitted as a 1 to 2 page summary. Please refer to the detailed author instructions provided on the conference web site www.comcas.org.

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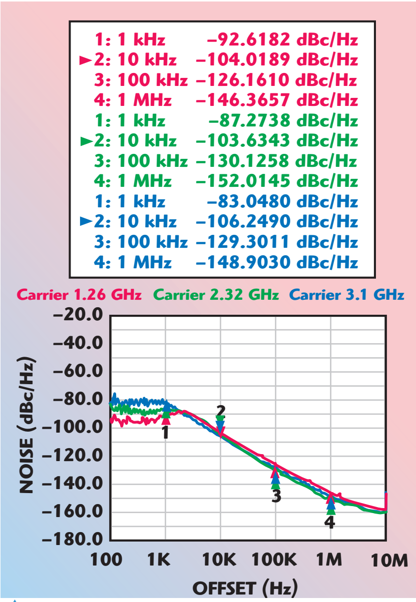
DROP-IN INDUSTRY REPLACEMENT FREQUENCY SYNTHESIZERS

EM Research has developed the ZLX Series of drop-in frequency synthesizers with models operating from 800 MHz to 3.8 GHz that are replacements for many industry standard PLOs and synthesizers. The ZLX Series is a cost-effective replacement that provides design engineers with improved signal source performance without any need to modify the circuit board or design and can be used in a wide variety of applications.



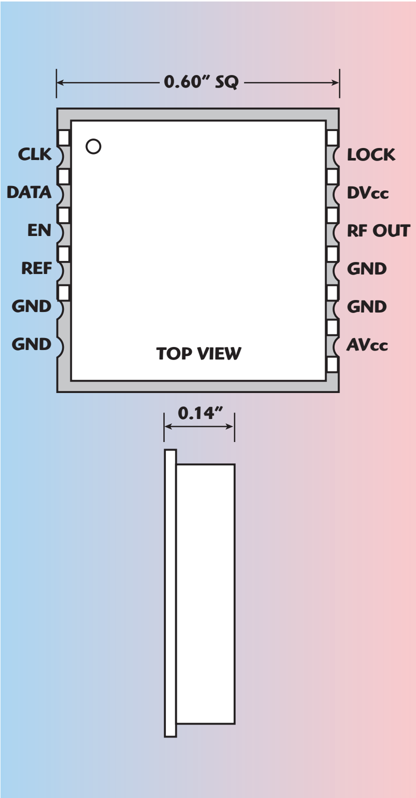
▲ *Fig. 1 Phase noise plots for 1.26, 2.32 and 3.1 GHz.*

The ZLX can be custom-designed to operate fixed or programmable from less than 800 MHz to over 3.8 GHz and is housed in a standard commercial surface-mount package. The ZLX offers extremely low phase noise; for example, less than −106 dBc/Hz at 10 kHz offset and −129 at dBc/Hz at 100 kHz offset at an output frequency of 3.1 GHz. The ZLX Series also provides low power consumption of less than 100 mW at +3.3 VDC operating voltage. ***Figure 1*** shows sample phase noise plots for three different frequencies (1.26, 2.32 and 3.1 GHz).

The bandwidth can be fixed or programmable (serial interface) up to 30 percent bandwidth with output power from 0 to +7 dBm. ***Table 1*** shows typical performance parameters for various models over the frequency range available. All models are available in the drop-in replacement housing measuring 0.6 x 0.6 x 0.14 inches (15.24 x 15.24 x 3.6 mm). ***Figure 2*** shows the outline drawing including pin outs.

The ZLX Series is available for high volume production and can be used in a wide variety of applications including commercial wireless, base station and subsystems, mobile radios, SatCom, point-to-point/multi-point radios, WiMAX, 2G and 3G repeaters, CATV and wireless infrastructure. EM Research provides the option of RoHS and non-RoHS designs on all products including the ZLX Series.

EM RESEARCH INC.
Reno, NV



▲ *Fig. 2 ZLX package outline and pin-out.*

TABLE I

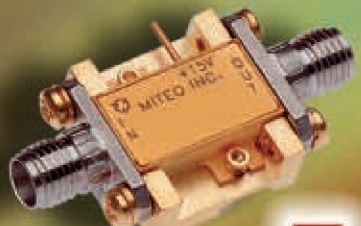
TYPICAL PERFORMANCE FOR SELECT MODELS

Model #	Freq. (MHz)	Power Out (dBm)	Harmonics (dBc)	Phase Noise, typ. (dBc/Hz) 10 kHz	Phase Noise, typ. (dBc/Hz) 100 kHz	Spurious (dBc)	Supply Voltage (Vdc)	Supply Current (mA)
ZLX-800-XX	800	+7	-20	-105	-125	-70	+5	55
ZLX-832-XX	832	+7	-20	-105	-125	-70	+5	55
ZLX-1030-XX	1030	+7	-20	-100	-120	-70	+5	55
ZLX-1090-XX	1090	+7	-20	-100	-120	-70	+5	55
ZLX-1260-XX	1260	+2	-20	-100	-120	-70	+5	40
ZLX-1410-XX	1410	+2	-20	-100	-120	-70	+5	40
ZLX-1620-XX	1620	+2	-20	-100	-120	-70	+5	40
ZLX-1850-XX	1850	+2	-20	-100	-120	-70	+5	40
ZLX-2090-XX	2090	+2	-20	-100	-120	-70	+5	40
ZLX-2320-XX	2320	+2	-20	-100	-120	-70	+5	40
ZLX-2700-XX	2700	+2	-20	-100	-120	-70	+5	40
ZLX-3100-XX	3100	+2	-20	-100	-120	-70	+5	40
ZLX-3200-XX	3200	+7	-20	-98	-118	-70	+5	55
ZLX-3500-XX	3500	+7	-20	-98	-118	-70	+5	55
ZLX-3800-XX	3800	+7	-20	-98	-118	-70	+5	55

As a cost-effective, pin-for-pin footprint-compatible design, the ZLX Series eliminates the need for rework or modification of the printed circuit board, while providing critical performance advantages over the competing products. The ZLX Series is ideal for design engineers looking for a functionally superior, drop-in industry replacement synthesizer.

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

RS No. 302



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- Variable Gain
- Limiter Input
- TTL Controlled
- High Dynamic Range
- Equalized Gain
- Built-in Test
- Detected Output
- Military Versions
- Space Qualified

Model Number	Frequency Range (GHz)	Gain (Min./Max.) (dB)	Gain Flatness (±dB)	Noise Figure (dB, Max.)	VSWR Input (Max.)	VSWR Output (Max.)	Output Power @ 1 dB Comp. (dBm, Min.)	Nom. DC Power (+15 V, mA)
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.

3 YEAR WARRANTY

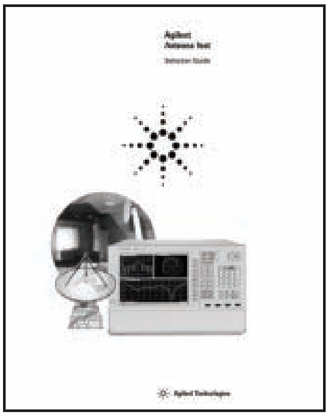
nqa. ISO 9001 Registered ANAB

RoHS compliant Available

This is only a small sample of our extensive list of standard catalog items. Please contact our Sales Department at (631) 439-9220 or e-mail components@miteq.com for additional information or to discuss your custom requirements.

MITEQ

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



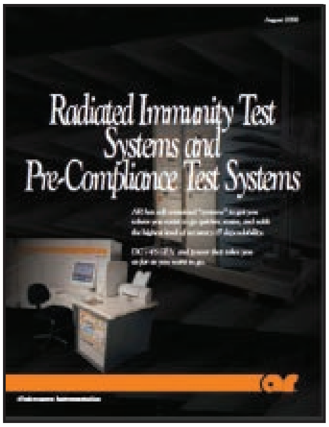
Selection Guide

VENDORVIEW

Agilent's updated Antenna Test Selection Guide now includes the PNA-X measurement receiver that offers a 30 percent faster data acquisition speed than any other antenna receiver on the market. This selection guide helps customers select the hardware necessary to make accurate antenna and radar and cross-section measurements. This guide shows customers how to easily migrate to the PNA-X receiver, understand issues related to antenna equipment selection, and provides insight about interface requirements between components.

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

RS No. 310



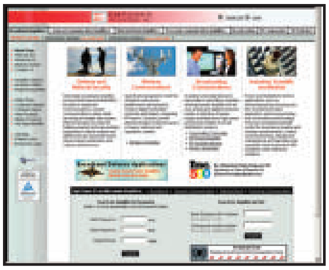
AR Systems Brochure

VENDORVIEW

AR RF/Microwave Instrumentation's newest brochure highlights the company's systems' capabilities and ARCell Precompliance Test Systems. AR has the capabilities to customize systems to solve your RF and EMC test problems with the power and frequency you need—from 10 kHz to 45 GHz. The ARCell systems are out-of-the-box immunity and emissions test systems that perform precompliance testing to IEC 61000-4-3 requirements as well as other industry specific standards.

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

RS No. 311



Interactive Product Catalog

The Empower RF website provides a comprehensive, user-friendly selection of the company's products and functionality to configure and submit quote requests. The site features a parametric search engine and a collection of RF engineer's applets such as a watts-to-dBm converter, gain calculator and links to contact Empower's sales team. There is also a mobile-friendly version accessible from devices such as a RIM Blackberry.

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

RS No. 312

Designer's Guide

VENDORVIEW

This 14th edition Designer's Guide catalog includes 100 new digital, mixed-signal, RF, microwave and millimeter-wave product datasheets, as well as quality/reliability, application and packaging/layout information. Full specifications are provided for 730 products across 20 product lines, including: amplifiers, attenuators, data converters, frequency dividers/detectors, frequency multipliers, high speed digital logic, interface, LIAs, mixers, demodulators/modulators, passives, phase shifters, PLLs, power detectors, sensors, switches, synthesizers, TIAs, VGAs and VCOs/PLOs.

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

RS No. 313

Test and Measurement Solutions

The best measurement set-up is only as good as its weakest link and in order to obtain reliable and reproducible measurement results, particular care must be taken in selecting the right components required for the measurement set-up. Therefore, this catalog highlights the company's extensive range of high-quality components that are matched to the various needs of test and measurement applications. The order number of the catalog is: No. 84068138.

HUBER+SUHNER AG, Herisau, Switzerland +41 71 353 4111, www.hubersuhner.com.

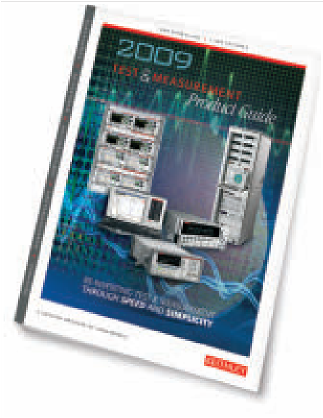
RS No. 314

Product Catalog

K & L Microwave's 128-page catalog can be used as a desktop reference guide that offers details and specifications to help designers and engineers choose products quickly. Integrated assemblies and a wide assortment of lumped component, cavity, ceramic and suspended substrate filters are among the many types of products featured in this catalog.

K & L Microwave, Salisbury, MD (410) 749-2424, www.klmicrowave.com, www.klfilterwizard.com.

RS No. 318



Test and Measurement Product Guide

Keithley's 2009 product guide includes information on the company's latest hardware and software innovations to address challenging test and measurement applications, as well as informative tutorials and selector guides. To request your free copy, visit www.keithley.com/at/556 or call (800) 588-9238.

Keithley Instruments Inc.,
Cleveland, OH (800) 588-9238, www.keithley.com.

RS No. 315

Product Catalog

VENDORVIEW

MECA's latest 104-page catalog (Volume 8) features many new products in the company's extensive line of RF/microwave components with industry leading performance, including fixed attenuators, directional and hybrid couplers, isolators/circulators, power divider/combiners, RF loads, DC blocks and bias tees and cable and adapters. Also included is an extensive RF glossary, frequency allocation charts, application notes, conversion tables, diagrams and microwave formulas.

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

RS No. 317

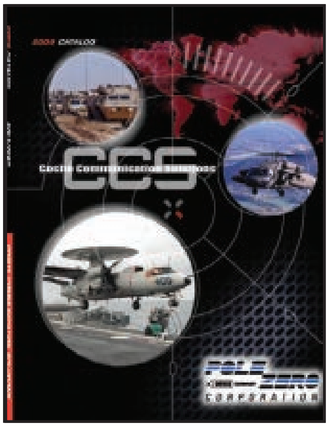
Component CD Catalog

VENDORVIEW

This full-line CD Components Catalog offers a comprehensive display of standard and custom capabilities. The CD includes thousands of pages of product specifications, outline drawings, test data, manufacturing flow diagrams, and a wide assortment of technical application notes. MITEQ designs and manufactures state-of-the-art microwave components such as UHF to millimeter-wave low-noise and medium power amplifiers, mixers, multipliers, switches, frequency sources, IF signal processing equipment, fiber optics and integrated microwave subassemblies. Emphasis is on high performance, custom engineering driven applications.

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

RS No. 319

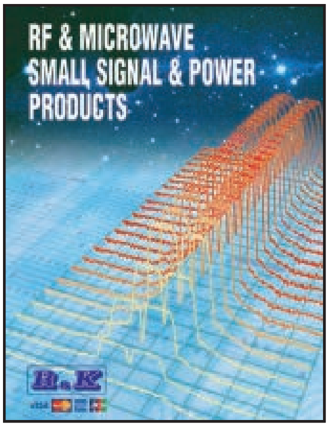


Tunable RF Filter Catalog

Are you looking for tunable RF bandpass and notch filters? Do you need pre/post-selectors, filter/amplifier cascades or LNAs? In the new 2009 catalog, Pole/Zero offers a complete line of tunable cosite filter products in the 1.5 MHz to 2 GHz range. Call or visit the website to get your copy and solve your tunable filter needs today.

Pole/Zero Corp.,
West Chester, OH (513) 870-9060, www.polezero.com.

RS No. 320



RF/Microwave Small Signal & Power Products

This comprehensive 600-page catalog provides full specifications and dimensional information, along with typical plotted performance for over 400 of the company's standard RF and microwave products. These include power amplifiers, low noise amplifiers, mixers, power dividers/combiners, couplers, switches, filters and many more. In particular, there is a section featuring connector and surface-mount modules that cover the DC to 16 GHz frequency range.

R&K Co. Ltd.,
Fuji-city, Shizuoka, Japan +81 545 31 2600,
www.rk-microwave.com.

RS No. 316

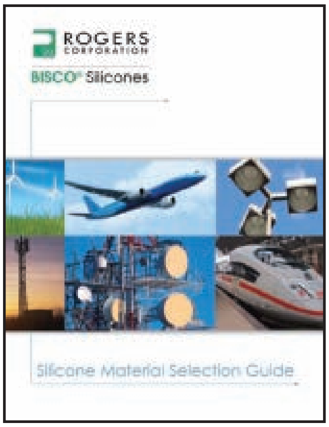
Coax Connector Solutions Catalog

The new 156-page RF Connectors Coax Connector Solutions Catalog highlights the company's line of coaxial connectors, adapters, tools and kits. It is available free of charge. The guide provides product specifications, stripping guidelines and photos for over 1200 coaxial products stocked for shipping. Extensive coverage is given to classic connector lines, such as BNC, TNC, N, UHF, Mini-UHF, SMA, SMB, MCX, MMCX, 7-16 DIN, FME, and those compatible with LMR® cables. Available in print, on CD and the company's website.

RF Connectors,
San Diego, CA (858) 549-6340, www.rfindustries.com.

RS No. 321

CATALOG UPDATE



Material Selection Guide

VENDORVIEW

This 16-page Material Selection Guide features the company's BISCO® Silicone material. These materials, which are offered in cellular, solid and specialty grades, are used in a wide range of markets, from transportation and communications to electronics and high intensity lighting. Applications include gaskets and seals, high temperature PCB thermal insulation and battery shields, automotive heat shields, and vibration and acoustic mitigation pads. The new BISCO Selection Guide includes product samples and tips for materials selection based on market applications.

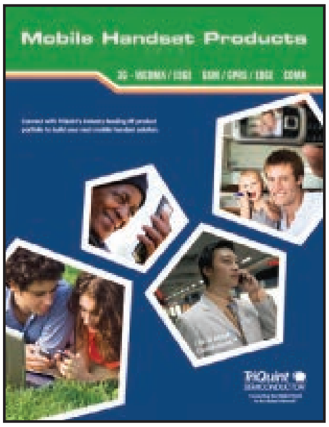
Rogers Corp., Rogers, CT (800) 237-2068, www.rogerscorp.com.
RS No. 322

Product Brochure

VENDORVIEW

San-tron Inc., a manufacturer of RF coaxial connectors and cable assemblies, has announced the release of its "RF & Microwave Coaxial Connectors and Cable Assemblies" brochure. The brochure outlines the company's entire product offering, categorized by connector types. Connector offerings include, but are not limited to, SMA, N, BNC, TNC, HN and 7/16 connectors. Adapters, cable assemblies and custom specialty connectors are also featured. The brochure is now available at www.santron.com.

San-tron Inc.,
Ipswich, MA (978) 356-1585, www.santron.com.
RS No. 323

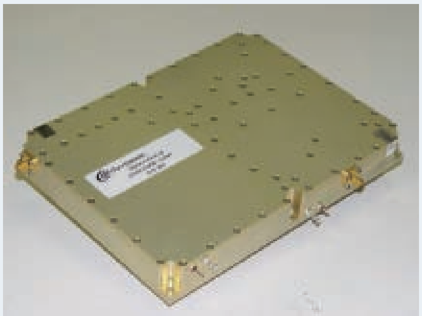


Mobile Handset Brochure

Are you building 3G/W-CDMA, GSM/GPRS/EDGE or CDMA mobile devices? Need an innovative RF solutions partner with high efficiency, high performance products delivered in compact packaging? Download TriQuint's latest Mobile Handset Brochure at www.triquint.com/prodserv/brochures/handset_brochure.pdf and find RF solutions for datacards and phones ranging from ultra-low cost to data centric.

TriQuint Semiconductor Inc.,
Hillsboro, OR (503) 615-9000, www.triquint.com.
RS No. 324

Multi-octave Power Amplifier

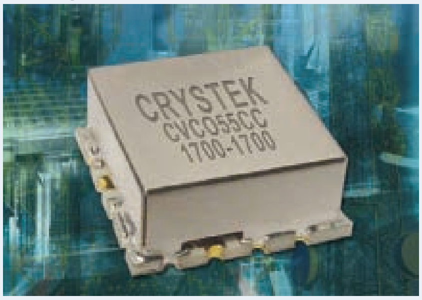


Model number SSPA 4.0-8.0-10 is a high power, broadband, RF amplifier that operates from 2 to 8 GHz. This PA is ideal for broadband military platforms as well as commercial applications because it is robust and offers high power over a multi-octave bandwidth. This amplifier operates with a base plate temperature -20° to +65°C. It is packaged in a modular housing that is approximately 6" by 8" by 1".

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

RS No. 216

Voltage-controlled Oscillator



Crystek's CVCO55CC-1700-1700 voltage-controlled oscillator (VCO) operates at 1700 MHz with a control voltage range of 0.3 to 4.7 V. This VCO features a typical phase noise of -120 dBc/Hz at 10 kHz offset and offers excellent linearity. Output power is typically +2.5 dBm. Engineered and manufactured in the US, the model CVCO55CC-1700-1700 is packaged in the industry-standard 0.5" × 0.5" SMD package. Input voltage is 5 V, with a maximum current consumption of 25 mA. Pulling and pushing are minimized to 1 MHz and 0.5 MHz/V, respectively. Second harmonic suppression is -15 dBc typical. Price: $18.46 each in volume.

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

RS No. 217

RF Power Transistors
VENDORVIEW

These laterally diffused metal oxide semiconductor (LDMOS) RF power transistors are designed to meet growing demand for reduced power consumption in cellular transmitters. Freescale's eighth generation high voltage (HV8) RF Power LDMOS technology is engineered specifically to meet the stringent demands of high-data rate applications such as W-CDMA and WiMAX, as well as emerging standards such as LTE and Multicarrier GSM. The portfolio of devices based on HV8 technology is optimized for operation in advanced power amplifier architectures, which includes Doherty used in combination with digital pre-distortion (DPD). A primary benefit of Freescale's HV8 technology is the increase in operating efficiency that helps reduce total power consumption of a base station system, thereby reducing operating costs.

Freescale Semiconductor, Austin, TX (800) 521-6274, www.freescale.com.

RS No. 218

Temperature-compensated Crystal Oscillator

The T124 Series of TCXOs is an ultra-low frequency oscillator that is available down to 650 Hz in a low profile, compact SMT package. The T124 Series TCXOs, available from 650 Hz to 1.25 MHz, provide extremely stable, low frequency square-wave output (temperature stability to ±0.3 ppm over -40° to +85°C). The T124 features 3.3 V input voltage and EFC (electrical frequency control, optional) to adjust for long-term aging. The T124 utilizes a rugged, AT strip crystal to provide superior aging characteristics to 3 ppm over 15 years. With compact size and low power consumption, the T124 Series is ideally suited to low jitter clocking for mobile RF applications.

Greenray Industries Inc., Mechanicsburg, PA (717) 766-0223, www.greenrayindustries.com.

RS No. 219

Variable Gain Amplifiers
VENDORVIEW

These digital variable gain amplifiers are ideal for automotive, broadband, cellular/3G, WiMAX/4G, military and test & measurement equipment applications between 30 and 1000 MHz. The HMC680LP4(E) is a digitally-controlled variable gain amplifier that operates from 30 to 400 MHz, and can be programmed to provide from -4 to 19 dB of gain, in 1 dB steps. The HMC681LP5(E) is a digitally-controlled variable gain amplifier that operates from DC to 1 GHz, and can be programmed to provide from 13.5 dB, to 45 dB of gain, in 0.5 dB steps.

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

RS No. 220

SATCOM Pre-filter Amplifier

The SATCOM pre-filter amplifier provides 30 1 dB of transmit band rejection with minimum impact on LNA noise figure. This RF module combines a low-loss input filter with a low noise amplifier, followed by a final clean-up filter. The entire module is housed in a small surface-mount package measuring 4" × 1" × 0.5". Microstrip input and output launches facilitate PCB attachment. Typical noise figure is 1.2 dB with 14 dB gain. The LNA is set for 14 dB gain, but can be set as high as 20 dB. The input filter minimizes transmit band co-site interference, reducing transmit third-order products in the SATCOM receive band. A final bandpass filter further reduces out-of-band interference for a clean receive channel signal. The entire cascade maintains less than 1 dB flatness across the full receive band. The module operates from a single 5 V power supply with a small 65 mA current draw.

K&L Microwave, Salisbury, MD (410) 749-2424, www.klmicrowave.com.

RS No. 221

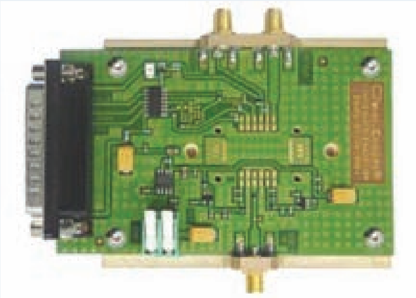
MMIC Power Amplifier
VENDORVIEW

The XP1072-BD is a GaAs MMIC high power amplifier with +35 dBm pulsed saturated output power and 22 dB large signal gain. This power amplifier covers 34 to 37 GHz and achieves 25 percent power added efficiency (PAE). The device is well suited for millimeter-wave military, radar, satellite and weather applications. This XP1072-BD multi-stage amplifier delivers industry leading power and efficiency for

Ka-band applications, with a saturated output power of nearly 4 W, providing a boost to applications that require both high power and efficiency in a small area.
Mimix Broadband Inc., Houston, TX (281) 988-4600, www.mimixbroadband.com.

RS No. 222

56 to 6010 MHz Synthesizers



Mini-Circuits design team can create a custom frequency synthesizer tailored to meet your specific requirements. They will review your requirements and, following technical discussions between your engineers and Mini-Circuits designers, will work closely with you to create final specifications that meet or exceed your requirements. To ensure high yields, the company will factor in component tolerances and even variations in manufacturing processes. You will have full access to performance data from sample units, and can even evaluate sample units in your system to ensure that final production units fulfill your performance requirements. For more information, visit www.minicircuits.com.
Mini-Circuits, Brooklyn, NY (718) 934-4500, www.minicircuits.com.

RS No. 251

High Performance Amplifiers

VENDORVIEW

MITEQ's cost-effective high performance LCN amplifier series are now available in frequency ranges from 1 to 2, 2 to 4, 4 to 8, 8 to 12, 12 to 18, 6 to 18 and 2 to 18 GHz. These amplifiers offer excellent low noise figures and great single unit pricing starting at $325.00. The LCN series amplifiers are available from stock, have industry standard hermetic housings, removable SMA connectors and drop in compatibility.
MITEQ Inc., Hauppauge, NY (631) 439-9220, www.miteq.com.

RS No. 223

Power Amplifiers

VENDORVIEW

RFMD's RF720x family of W-CDMA/HSPA+ power amplifiers (PA) is comprised of four PAs designed for 3G multimode devices implementing mode-specific, band-specific front-end architectures. The RF720x product family accommodates all major W-CDMA/HSPA+ bands and band combinations and is optimized to mate with reference designs from the industry's leading open market 3G chipset supplier. The RF7200 (band 1), RF7206 (band 2), RF7203 (band 3, 4, 9 or 10) and the RF7211 (band 11) are designed for single-band operation, while the RF7201 (band 1/8), RF7202 (band 2/5) and the RF7205 (band 1/5) feature two band-specific PAs integrated in a single module package.
RFMD, Greensboro, NC (336) 664-1233, www.rfmd.com.

RS No. 224

Low Noise General Purpose Amplifier

The SKY65038-70LF is a low noise amplifier that operates in a frequency range from 250 MHz to 6 GHz. The SKY65038 is a general purpose, broadband amplifier fabricated from Skyworks' PHEMT process and packaged in a miniature SOT-89 package. The amplifier's low noise figure of 2 dB and high output IP3 of 40 dBm at 1 GHz allows these devices to be used in various transmit/receive applications. In addition, the amplifier's output impedance is 50 Ω, which enables these devices to be easily cascaded with a simple input impedance matching network.
Skyworks Solutions Inc., Woburn, MA (781) 376-3000, www.skyworksinc.com.

RS No. 225

Bi-directional Power Amplifier

The SMTR2425-11B40-2 is a military grade bi-directional power amplifier (PA) that is capable of up to 10 W of 802.11b and 2 W of 802.11g or 802.16. Primary applications include: WLAN, video link and C2 products for UAVs. The unit operates from 2.4 to 2.5 GHz and outputs +40 dBm exceeding 802.11b EVM requirements. Transmit/receive gains are 25 and 16 dB, respectively. The PA measures 3.5" × 2.9" × 0.56" and weighs approximately 4 oz.
Stealth Microwave Inc., Trenton, NJ (888) 772-7791, www.stealthmicrowave.com.

RS No. 226

Ultra-low Noise VCXO

The VFVX100 VCXO is a low jitter and phase noise timing solution for Universal Edge QAM. The VFVX100 provides a PECL or LVPECL output with a frequency range of 200 MHz to 1 GHz (245.76 MHz STD). With less than 0.2 ps jitter, the VFVX100 gives a cleaner I-Q constellation, providing lower BER's and higher data throughput. Wider pull ranges of ±20 to ±100 ppm are available with phase noise of -142 dBc/Hz at 10 kHz offset for 622.08 MHz. Operating at +3.3 or +5 V power supply, the VFVX100 typically consumes 0.25 W. The VFVX100 is available in a 9.0 × 14.0 mm surface-mount package and is RoHS 6/6 compliant.
Valpey Fisher Corp., Hopkinton, MA (508) 435-6831, www.valpeyfisher.com.

RS No. 227

Voltage-controlled Oscillator

The model CRO0410A-LF is a new RoHS compliant voltage-controlled oscillator (VCO) in the UHF band. The CRO0410A-LF operates in a frequency range from 390 to 430 MHz with a tuning voltage range of 0.5 to 4.5 VDC. This VCO features a typical phase noise of -117 dBc/Hz at 10 kHz offset and a typical tuning sensitivity of 17 MHz/V. The CRO0410A-LF is designed to deliver a typical output power of -4 dBm at 5 VDC supply while drawing 36 mA (typical) over the temperature range of -30° to 70°C. This VCO features typical second harmonic suppression of -15 dBc and comes in Z-Comm's industry standard MINI-16 package measuring 0.5" × 0.5" × 0.22".
Z-Communications Inc., San Diego, CA (858) 621-2700, www.zcomm.com.

RS No. 228

Components

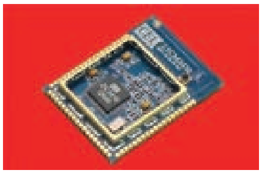
SMA Attenuators

Designed for volume applications and available from stock, Aeroflex Inmet's AHC family of SMA attenuators offer performance at an affordable price. These 2 W units operate in a frequency range from DC to 6 GHz with a 1.20 VSWR while providing excellent attenuation flatness. Built for ruggedness, the AHC attenuators are available in dB values of 1-12, 15, 20 and 30.

Aeroflex/Inmet, Ann Arbor, MI
(877) 367-7369, www.rfmw.com/inmet.

RS No. 229

ZigBee Radio Transceiver



CEL is now shipping its MeshConnect ZigBee radio module, adding to its rapidly growing line of ZigBee/IEEE 802.15.4 transceiver solutions. The module, based on CEL's own MeshConnect single chip integrated circuit (IC), is unique in its ability to deliver market-leading RF performance and range with a very low cost design. It is FCC, CE and IC certified, eliminating costly and time consuming regulatory testing. In conjunction with its development kit, the module is a complete hardware platform with a choice of software tools that enable customers get to market quickly and efficiently.

California Eastern Laboratories (CEL), Santa Clara, CA (408) 919-2500, www.cel.com.

RS No. 230

SPDT Coaxial Switch

The D2Series SPDT coaxial switches come in a variety of connectors, such as BNC, TNC, N Type, and SMA. Models operate in a frequency range from DC to 12.4 GHz. Actuator options come in Latching and in Failsafe modes, also available are units with TTL circuitry and Integrated Indicator circuits. These switches offer an RF impedance of 50 ohms nominal; operating temperature of -35° to +85°C ambient; operating life of 1,000,000+ cycles; switching time of 35 mSec maximum; switching sequence of Break before Make; and environmentally designed to meet MIL-E-5400 and Mil-S-3928.

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

RS No. 231

Flexible Coaxial Cable Assembly

This highly flexible series of phase stable M/W flexible coaxial cable assemblies provides accurate and reliable measurements and claims to offer better performance than general flexible cable assemblies. Typical phase and amplitude stability is ±4° and ±0.08 dB up to 18 GHz. With an impedance of 50 Ω, the PS-Series exhibits a typical insertion loss for 1 m (including two connectors) of 1.6 dB at 18 GHz and has a VSWR of 1.3 up to 18 GHz.

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

RS No. 232

Low Pass Filter

Part number 2515-S is a surface-mount 50 MHz group delay and amplitude equalized low pass elliptic filter. The filter offers a typical insertion loss of 1 dB. Passband ripple to 50 MHz is 0.25 dB maximum and the filter attains over 40 dB by 68 MHz and over 60 dB by 73.6 MHz. Group delay variation is < 5 nsec to 44 MHz and typically < 7 nsec to 50 MHz. The filter is supplied in a surface-mount package measuring 2" × 0.5" × 0.3" and can also be supplied connectorized. The filter can be customized for other center frequencies and bandwidths.

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

RS No. 233

In-building Combiner Diplexer

Lorch Commercial and Wireless (LCW) offers WP-E056-1, a combiner diplexer that covers the full PCS and AWS frequencies. The combiner diplexer exhibits less than 1 dB of insertion loss across the passbands of 1710 to 1755/2110 to 2155 MHz and 1850 to 1990 MHz while providing greater than 60 dB of isolation. The unit measures 7" × 5" × 2", is well suited for in-building applications and is available from stock.

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

RS No. 234

Drop-in Isolators and Circulators

These drop-in isolators and circulators are designed for 802.11a broadband systems operating in the frequency range of 5.15 to 5.825 GHz. These ferrite devices offer 20 dB isolation over the frequency range of 5.15 to 5.825, allowing manufacturers to stock one device for all 12 of the 802.11a channels. The isolators and circulators feature small dimensions (0.375" × 0.500"), and use ceramic magnets for reliability. Isolators include a termination rated at 10 W.

M2 Global Technology Ltd., San Antonio, TX (210) 561-4800, www.m2global.com.

RS No. 235

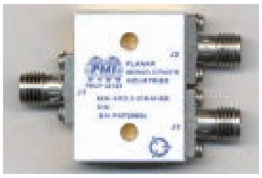
SMP Connectors

Phoenix's SMP series subminiature connectors offer superior electrical performance from DC to 26.5 GHz. Blind-mate feature allows for board-to-board, cable mount and PCB mount. In-series adapters provide solutions for rack and panel applications. All products manufactured to Mil-Std-348. Features include: subminiature size for high density applications; snap feature for quick mating and reduced assembly time; axial alignment reduces stress from multiple blindmate connections; gang mating is possible. It compensates for up to 0.020" radial and axial misalignment (when used with an adapter); and center-to-center spacing of 0.170".

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

RS No. 236

Power Divider

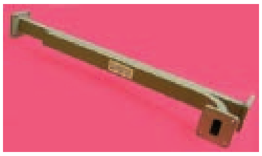


The model DP-2-218-M-BB is a miniature power divider designed to operate in a frequency range from 2 to 18 GHz. The power divider offers an insertion loss of only 2.2 dB maximum, isolation of 16 dB minimum and a VSWR of 2.0 maximum. The power handling is 1.5 W at 2.0 VSWR and 2.0 W at 1.2 VSWR. The size is only 0.779" × 1.026" × 0.300" with the connector shrouds removed.

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

RS No. 237

Waveguide Broadwall Coupler



RLC Electronics offers a standard range of multi-hole broadwall directional couplers that operate in a frequency range from 2.6 to 40 GHz in standard waveguide sizes. The electrical characteristics of high directivity and coupling flatness are achieved by using a precise machined coupling hole pattern and a precision load in the secondary arm. Non-standard configurations or selected electrical parameters are available on request.

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

RS No. 238

2009 National Conference on Microwave and Millimeter Wave in China (NCMMW)

2009 MICROWAVE INDUSTRY EXHIBITION IN CHINA

MIE 2009

SPONSORS:
Chinese Institute of Electronics (CIE)

ORGANIZERS:
Microwave Society of Chinese Institute of Electronics (CIE)
Xidian University
Kingradio Technology [Shenzhen] Co. Ltd.

COLLABORATING JOURNALS / WEBSITES:
Journal of microwaves
Mobile Communications
Microwave online(kilomega)
Microwave and RF network (mrfn)
Microwave Journal(mwjournal)

CONFERENCE / EXHIBITION DATE: May 23-26, 2009

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

BACKGROUND OF MICROWAVE INDUSTRY EXHIBITION IN CHINA

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

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

BACKGROUND OF NCMMW

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

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

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

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

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

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

NOTES:

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

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

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

WHY YOU SHOULD ATTEND?

MIE 2009 is the largest event of microwave field in China, which is organized by Microwave Society of Chinese Institute of Electronics.

MIE 2009 is where to provide a nice opportunity for the scientists and engineers specialized in the field of Microwave and Millimeter wave to present your new ideas and learn from each other.

MIE 2009 is where to provide a platform for enterprises engaged in Microwave Millimeter wave and RF field to publicize your company/ products in China.

EXHIBITORS TO BE ATTENDED:

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

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

FOR ENQUIRY,PLEASE CONTACT: Mr. Wei Zilun
TEL: 86-755-83655339
FAX: 86-755-83629073
EMAIL: kingradio@163.net, mwrf@vip.163.com
OR VISIT:

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

Antennas

Cavity Backed Spiral Antennas

Cobham SASL's ASO/AST-1492 2.4-inch diameter spiral antennas provide superior performance for use in applications requiring circular polarization. With excellent input VSWR, these antennas provide smooth broadband gain, low axial ratios and consistent pattern performance over 2 to 18 GHz. This model was designed and developed for radar warning receiver airborne applications. The ASO/AST 1492 series is available in either a left or right circular polarization antenna. A hemispherical radome is also available for this antenna. Customers can choose either a SMA Female connector (ASO-1492) or a TNC Female connector (AST-1492).

Cobham SASL, Lansdale, PA
(215) 996-2416, www.cobhamdes.com.

RS No. 239

Blade Array Antenna

The model 135DBA1 is a new C/D-band blade array antenna designed for airborne electronic support measures. This antenna provides five simultaneous outputs, four quadrant direction finding beams and an amplified omni-directional beam over the C/D-band frequency range. Model 135DBA1 has a vertical linear polarization and a VSWR of 3:1 maximum. The antenna is qualified for tactical aircraft applications and the radome cover is protected with rain erosion paint for extended life. The antenna also has the capability of integrated BITE function.

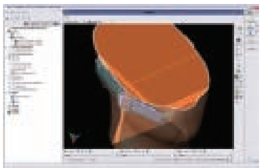
Cobham Sensor Systems - Sensor Electronics, Baltimore, MD
(410) 542-1700, www.cobhamdes.com.

RS No. 240

Software

EM Simulation Software

VENDORVIEW



Remcom announces the release of XFdtd® 7.0 (XF7), a new electromagnetic simulation tool for antenna design and analysis, biological EM analysis, microwave circuit design, and other EM simulation applications. XF7 marks a departure from other standard 3D EM solvers with a simplified and streamlined user interface, cross-platform functionality, and several time-saving features that are unique to the market. XF7's most important benefit is improved efficiency due to faster, easier simulation workflow.

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

RS No. 241

Foundry Process Design Kit

This process design kit (PDK) for H2W PH50-00 process includes enhancement/depletion-mode PHEMT and HBT process technology. The WIN PDK, developed for use with Advanced Design System (ADS) EDA software from Agilent Technologies, enables high frequency RF and microwave designers to create compact integrated circuits composed of power amplifiers, switches, low noise amplifiers, mixers and logic circuitry. The WIN PH50-00 kit supports a complete ADS front-to-back monolithic microwave integrated circuit (MMIC) design flow with design rule checker, and includes discontinuities models, scalable capacitors, inductors and resistors, pads, vias and nonlinear models for active devices (PHEMTs and HBT).

WIN Semiconductors Corp., www.winfoundry.com.

RS No. 242

Sources

Ku-band Compact Synthesizer

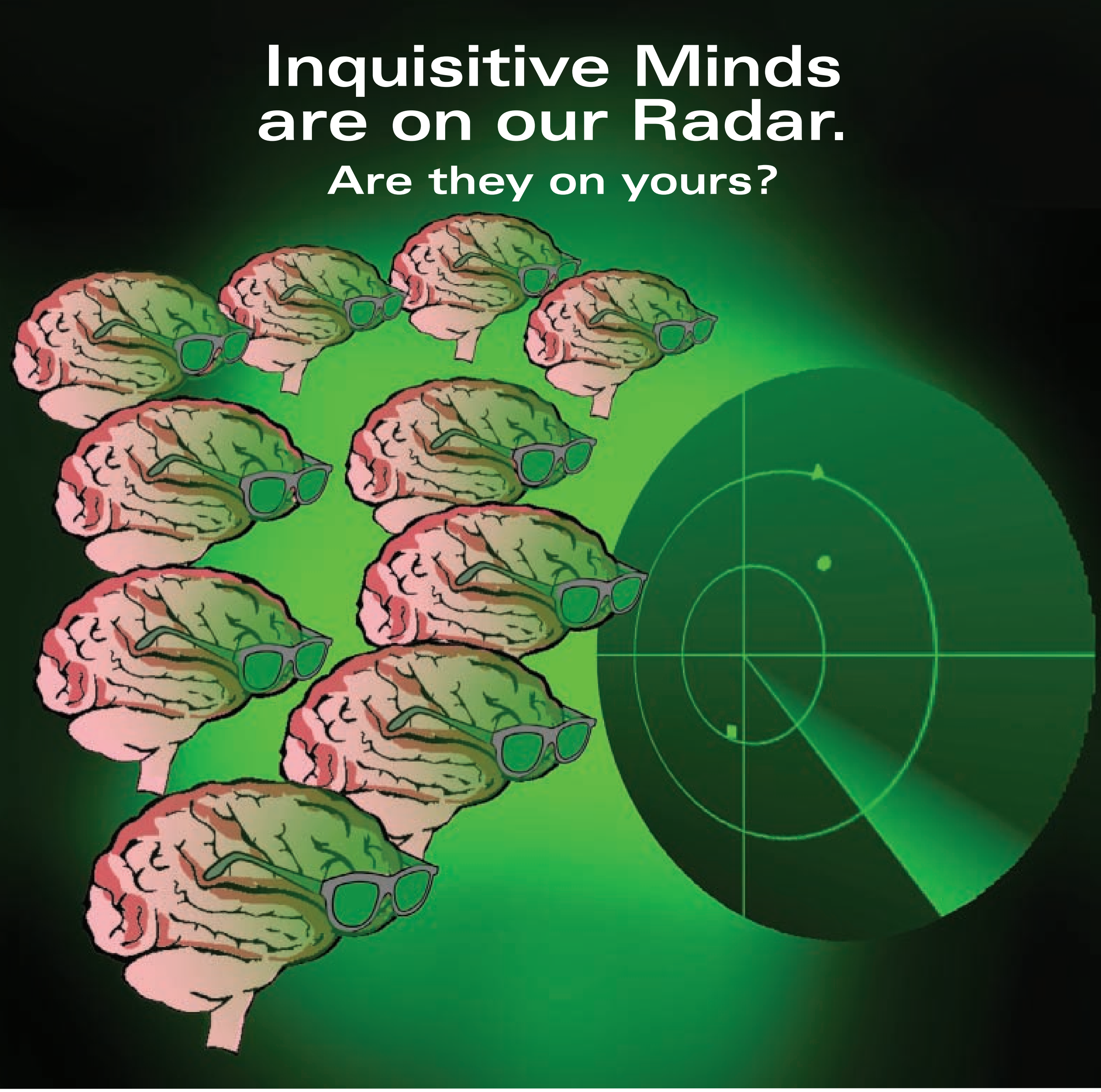
The BSVQ11 is a small, fine step Ku-band frequency synthesizer equipped with a LCD display to monitor the output frequency. It operates in the 11,500 to 13,700 MHz frequency range and can be stepped in 1 kHz increments. Due to its compact size (140 by 90 by 38 mm) it is suitable as an independent testing tool but can also be integrated into other test equipment. It has good internal reference stability (±0.2 ppm), spurious value (<- 50 dBc) and phase noise better than -100 dBc/Hz at 100 kHz away from the centre frequency. The BSVQ11 joins the company's product family that covers the 500 MHz to 18 GHz frequency range.

Bonn Hungary Electronics Ltd. (BHE), Budapest +36 1 233 2138, www.bhe-mw.eu.

RS No. 243

Frequency Synthesizer

The THOR-14000 frequency synthesizer is used as a local oscillator for a VSAT radio receiver. The unit operates from 13800 to 14000 MHz with 1 MHz step size utilizing a 10 MHz reference. The THOR-14000 features fast switching speeds (< 500 mSec), +7 dBm output power and low phase noise (<-85 dBc/Hz at 100 kHz typical). The THOR is housed in a connectorized (optional hermetically sealed), 2.5" × 1.1" × 0.4" package and features two removable SMA connectors that can be gull-winged for SMT applications. The THOR Series, Ku-/K-band frequency synthesizers are ideal for Manpack Radios, UAV, EW,


Inquisitive Minds
are on our Radar.
Are they on yours?

IED Jamming and other mobile applications requiring a high frequency, lightweight design with low power consumption.

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

RS No. 244

Composite N Receptacle

Radiall Composite N receptacle is made with a typical metal RF insert, maintaining the standard N dimensions and performance, and a composite (plastic) outer body or housing offered in a variety of colors. Composite N receptacles offer outstanding electrical performance and are the best compromise in terms of weight/cost/mechanical characteristics to replace existing brass technology. These connectors feature 100 percent compatibility with standard N brass connectors (MIL-STD-348-304); intermodulation performance of IMP3 < -115 dBm; low VSWR of 1.14 maximum at 6 GHz; 50 percent weight reduction; and corrosion free housing.

Radiall AEP Inc., New Haven, CT
(203) 776-2813, www.radiall.com.

RS No. 245

Temperature-compensated Crystal Oscillator

This ultra-compact temperature-compensated crystal oscillator (TCXO) features solderable reflow and SMD package base offers superior flatness. This TCXO is ultra-compact (2.0 × 1.6), low height (0.8t maximum) light weight and low current consumption type. High frequency (f0 = 52 MHz) and low frequency are available using built in 1/2 frequency divide down function. These TCXOs are RoHS compliant. Applications include: cell phone, base station, GPS and mobile radio application.

TEW America, San Jose, CA
(650) 962-8330, www.tewamerica.com.

RS No. 246

Subsystems

Two Down-converters

The FBC-xx-xx series is a down-converter for use as a frequency extender for noise figure measurement test systems. It is available in a 2U 19 inch rack system. The systems consist of a single waveguide input (WR-28 to WR-10) and an IF output (SMA-F). The RF input frequencies are down-converted to an IF in the 4 to 18 GHz range, which is suitable for frequency extending any standard noise figure analyzer. Also, the FBC-K-xx series is a down-converter for use with a 2 to 20 GHz tuned receiver, which is available in a 1U 19 inch rack system. The system consists of a three RF channel input with one IF output. The three channels are selectable by TTL control.

Farran Technology Ltd.,
Ballincollig, Co. Cork, Ireland,
+ 353 21 487 2814, www.farran.com.

RS No. 247

Rental Offer

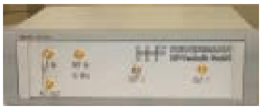
VENDORVIEW

AR has introduced a new rental plan with great low rates and an incredible buyout to make it easy to get the AR equipment you need now. With a three-month minimum rental, credit towards a buyout will accumulate at 90 percent of each rental payment—up to 95 percent of the list price. For full details on AR's rental program, please visit the company's website at www.ar-worldwide.com.

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

RS No. 248

Comb Generator



The innovative SG-CG1 comb generator has a wide input frequency range from 30 MHz to 4 GHz, a low input power requirement of 0 dBm and its output harmonics reaches 18 GHz. It is applicable with an internal (100 to 200 MHz) or external synthesizer. Features include two ECL compatible outputs, 400 kHz tuning step size and PC interface (serial/USB). It can be used for a wide range of applications such as frequency multipliers, signal generators, EMC source, UWB applications and FMCW radars.

Heuermann HF-Technik GmbH,
Aachen, Germany +49 (0) 241 6009-52108,
www.hhft.de.

RS No. 249

Test Equipment

Next-generation PHS Technology

VENDORVIEW

Anritsu Co. introduces test solutions that support next-generation PHS (XGP: eXtended Global Platform) to help ensure the successful rollout of XGP in the marketplace. Three software packages have been developed for use with Anritsu's MS269xA signal analyzers and MG3700A vector signal generator to offer designers and manufacturers of XGP mobile devices, base stations and devices a test solution to ensure the performance of their products and speed time to market. The MX269016A XG-PHS Measurement Software and the MX269909A XG-PHS IQproducer are for use with the MS269xA series, while the MX370109A XG-PHS IQproducer PC software is for the MG3700A.

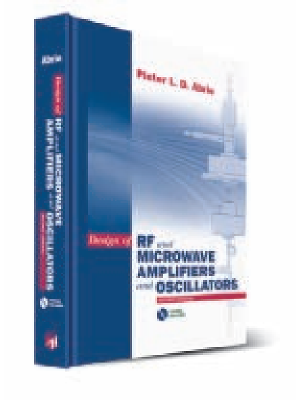
Anritsu Co., Richardson, TX
(800) 267-4878, www.anritsu.com.

RS No. 250

MICRO-ADS

Visit http://mwj.hotims.com/23284-(RS#)

Design of RF and Microwave Amplifiers and Oscillators, Second Edition



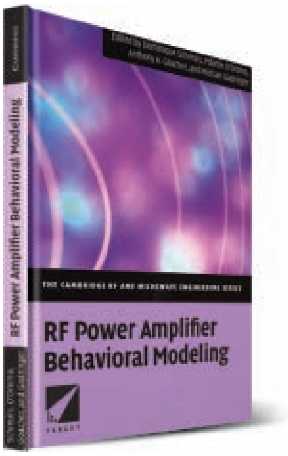
Pieter L.D. Abrie

This newly revised edition of this classic book has been updated to include expanded derivations and problem sets, helping to make the material even more accessible and easier to master. The second edition adds critical coverage of nodal analysis and derivation of the power parameters for simple FET and bipolar transistors. There is also a new chapter on wideband distributed amplifier design, more focus on power amplifiers, and new tables of network elements for resistive matching networks over various passbands. This practical book helps one estimate the 1 dB compression point of class A and class B linear circuits, initialize the fundamental component voltages and currents in a harmonic balance simulator, and more easily generate load-pull contours for class A and class B transistors. Considered as a generalization of the Cripps approach, this book presents an independently developed method that can be applied easily to control or predict the output power in single- or multi-stage amplifiers.

To order this book, contact:

Artech House · 685 Canton St. · Norwood, MA 02062 · (781) 769-9750 ext. 4030; or
16 Sussex St. · London SW1V 4RW, UK · +44 (0) 207-8750
600 pages; $118, £63 · ISBN: 978-1-59693-098-8

RF Power Amplifier Behavioral Modeling



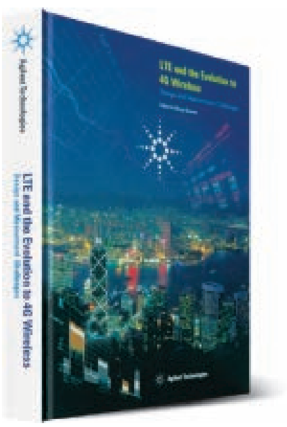
Dominique Schreurs, Mairtin O'Droma, Anthony A. Goacher and Michael Gadringer, Eds.

This is a very good book for the engineer or RF designer who is working with wireless transmitter power amplifier models as a comprehensive and up-to-date review of nonlinear theory and power amplifier modeling techniques. Including a detailed treatment of nonlinear theory, as well as chapters on memory effects, implementation in commercial circuit simulators and validation, this one-stop reference makes power amplifier modeling more accessible by connecting the mathematics with the practicalities of RF power amplifier design. The book explains systematically how to evaluate a model's accuracy and validity, compares model types and offers recommendations as to which model to use in which situation.

To order this book, contact:

Cambridge University Press · 100 Brook Hill Drive · West Nyack, NY 10994-2133 · (845) 353-7500
288 pages; $99 · ISBN: 978-0-52188-173-9

LTE and the Evolution to 4G Wireless—Design and Measurement Challenges



Moray Rumney, Ed.

This book draws on the expertise of engineers in Agilent Technologies with contributions by Anite and LTE expert K.F. Tsang to present valuable insight into the LTE specifications and its design and verification challenges. It begins with an LTE overview, describes the evolution from UMTS and how to access the LTE specifications before offering insights into air interface concepts such as OFDMA, SC-FDMA, the new uplink transmission scheme and MIMO. It aims to provide an understanding of FDD and TDD physical layers and upper layer signaling, and describes the System Architecture Evolution (SAE) project. The book provides a detailed study of the extensive range of design and measurement techniques and tools that are available to help bring LTE from theory to deployment. It offers the latest information on RF and signaling conformance testing and concludes by looking toward 4G – LTE Advanced.

To order this book, visit:

www.agilent.com/find/ltebook
455 pages; $100 · ISBN: 978-9-88179-351-5

Hiring RF Engineers: Matching Personality and Organization

Whether you are hiring or looking to be hired, a resume is an inevitable introductory step. For us RF engineers, a typical resume is very much like a technical spec sheet, detailing the diverse range of skill-sets to include every achievement, course and technology.

Yet, one aspect is often ignored—the human perspective.

Microwave engineers typically seek to satisfy more than one goal when making a career decision. They also tend to get bored if the job is not challenging enough or if the professional challenges turn out not to be within their line of interest. Workplace environment is a factor affecting the success of the match because it relates to personal likes and dislikes. Successful placement will therefore have the engineer placed in a position where he or she is most comfortable, creative and passionate about their job.

Many hiring managers include and highlight the workplace environment among other benefits in published job descriptions. They know that this increases the value of their proposition. These recruiters have already realized what people look for in a workplace beyond compensation and technology. In a similar way, the manager reading through piles of resumes is looking for the person behind the skills.

The words of wisdom in the article below highlight these important and often overlooked aspects when writing your resume. These observations really boil down to the basic things people look for in a workplace, in colleagues and employees. This is definitely something to think about when writing your resume or reading someone else's.

Isaac Mendelson
ElectroMagneticCareers.com
Isaac@ElectroMagneticCareers.com

The Boring Resume: Who Are YOU

Our DC to Light crowd is undoubtedly made up of great engineers, technologists and researchers, but to sift through these resumes is like reading one technical paper after another. Don't get me wrong—you will be hired for your technical skills and your ability to produce for the company.

The resumes I see just bore me to death and I know why. You have all read books on "How to Write an Effective Resume" written by an unemployed person.

Rules of Thumb:

1. Put yourself in the position of the person that may want to hire you. Imagine trying to cram 13 years of experience on to one page. That cannot work!

2. Write as many pages as you think the hiring manager will be interested in for the position.

3. Show that you are versatile and can multitask, which will be an asset to the department and company.

4. List your goals so the company will know what you want.

Who You Are:

With my almost 40 years of recruiting primarily in the RF/microwave/defense fields, I have found that people who are interesting get hired first even if they have less experience.

When I interview a candidate I also interview the spouse (if they have one) and the children. I look for the family's goals and interests (hobbies) to insure that the hiring company is right for them including location.

For example, a small paragraph at the end of the resume stating:

My outside interests are running, white water rafting, volcano hiking, fishing (salt water), golf, hiking and reading.

I am married to Mary who is a volunteer for the Red Cross, and has a part-time business teaching people basic computer skills.

We have two children, Jack who plays soccer and swims on the school team, and Jenny, who is a violinist and plays field hockey. Both children are on the dean's list.

With this, you have given to the company your personality and a better reason to hire "A PERSON". All this extra shows WHO You ARE beyond a spec-sheet of skills.

David Germond
Cleared Executive Search
dave@clearedsearch.com
(813) 425-3100

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20	Ciao Wireless, Inc.	42	805-389-3224	805-389-3629	http://mwj.hotims.com/23284-20
21,22	Cobham Defense Electronic Systems	11,20-21	215-996-2000		http://mwj.hotims.com/23284-21
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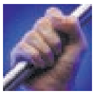

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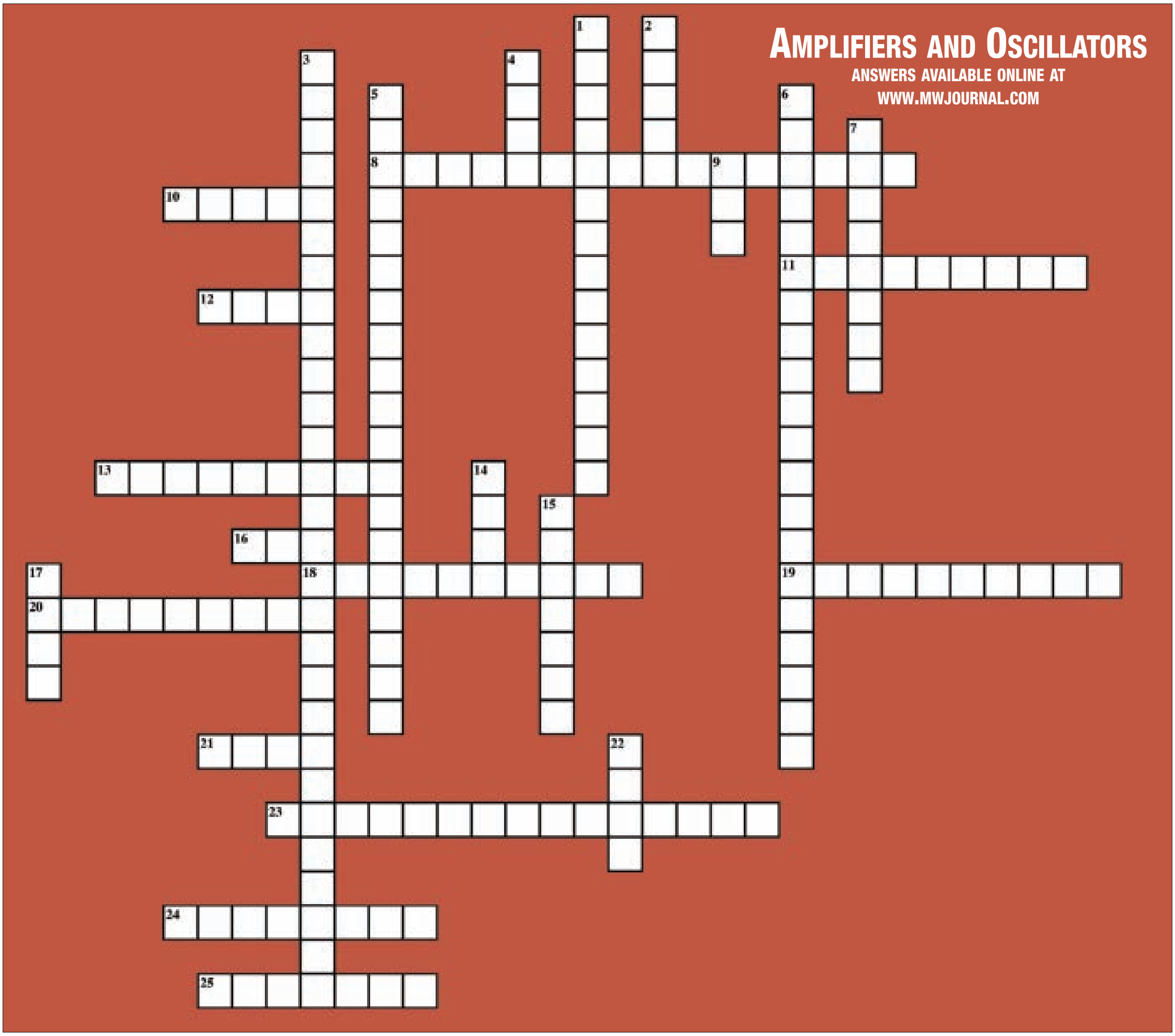

ACROSS

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

10 Pseudo-morphic high electron mobility transistor

11 A circuit or device whose output signal is a faithful version of the input signal but with increased amplitude

12 The terminal of a field effect transistor that controls the resistance of the channel through the application of an electric field

13 The state of operation of a device or circuit in which there is no increase in output for an increase in input

16 Phase-locked loop

18 A measure of the random phase instability of a signal (2 words)

19 A circuit that produces an alternating current signal

20 The region of a bipolar transistor into which current flows from the base of the transistor under the influence of reverse bias across the two regions

21 Complementary metal oxide semiconductor

23 The change in frequency of the oscillator after it has been driven to and attained a new frequency and after the tuning voltage has reached a stable state (3 words)

24 Undesired signals present at the output of a device under test that are neither harmonics nor intermodulation products

25 The failure mode in a device that is induced by excessive power dissipation in the device

DOWN

1 Wideband gap material being used to produce very high power amplifiers (2 words)

2 Laterally diffused metal oxide semiconductor

3 The digital implementation of the predistorter and presence of a feedback loop adapting to the changes in the response of the PA due to varying operating conditions (3 words)

4 Adjacent channel leakage ratio

5 The modification of the magnitude of a higher, constant frequency carrier signal controlled by the amplitude and phase of a lower frequency baseband or audio signal (2 words)

6 A feedback system that changes the gain of an amplifier or the attenuation of an attenuator in response to variations in magnitude of the input signal, thereby maintaining the output signal of the system (3 words)

7 The process of varying the impedance seen by the output of an amplifier to other than 50 ohms in order to measure performance parameters (2 words)

9 Peak to average power ratio

14 The ratio between the amplitude of the output signal of a device or circuit compared to the amplitude of the input signal

15 The layer of a bipolar transistor through which all current flows and from which majority carriers are injected into the base of the transistor

17 Oven-controlled crystal oscillator

22 The reduction in gain of an amplifier by 1 dB that results from saturation as a consequence of increased input signal magnitude

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

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Power Amplifier	XP9003	1.6	38.0	+/-0.5	+43.0	-	2.9 A @ 9.0	40x36
Power Amplifier (QFN)	XP1035-QH	5.9-9.5	26.0	+/-1.0	+29.0	+39.0	500 @ 6.0	4x4
Power Amplifier (QFN)	XP1050-QJ	7.0-9.0	15.0	+/-0.5	+34.5 Psat	+48.0	1.2 A @ 8.0	6x6
Power Amplifier (QFN)	XP1042-QT	12.0-16.0	21.0	+/-1.0	+25.0	+38.0	500 @ 5.0	3x3
Power Amplifier (QFN)	XP1043-QH	12.0-16.0	21.5	+/-1.0	+30.0	+41.0	700 @ 7.0	4x4
Power Amplifier	XP1057-BD	13.5-16.0	17.0	+/-1.0	+39.0	+48.0	3.7 A @ 7.5	DIE
Power Amplifier	XP1058-BD	14.5-16.0	27.0	+/-1.0	+36.0	+44.0	2.2 A @ 8.0	DIE
Power Amplifier	XP1072-BD	34.0-37.0	22.0	+/-2.0	+35.0 Psat	-	2.4 A @ 5.5	DIE
Power Amplifier	XP1073-BD	34.0-37.0	22.0	+/-2.0	+37.0 Psat	-	4.8 A @ 5.5	DIE

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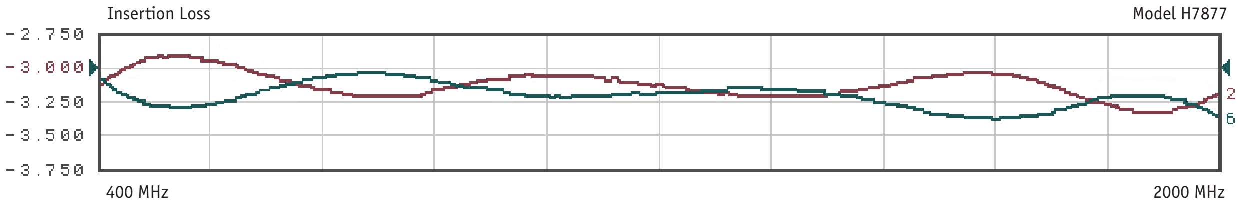

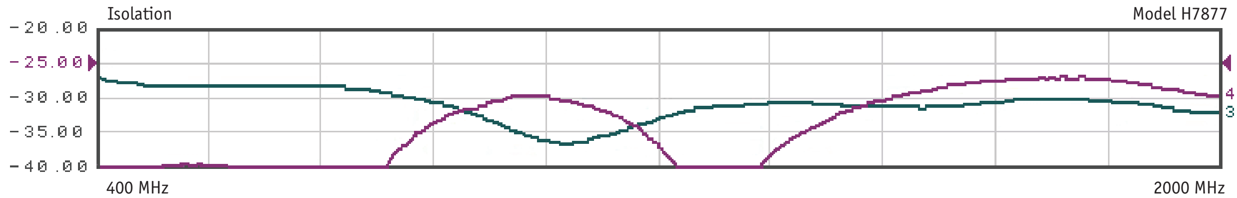

Model	Frequency (MHz)	Power (Watts)	Insertion Loss (dB)	VSWR	Isolation (dB)	Size (Inches)
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H6152	0.2-35	50	0.4	1.30:1	20	2.5 X 1.5 X 1.12
H1484	2-32	500	0.2	1.30:1	25	5 X 3 X 2
H6751	20-512	50	0.8	1.40:1	25	4 X 1.6 X 0.8
H7450	100-500	200	1.0	1.35:1	20	6 X 5 X 2.25
H7733*	100-500	2000	0.2	1.30:1	20	15 X 10 X 2
H3670	200-400	400	0.2	1.40:1	20	5 X 3 X 2.25
H7498*	200-1000	750	0.3	1.30:1	20	8.5 X 5 X 1.5
H7877*	400-2000	300	0.35	1.25:1	20	4.5 X 2.5 X 1.2
H7492*	500-2500	200	0.4	1.30:1	20	4 X 2.2 X 0.85

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