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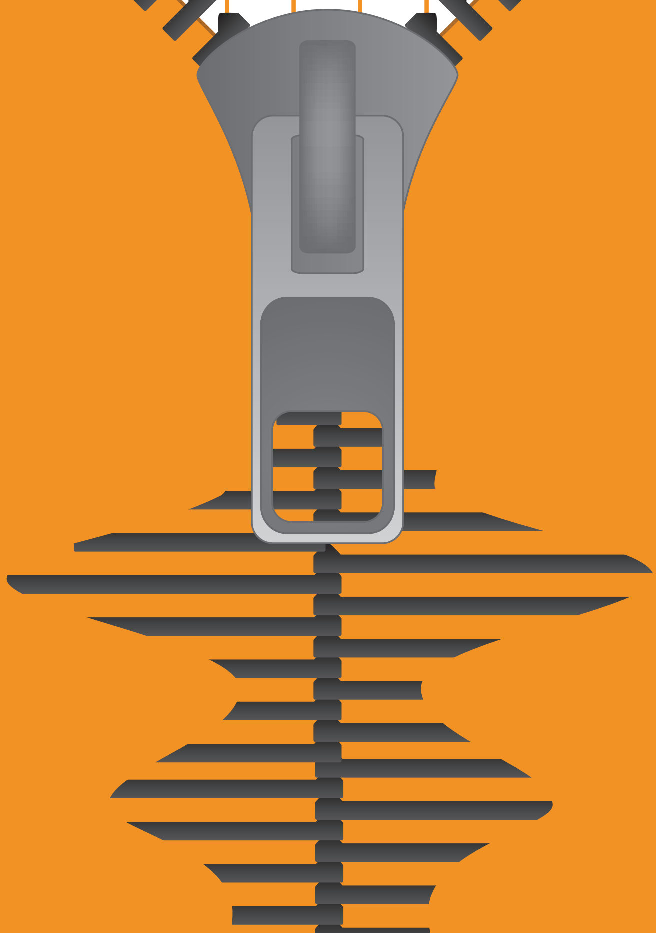

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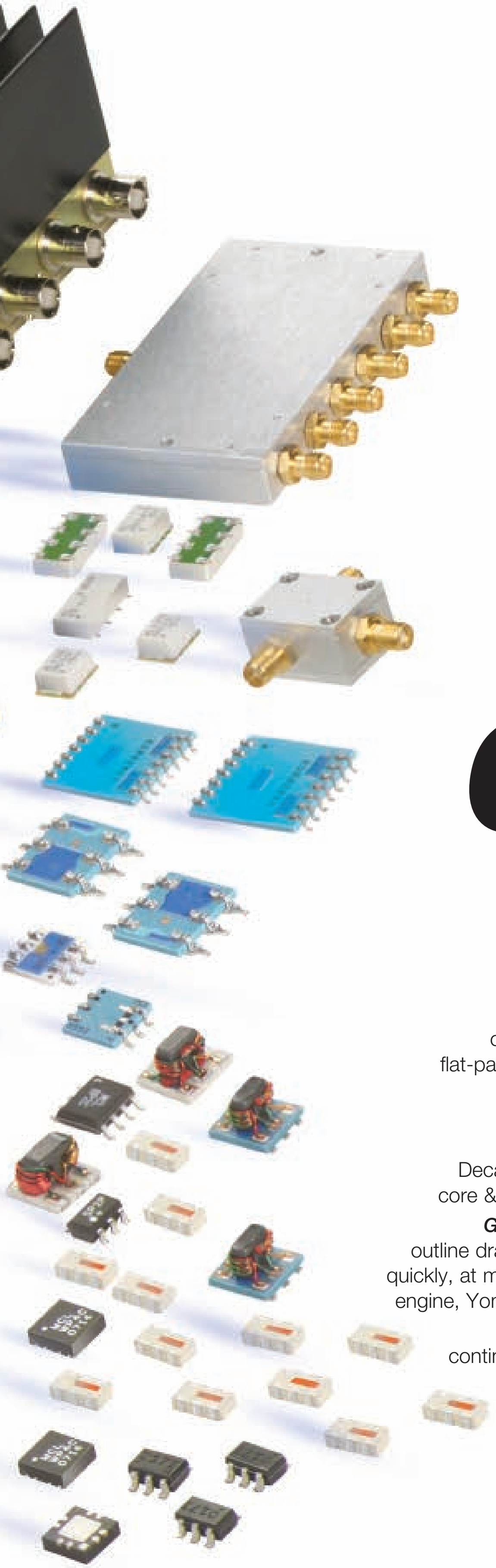

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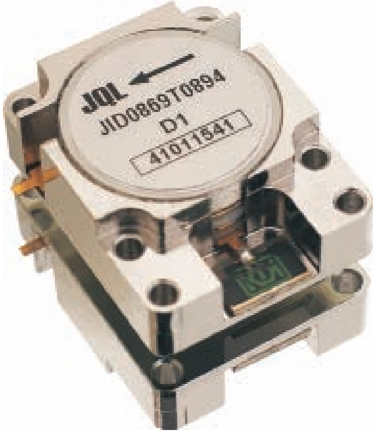

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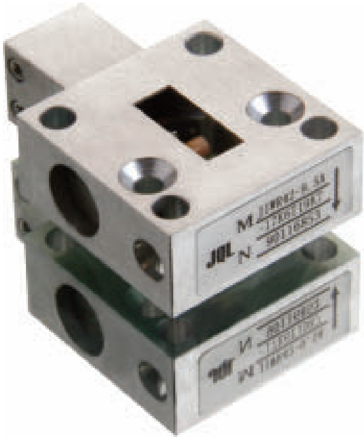

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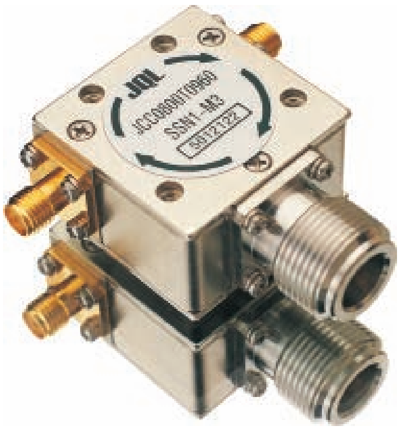

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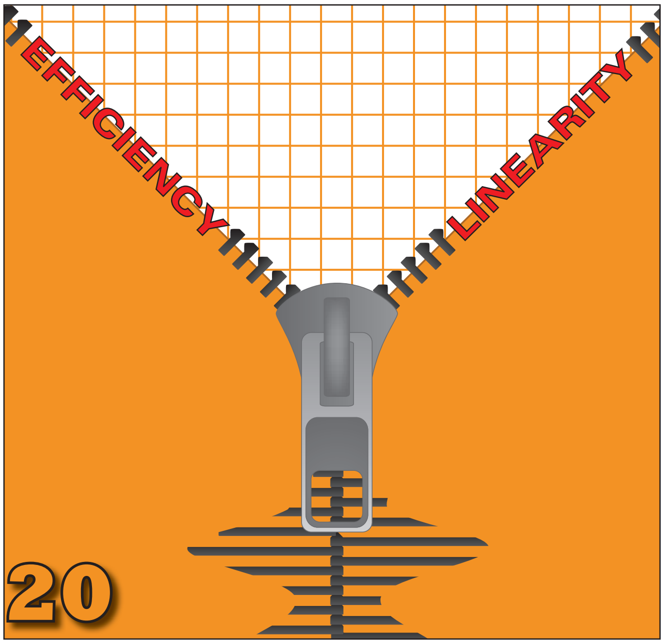
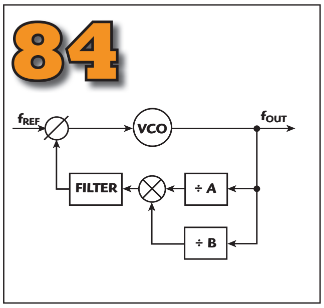
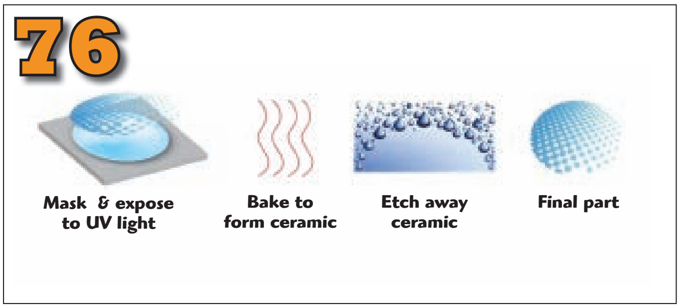
CONTENTS







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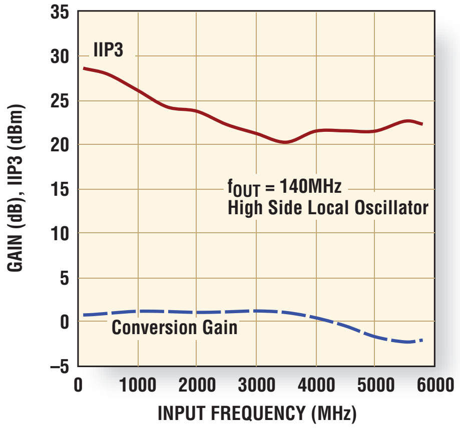

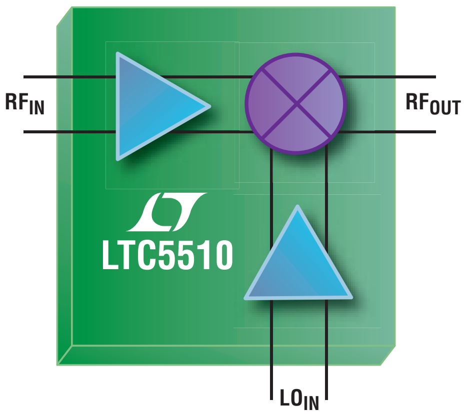

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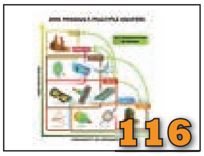

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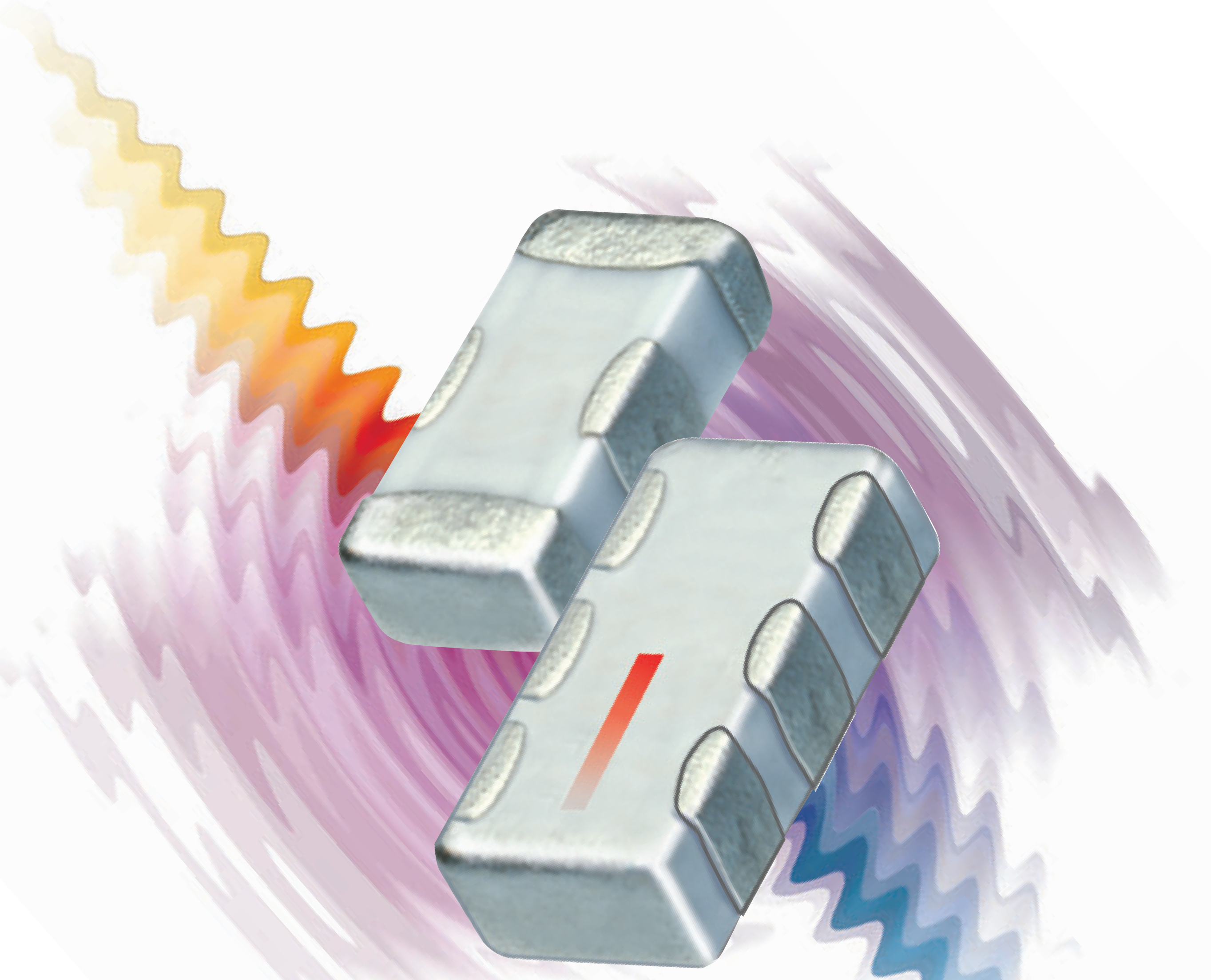

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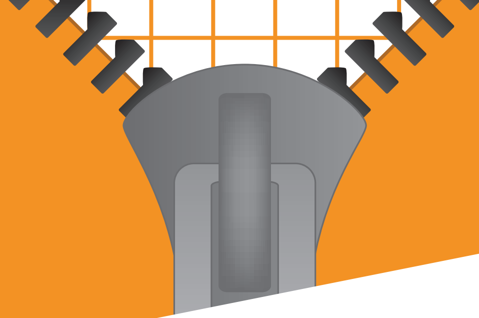

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Modern High Efficiency Amplifier Design: Envelope Tracking, Doherty and Outphasing

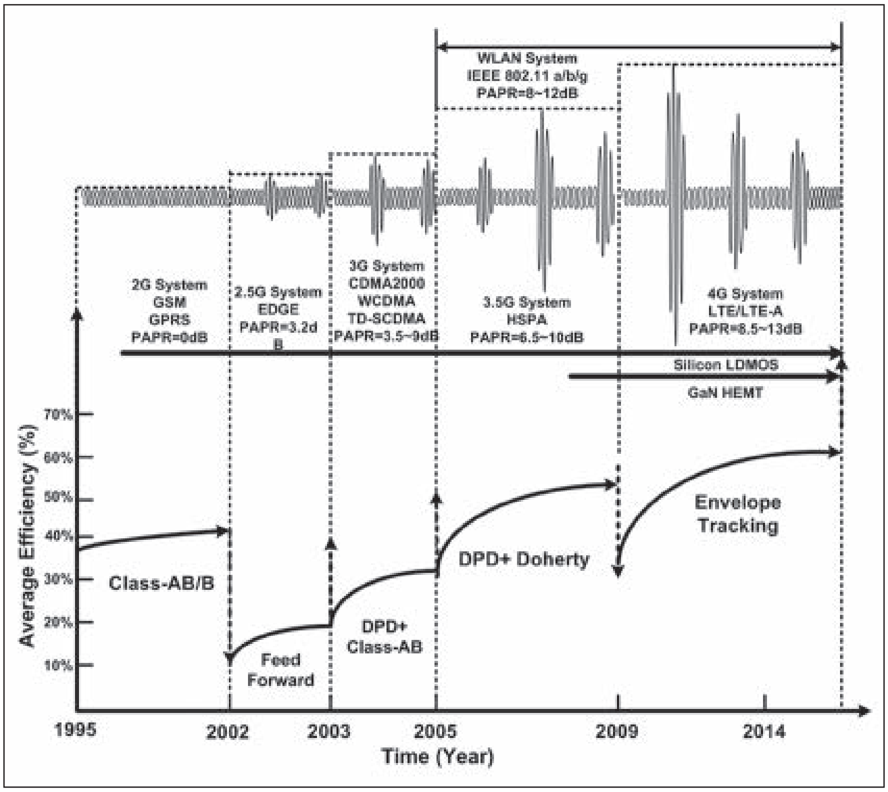
With the evolution of mobile services from 2G to 4G, progressively more complex signal modulation schemes have been introduced to fulfill the ever increasing data capabilities. Broader bandwidths and higher peak-to-average power ratios (PAPR) demands have had a direct impact on RF PA designs, as shown in ***Figure 1***. From the 2G Global System for Mobile Communications (GSM) to current 4G LTE-A systems, increasing transmission rates have evolved up to 100 Mbps in the downlink and up to 50 Mbps in the uplink resulting in the need for advanced modulation techniques. The problem is how to achieve high efficiency over a broad bandwidth to decrease power consumption while maintaining linearity to ensure modulation accuracy and minimize spectral regrowth.

This article takes a look at some of the high efficiency PA design techniques and compares their advantages and disadvantages. Several industry design experts from leading companies contributed articles on each technique: Nokia – Envelope Tracking (including Multi-Nested ET), Freescale – Asymmetric Doherty, NXP – Chireix Outphasing and Cree/Eta – Envelope Tracking/Outphasing Hybrid (Asymmetric Multilevel Outphasing).

ENVELOPE TRACKING POWER AMPLIFIER DESIGN

Zhancang Wang
Nokia, Beijing, China

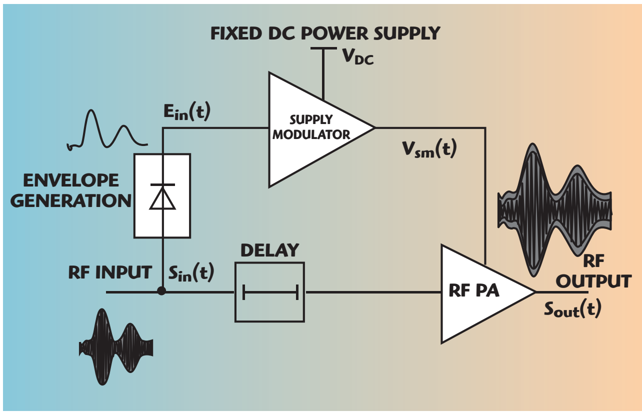
The ET approach is one recommended power supply technique that maximizes the energy efficiency of the PA by keeping it in compression over the whole modulation cycle, instead of just at the peaks, by dynamically adjusting the supply voltage to the RF PA. The ET technique can be understood as a simplification of the envelope elimination and restoration (EE&R) technique.[2] Rather than take out both the phase modulation (PM) and amplitude modulation (AM) information into separate paths, only the envelope AM information is extracted. Therefore, the RF PA operates in the linear region and its supply voltage altered according to the AM information. However, the supply voltage needs to be varied with adequate headroom to reduce distortion to the minimum possible amount. With the headroom available, carrying out an ET PA could be achieved without the tremendous effort as an EE&R counterpart since the ET timing matching is not as critical as that in EE&R. The block diagram and



▲ *Fig. 1 The technology development of the RF PAs with the increased PAPR of signal for wireless communication standards evolution (reprinted with permission from Artech House).*[1]

principle of an ET PA are presented in ***Figure 2***.

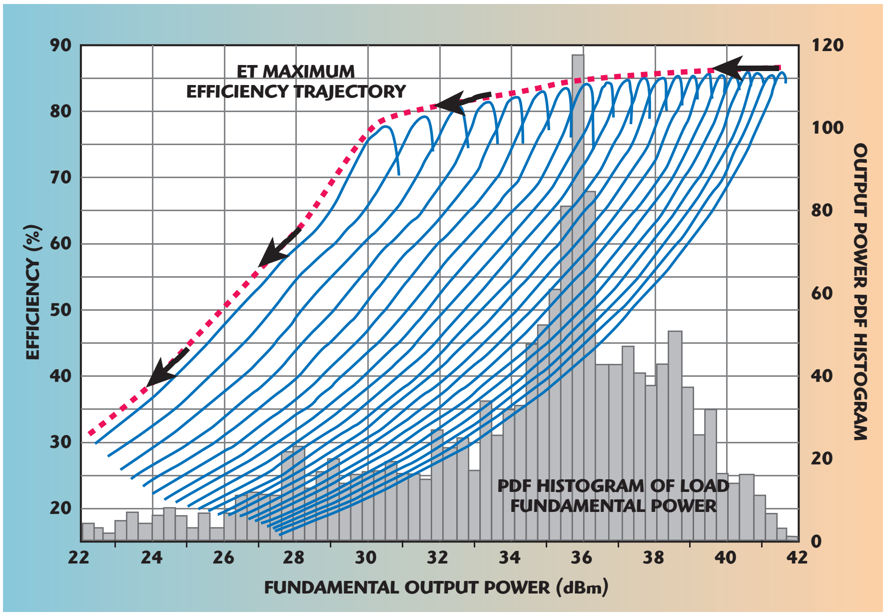
Statistical average efficiency is an indicator for average power consumption in most wireless communication systems with time-varying envelopes. The principle behind ET is to operate the PA in the compression region as frequently as possible. This technique takes advantage of the statistic that both the point of peak efficiency and the point of peak output power vary as the supply voltage ranges between ups and downs. ***Figure 3*** shows the drain efficiency trajectory as a function of output power for a group of supply voltage values. The output power of peak efficiency increases with a rise of supply voltages, but has a constant high efficiency across a wide output power range to tolerate back-offs for high PAPR signal probability density function (PDF) distribution. For that reason, the straightforward impression of ET is to map instantaneous output power to an optimal supply voltage value. In this manner, the PA is on the edge of the compression region most of the time. The theoretical efficiency using ET for a particular PA is presented in ***Figure 4*** as the dashed thick black trace. As illustrated, the effective drain efficiency is substantially superior to the actual drain efficiency of a fixed supply voltage.



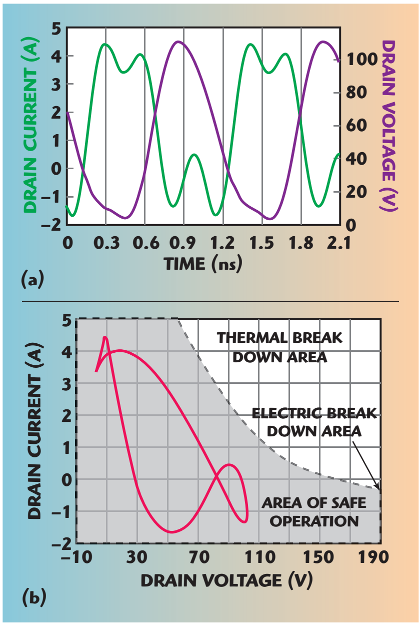
▲ *Fig. 2 Block diagram of classical envelope tracking power amplifier with analog envelope generation scheme and RF delay for branch timing (reprinted with permission from Artech House).*[1]

Envelope Generation

One of the critical aspects of ET PA design is firstly stripping the RF carrier off to reveal the envelope and then transferring it with appropriate scaling to the supply bias of RF PA in real-time manner. There are mainly two methods to realize the envelope generation. One is utilizing the RF envelope detector analog circuitry. The other is digitizing the waveform of the signal and performing a mathematical fit to determine the exact en-



▲ *Fig. 3 Influence of signal statistics on time-averaging efficiency of an ET PA by comparison of PDF histogram and ET single tone efficiency trajectory over various drain supply voltage levels (reprinted with permission from Artech House).*[1]



▲ *Fig. 4 Time-domain current and voltage waveforms observed at package plane (a) and load lines of the Class P PA up to the third harmonic (b) (reprinted with permission from Artech House).*[1]

velope values in baseband processing.

For the interfacing between envelope source and supply modulator, there are specifications to guarantee the signal integrity. For example, The Mobile Industry Processor Interface (MIPI®) Alliance, an international organization that develops interface specifications for mobile and mobile-influenced industries, has a standard analog reference interface specification between generator and supply modulator for ET called eTrak℠.[1] eTrak is a multi-source vendor, independent interface that provides interoperability between the envelope generator and ET supply modulator, enabling wide deployment of ET technology in the industry. eTrak is unique in that unlike other MIPI specifications, it provides a full analog interface rather than only a port physical layer (PHY).

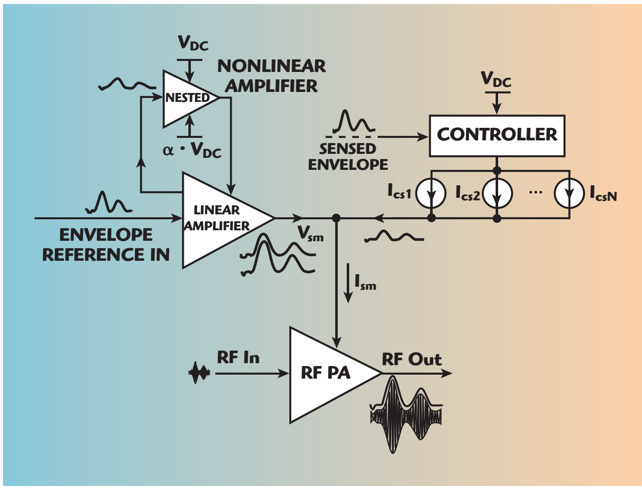


Fig. 5 Nested supply modulator with controlled current source array, which can be seen as another variant of combined hybrid topology with continuous serial hybrid and multi-current-source parallel hybrid in conjunction (reprinted with permission from Artech House).[1]

RF Power Amplifier Design for ET

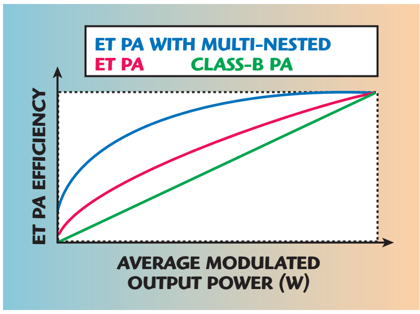
In ET PA design, the link between the supply modulator and RF PA should be examined carefully in order to maximize efficiency and linearity systematically. Unlike small signal amplifiers that operate in the linear region, the RF PA operates in the large-signal regime, where the voltage and current pass through the entire active region of the transistor, and sometimes fall into cut-off and saturation regions. The strong nonlinearities of the RF PA result in the phenomenon of intermodulation distortion, wherein the spectral content at integer multiples of the stimulus appears at both the input and output. The linearity and efficiency performance of the RF PA is established only when these individual mixing products are handled properly.

Even with all the advantages of the reduced conduction angle, the main problem of such PAs lies in the fact that it involves an increase in the input RF signal with the reduction in the conduction angle if the peak current is to be maintained constantly. As a consequence, the gains of such PAs are reduced, which limits the usefulness of these techniques in the design of PAs with devices possessing high gain. An alternative solution to enhancing peak efficiency while overcoming the problems caused by harmonics present in the output of the PA is to provide drain current and voltage engineered shaping for achieving Class-F, Class-F^{-1}, Class-J and Class-P operation modes, in order to obtain increased output power and peak drain efficiency for ET. The Class-P design has been introduced in reference 1, as shown in Figure 4.

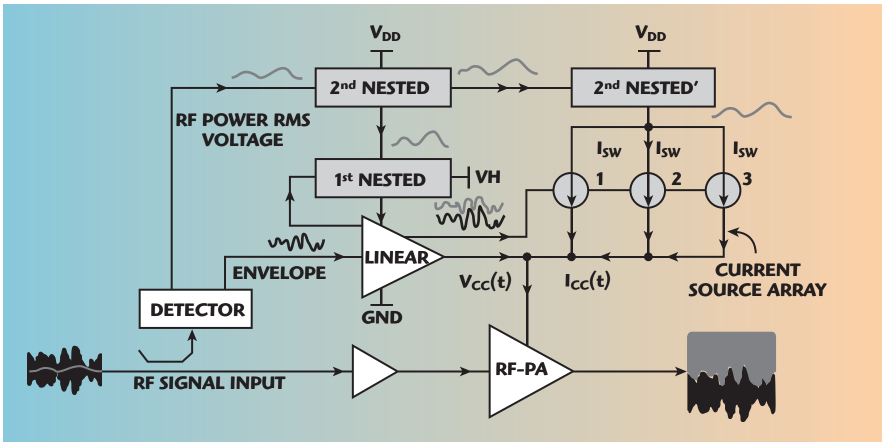
To alleviate the negative effects of ET, several design methods from supply modulator, RF PA and digital front end algorithms have been introduced to enhance ET techniques for wireless communication applications. Although linearity and efficiency are mutually exclusive properties in traditional fixed supplied RF PAs, ET PAs can linearly amplify amplitude and phase modulated signals with much higher efficiency. Both linear PAs and high efficiency switch mode PAs can benefit from ET with modern predistortion schemes.

Nested and Multi-Nested Envelope Tracking

For a wideband operation of the parallel hybrid supply modulator, the switching frequency of the buck



▲ *Fig. 6 RF PA efficiency compared to an average modulated output–the multi-nested solution provides more tolerance to average power again (reprinted with permission from Artech House).*[1]



▲ *Fig. 7 Block diagram of the multi-nested supply modulator with ideal current source array.*

switcher should be very high, leading to deterioration of the efficiency of the switcher from switching losses. This switching operation efficiency may be too high to efficiently provide the power for high PAPR signals having a broad bandwidth. In addition, to compensate for the switching ripple current, the bandwidth of the linear modulator must cover the switching frequency so that it consumes a large amount of DC power, a further deterioration in the overall efficiency.

To preserve the benefits of the combined hybrid supply modulator for higher efficiency, a further new variant of ET is the nested supply modulator. As a similar concept to the combined hybrid in ***Figure 5***, the nested supply modulator combines the nested structure and controlled current source array technology to generate at least three points of maximum efficiency of the supply modulator in theory. In this way, the modulator can tolerate more power back-offs in handling PDF peak, which is always in motion to the low output power region and maintains high average efficiency over a wide range of power and bandwidth.

The envelope voltage shaping functions are not effective for the efficiency enhancement. However, the envelope current shaping can be effective for efficiency improvement of the supply modulator. Therefore, the controlled current source array in the nested supply modulator, with envelope input control with shaping functions as efficiency is optimized to enable envelope current shaping, coordinates with envelope voltage shaping to further enhance the efficiency of the supply modulator as well as linearity optimization.

By means of this scheme combined "fast and slow" envelope tracking, the instantaneous supply voltages to RF PA drain/collector are not only correlated with instantaneous envelope shape, but also the average power of long term RF levels. Therefore, the back-off efficiency boosting capability of envelope tracking is further enhanced to wide dynamic range. It can be employed to realize highly efficient power amplification over a flexible power saving mode in LTE-A application scenarios.

Therefore, the most significant feature of a multi-nested supply modulator is to realize fast ET combined with slow average power tracking (APT) simultaneously. It further boosts the average efficiency of high PAPR signal amplification with even average output power back-off scenarios as shown in ***Figure 6***. The slow mode APT is

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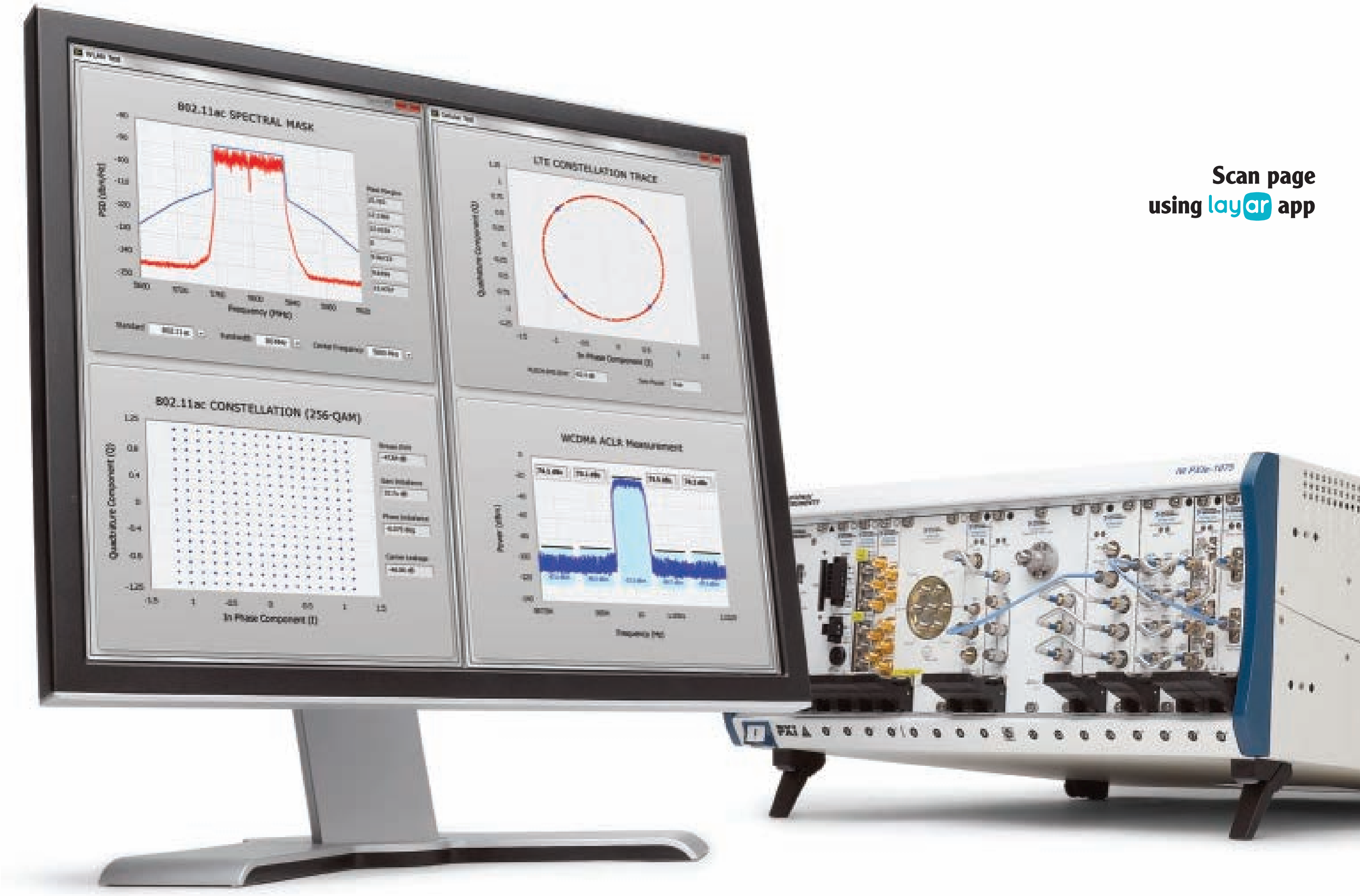

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introduced to adjust average output power according to wireless traffic profile change as a slow way of ET to compensate the efficiency drop by adjusting overall supply voltages with traffic profile shape. Therefore, besides tracking the instantaneous envelope signal, the change of average RF power envelope can also be tracked, which determines the dynamic range parameter in the RF transmitter system and creates another dimensional capability for ET rather than the conventional fast ET only. By adding another dimension of envelope tracking, the average back-off efficiency can be extended.

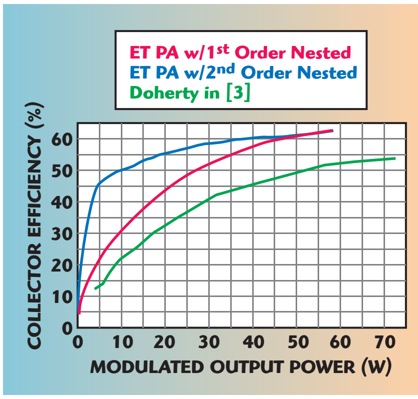
Measurement Results

The schematic of this proposed envelope tracking system is shown in ***Figure 7***. The power amplifier at 2140 MHz in reference 3 was tested with W-CDMA 10 MHz, two carrier, PAPR=6.5 dB; the proposed modulator with first and second order nested structures were implemented on the 120 W GaAs transistor with LTE 20 MHz, one carrier, PAPR clipped into 6.6 dB.

From the sweeping test results in ***Figure 8***, higher instantaneous efficiency and back-off efficiency were observed, especially when 2nd order nested structure was applied. Approaching 63 percent collector efficiency at 58 W average output power was observed, without any linearization; greater than 45 percent collector efficiency was observed from 5 to 58 W average output power range. The average saturated output power of the transistor was increased close to 2 dB when collector modulation was implemented. However, due to Doherty utilizing two transistors, the overall saturated output power of ET PA was still lower.

As shown in Figure 4, the ET PA with and without multi-nested scheme was tested and compared. 100, 40 and 11 percent of full power was defined as the metric of wide dynamic range for enhanced LTE power saving scheme. There was no advantage when multi-nested was running in full power. However, the efficiency could be boosted by 13.3 and 24.8 percent when compared to the scenario when only single nested was implemented. These results showed benefits for wide dynamic range during power saving mode. And the concept of the proposed multi-nested was verified by this test scheme.

The multi-nested envelope tracking PA is proposed for wide average power dynamic range, which can



▲ *Fig. 8 Collector efficiency comparison between Doherty and the proposed ET PA technology with/without 2nd nested ET scheme.*

keep high efficiency during large average output power back-offs. Principally, the PA supply is varied based on the monitored envelope levels and changed all the time so as to correctly meet the output power level of the PA at each moment of time to achieve high efficiency.

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ASYMMETRIC DOHERTY POWER AMPLIFIER DESIGN

Damon Holmes
Freescale Semiconductor, Austin, TX

In essence, the Doherty PA architecture utilizes dynamic loading of a Class-B amplifier. The amplifier is designed to operate into a load that is favorable to high efficiency under low RF signal levels and conversely operate into a load favorable to high power under high RF signal levels. The dynamic loading is accomplished through the synthesis of virtual loads by means of a secondary amplifier based on instantaneous output power requirements.

The Doherty PA's implementation is relatively straightforward using standard RF matching techniques and is shown in its classical form in ***Figure 9***. Main and peaking are tuned amplifiers typically biased in Class-B and Class-C. The two amplifiers connect to a common load through a quarterwave transmission line. At instants in time when the input signal envelope is large (thus a high output power condition), current is injected from each amplifier in-phase into load R0. At times when the input signal has low envelope levels, the peaking amplifier is disengaged and does not contribute current into the load thereby leaving only the main amplifier contributing to the output. During low envelope signal conditions, the peaking amplifier ideally acts as an open circuit.

The quarterwave transmission line acts as an impedance inverter when high output power is required. An increasing current injected from the peaking amplifier into the com-

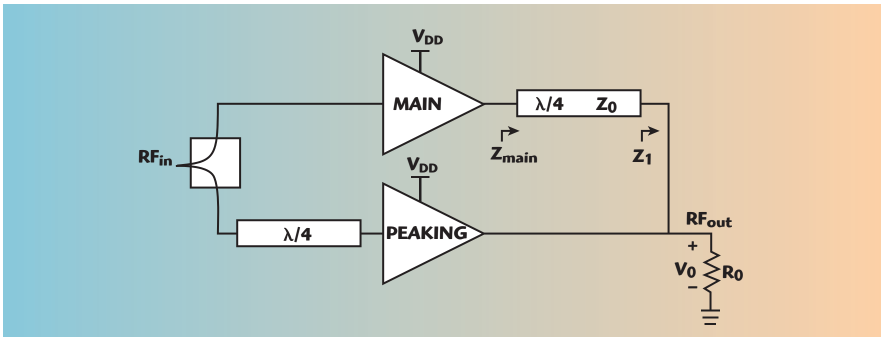

Fig. 9 Ideal two-way Doherty power amplifier.

mon load R0, increases the effective load on the quarterwave line, Z_1. This forces a reduction in the loading of the main amplifier as a consequence of the familiar quarterwave line impedance relationship of Equation 1.

$$Z_{main} = \frac{Z_0^2}{Z_1} \quad (1)$$

With a reduced load, the main amplifier can contribute more current and therefore more power without clipping its voltage waveform – this loading effect is critical when the envelope of the signal reaches a peak.

The Doherty PA efficiency is shown in ***Figure 10*** where significantly high efficiency is achieved over a large power range compared to a Class-B amplifier. The droop in Doherty PA efficiency is caused by the relatively low efficiency of the peaking amplifier when it contributes low output power and has low voltage swings at its output. For Doherty amplifier designs with very large peaking amplifiers, the efficiency peak is pushed to further power backoff levels, but the efficiency droop becomes excessive.

Idealized average efficiency can be determined using the amplitude statistics of the signal waveform. In ***Figure 11***, the average efficiency of various ideal Doherty PAs are plotted

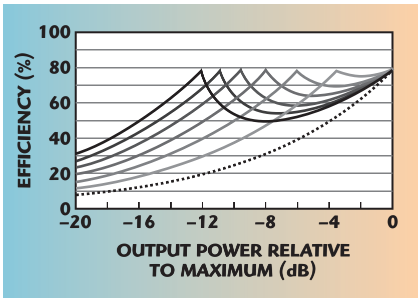

Fig. 10 Doherty power amplifier instantaneous DC-RF conversion efficiency over output power for variously sized peaking sub-amplifiers.

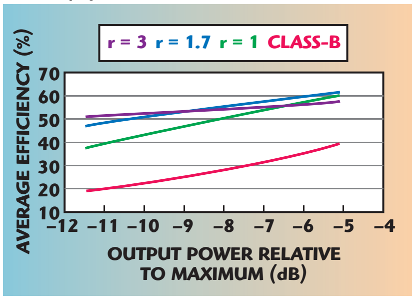

Fig. 11 Idealized average Doherty power amplifier efficiency over output power for various asymmetry ratios.

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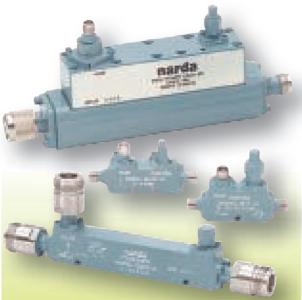

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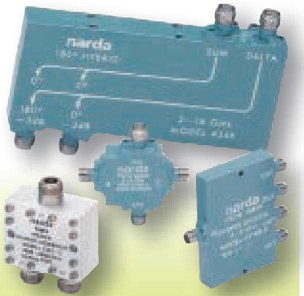

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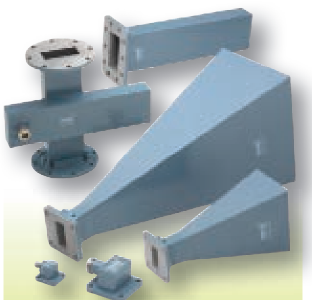

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as a function of backoff power levels using a W-CDMA test signal waveform that is common to cellular infrastructure base stations.

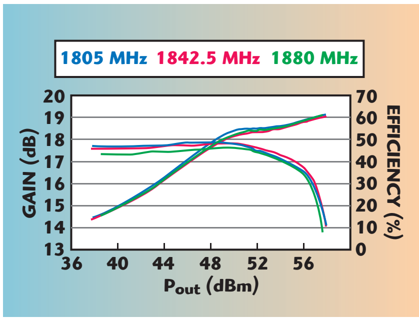
At 8 dB power backoff from maximum, the idealized Doherty amplifier has an average efficiency near or greater than 50 percent. This compares to an ideal Class-B whose average efficiency is only about 27 percent. For applications where the PA operates more than about 7 or 8 dB power backoff, the Doherty amplifier with an asymmetry ratio r=1.7 achieves greater than 5 percent points higher average efficiency than the traditional symmetric Doherty of r=1.

Design Tips

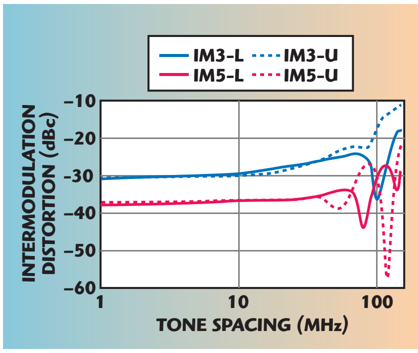
Traditional RF matching techniques can be used for the input match of the main and peaking amplifiers. This includes multisection topologies. However, for broadband RF performance, the output matching networks should be designed using minimum phase networks. In addition, the main amplifier output match should be designed such that main experiences loadline modulation similar to Figure 10 as viewed at its current source plane in response to the peaking amplifier current that is modulated into the common load. In a practical Doherty design, it is possible to generate such loadline modulation by designing a singular output match based on loadpull measurements that satisfies a high efficiency load tuning with no peaking current injection, and a high power load tuning with full peaking current injection. Alternatively, if an active device model of reasonable accuracy is available, the loadline very near the main current source can be simulated and inspected in RF CAD tools during the design of the output match. Of course any charge storage on the output terminal of the active device model may displace the simulated loadline, but even this displaced loadline is usually sufficient to design the output match to ensure proper load modulation.

The peaking amplifier should be designed to behave as an open circuit at the reference plane of the output combining node during low signal envelope conditions. The offset line technique used by Yang[1] has proven to be an important step in practical Doherty design so as to reduce parasitic loading of the main amplifier under low envelope signal conditions. Although a comprehensive analysis of the effects of such parasitic loading has yet to be documented, particularly for broadband Doherty designs, the offset line approach is known by Doherty practitioners to improve overall amplifier efficiency.

The input signal is typically split using a 90 degree hybrid coupler. For Doherty designs with large peaking amplifiers relative to main (r > 1), it is recommended that additional power is used to drive the peaking amplifier. For example, a 5 dB directional coupler can be used for asymmetric Doherty designs in an attempt to mimic the ideal Doherty behavior shown in Figure 11. A more robust method of splitting the input signal is to use a commercially available Doherty alignment module such as Freescale's MMDS20254HT1.[2] This board level component allows for independent and dynamic digital control of amplitude and



▲ *Fig. 12 AFT18H357-24S asymmetric Doherty power amplifier pulsed CW gain and efficiency over output power.*



▲ *Fig. 13 AFT18H357-24S asymmetric Doherty two-tone video bandwidth response.*

phase of each main and peaking input RF signal.

Doherty Circuit Performance

To demonstrate the performance of an asymmetric Doherty power amplifier, such a circuit was designed around a commercially available Airfast™ AFT18H357-24S packaged transistor product.[3] The product represents the latest generation of silicon LDMOS device technology and was specifically designed for Doherty cellular infrastructure applications with high peak-to-average power ratios. The AFT18H357-24S peaking to main power ratio is r=1.7. The PCB measures 4 × 5 inches. The circuit can deliver over 400 W of peak output power, achieves 50 percent average efficiency at 60 W average output power, reaches over 17 dB of gain, and linearizes to stringent spectral mask requirements – all across the entire DCS downlink band (1805 to 1880 MHz). ***Figure 12*** shows the pulsed CW gain and efficiency response as a function of output power.

The circuit achieves excellent video bandwidth with a two-tone resonance of about 80 MHz, as shown in ***Figure 13***. A large video bandwidth is necessary to support wide instantaneous bandwidth signals such as multicarrier GSM, LTE and W-CDMA. In addition, for Doherty PA applications where a predistorter is used for linearization, a large video bandwidth is especially important because the predistorter tends to further increase the bandwidth of the RF driving signal.

The asymmetric Doherty circuit also meets spectral mask requirements when linearized with commercially available digital predistortion systems. ***Figure 14*** shows the linearized spectral performance of a 20 MHz wide two-carrier W-CDMA test waveform at 60 W average output power at a carrier frequency of 1843 MHz. Similar corrected performance was achieved across the DCS band.

The Doherty power amplifier provides excellent efficiency enhancement, with only marginally increased RF design complexity compared to Class-AB amplifiers. It has proven itself to be an elegant power amplifier solution in cellular infrastructure

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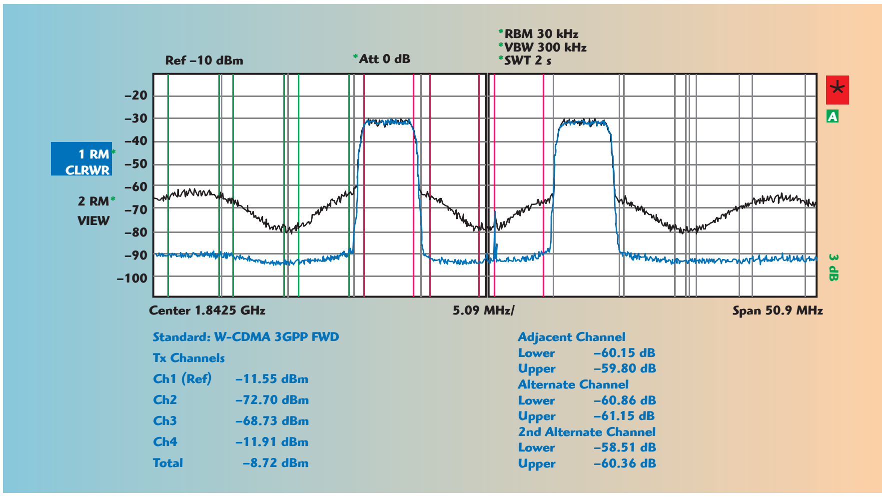
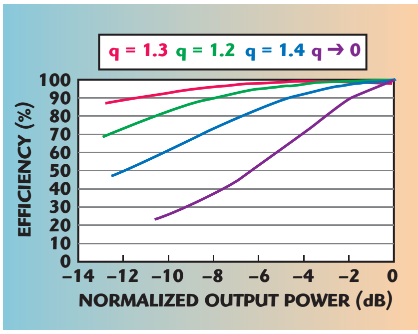
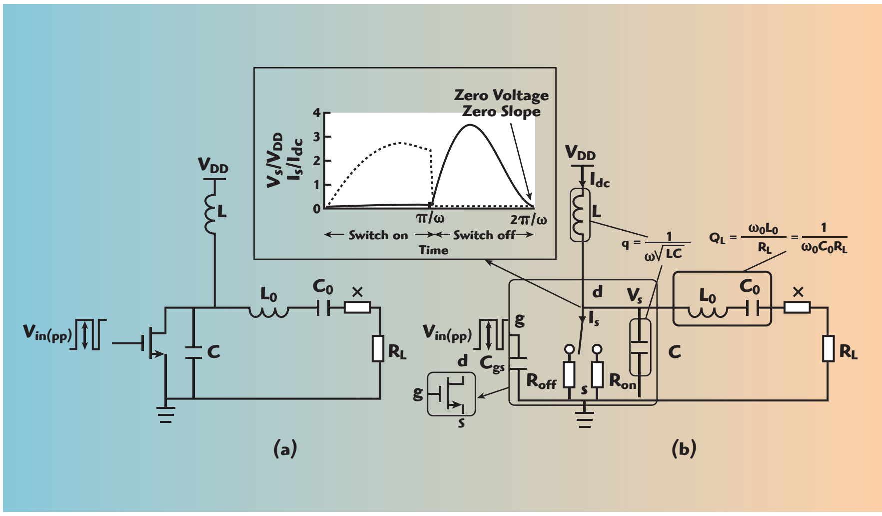


▲ *Fig. 14 Linearized spectral performance of Freescale asymmetric Doherty power amplifier at 60 W average output power, 50 percent efficiency, f_c = 1843 MHz.*



▲ *Fig. 16 Efficiency as a function of normalized output power (in dB) obtained by sweeping the normalized resistance R_{NORM} = R_L/R_{OPT} from 1 to 20 for different values of q. Best efficiency is observed for q = 1.3.*



▲ *Fig. 15 (a) Class-E schematic with finite DC feed inductor 1 (b) Model of Class-E. Note that X is a small reactance to help maintain voltage and current orthogonality.*

thanks, in part, to advances in digital predistortion. Asymmetric Doherty power amplifiers are now achieving 50 percent efficiency near 2 GHz with 17 dB gain for 60 W average power applications – all using cost effective silicon LDMOS device technology. It remains to be seen if an alternative amplifier architecture can ever displace Doherty's 75 year old invention – at least in cellular infrastructure.

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2. Airfast™ MMDS20254HT1 datasheet available at www.freescale.com.
3. Airfast™ AFT18H357-24S datasheet available at www.freescale.com.

Damon Holmes *received his B.Sc. and M.Sc. degrees from the University of Calgary, Canada in 2002 and 2005, respectively. He began his industrial experience at Nortel Networks, Calgary, where he was involved with the design and characterization of transceiver circuits and Doherty power amplifiers for cellular infrastructure applications. Since 2008, he has been with the RF division at Freescale Semiconductor Inc., Tempe, AZ. His research interests include MMIC design, broadband power amplifiers, high efficiency Doherty circuits and resolving power amplifier impairments. In 2013, he organized and co-authored an IMS workshop: "Tutorial on Doherty Power Amplifier Circuits & Design Methodologies." He holds five patents awarded and pending.*

CLASS-E PACKAGE BASED CHIREIX OUTPHASING POWER AMPLIFIER

Mustafa Acar, Robin Wesson and Mark P. van der Heijden
NXP Semiconductors, Nijmegen, The Netherlands

A new approach in power device integration, matching and packaging is presented that allows designers to easily realize the benefits of Class-E in practicals designs. A new quasi load insensitive mode of Class-E that has been demonstrated to be particularly suitable for load modulation architectures.[1-5]

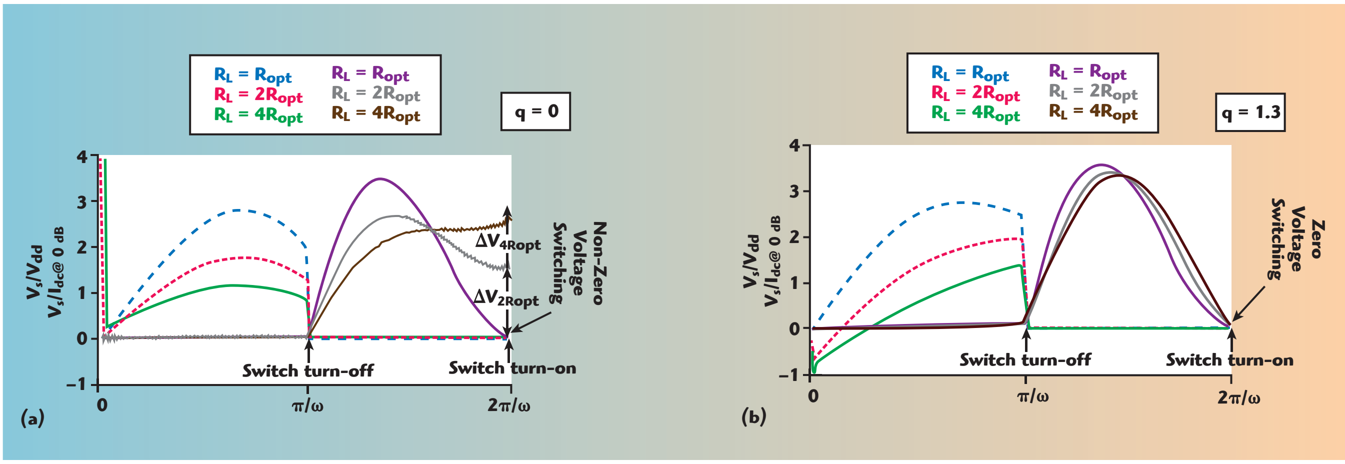
Quasi Load Insensitive (QLI) Class-E

In research circles, the Class-E PA has been popular due to its high efficiency and simple circuit structure shown in references 6, 7 and 10. In Class-E, the inductance of the RF choke is typically reduced to resonate with the device output capacitance. This is termed a 'finite inductor' Class-E implementation. Recent analysis on Class-E with finite bias inductor demonstrates that there exists a continuum of modes of operation which arises as the relation between load network elements and input parameters are varied as a function of the resonance factor

$$q = \frac{1}{\omega\sqrt{LC}}$$

(see ***Figure 15***).[1-5]

Among the many design solutions, there exists a unique Class-E mode of operation for q = 1.3 which yields optimum efficiency over a range of load resistances[1-4] (see ***Figure 16***). This makes it the best candidate for systems based on load-modulation such as Doherty, dynamic load modulation, or Chireix outphasing. This mode may also be advantageous where a system has to operate efficiently into an uncertain load, for example, in an RF energy delivery or microwave heating application. The conventional Class-E mode, where q → 0 with infinite inductor impedance is not ideal for load-modulation unless a more complex – and therefore more lossy – vari-



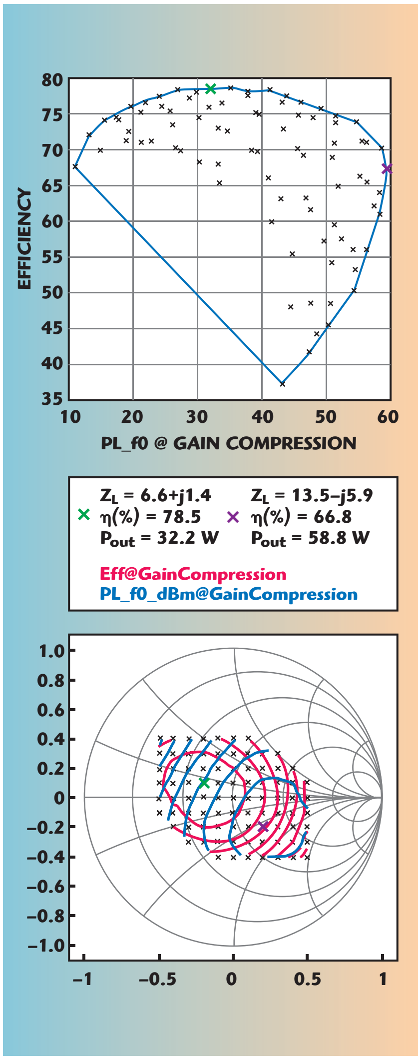
▲ *Fig. 17 Class-E switch voltage and current waveforms for q = 0 (a) and q = 1.3 (b) across a range of loads.*

able load network is deployed.[5,8]

Waveforms of current through, and voltage across, the active device as simulated using the model in Figure 15(b) are shown in ***Figure 17*** for both the classical Class-E mode and the QLI mode. Figure 17a shows that the voltage waveform for the classical mode at nominal load resistance reaches zero at switch turn on time, a condition critical for efficiency. As the load resistance is increased, however, the voltage at the instant of switch turn-on moment increases. This has the effect of allowing simultaneous voltage drop and current flow to exist at the switch plane, and dissipation to occur. By comparison, as shown in Figure 17b the unique property of the QLI mode is that as the load resistance increases, the turn-on voltage slope changes from zero to a negative value while still maintaining the turn-on voltage close to zero.

Theory to Measurement – QLI Class-E in Package

When considering how to make use of high efficiency switching modes, the high frequency of opera-



▲ *Fig. 18 CW 2.14 GHz load-pull data at 4 dB gain compression of CEiP device.*

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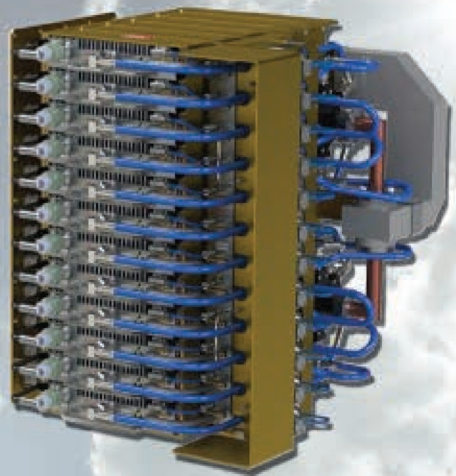

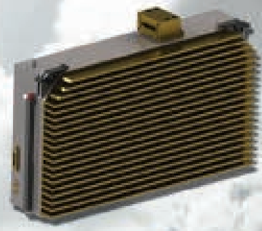

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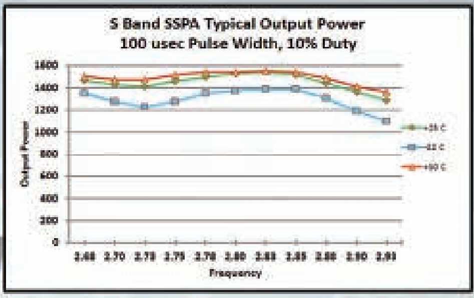

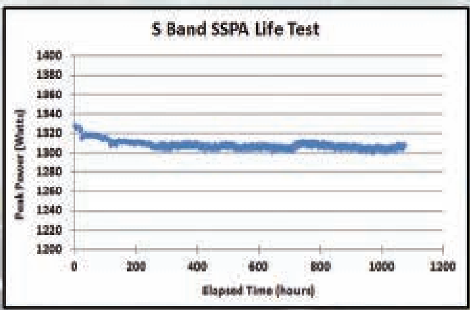

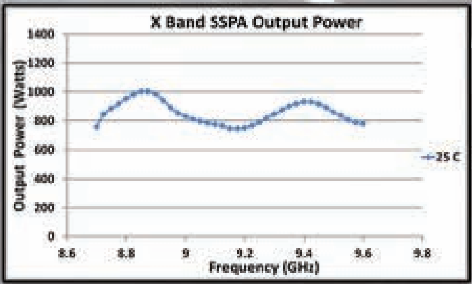

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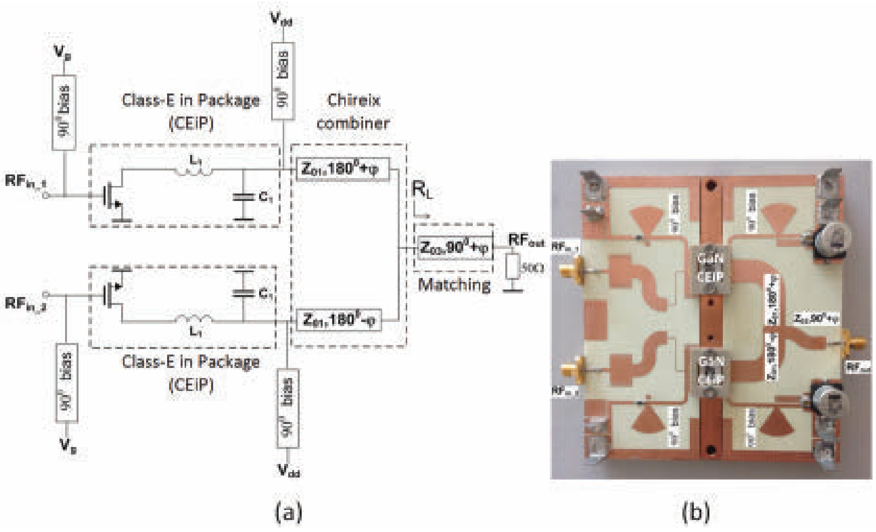
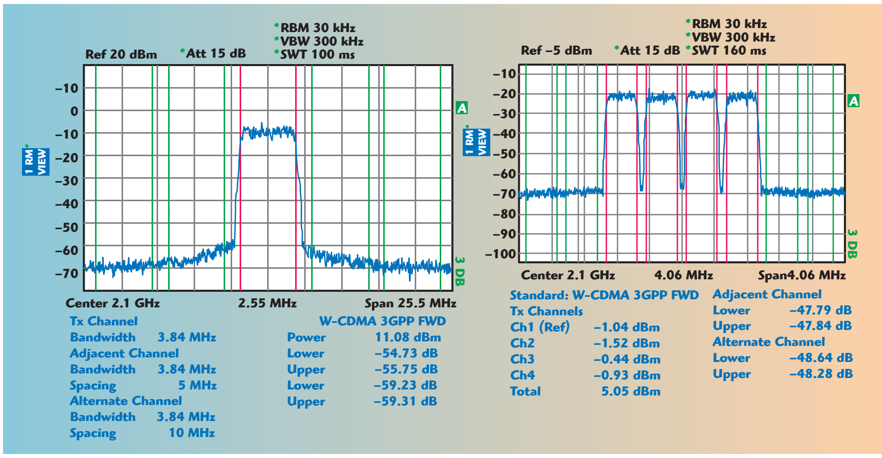


▲ *Fig. 19 Circuit model of the Class-E in package (CEiP) based Chireix outphasing PA including the output matching network (a)–the input match is not shown for the sake of simplicity. Photograph of the 2.1 GHz mixed-mode Chireix outphasing power amplifier module (b).*



▲ *Fig. 20 Linearized ACPR for single and quad-carrier W-CDMA signals.*

tion of GaN makes it an ideal choice. The first design[2] to make use of the QLI Class- E mode was an asymmetric combiner Chireix outphasing PA featuring bare 2.4 mm GaN dies wire bonded to the planar coupler based combiner and matching circuit. However, in standard ceramic packages, the device designer is limited by the available matching network topologies that can be practically realized. The series capacitor in particular is difficult to implement internally, so a functionally identical transformed arrangement has been derived from the Class-E network.

The Class-E in package (CEiP) has been built using NXP 0.25 um, 28 V GaN HEMT technology and commercially available NXP flanged ceramic package SOT1135A. The inductor L1 is realized inside the package using bond wires. Since the higher harmonic terminations are handled inside the package, a conventional fundamental load pull system is sufficient to obtain the optimum impedance for both maximum efficiency and maximum output power, as is shown in ***Figure 18***. Equally useful, a conventional fundamental-only matching circuit is all that is required to achieve these high efficiency figures in practice.

To prove out the design of high efficiency linear PAs using the new CEiP device technology, a mixed mode Chireix outphasing PA has been constructed for 2.1 GHz operation, as shown in ***Figure 19***. The Chireix outphasing combiner topology and the mixed mode operation is described in reference 9.

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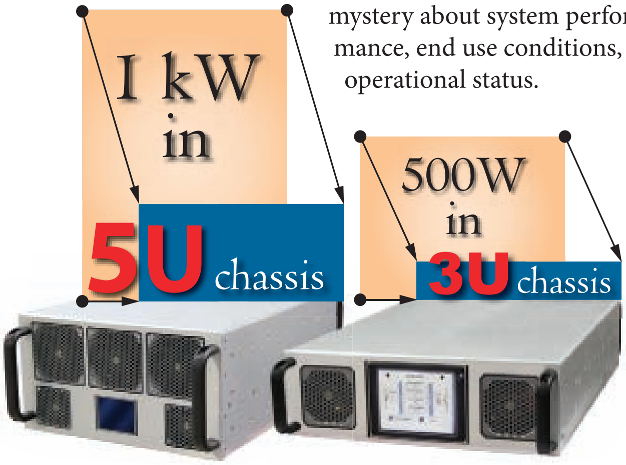

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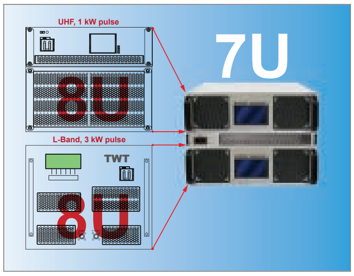

Amplifier Software

Embedded web server
Real time power amplifier diagnostics
Remote monitoring and control

User interface capabilities of Empower Next Generation power amplifiers allow the user to initiate remote management and diagnostics via an embedded web server, enabling network managed site status and control simply by connecting the unit's Ethernet port to a LAN or accessing the unit's IP address. For machine to machine interface (M2M), Empower offers TCP/IP or UDP protocol sockets accessed through the Ethernet port.

The feature rich menu that is available on these high power amplifiers includes real time monitoring, protection and control, sensor driven dynamic adjustments to the amplifier while in operation, remote user access, and a selection of communications protocols that can be enabled by the end user during system set up. Software updates can be delivered via a "direct connect" link, if permitted by the customer, from Empower to the fielded amplifier via the amplifier's embedded web server or updated via a USB drive inserted directly into the back panel of the amplifier. The USB upload process is streamlined for "ease of use" with a self extracting and self loading program.

Scalable output power architecture

Next Generation Building Block Modules

Our advances in RF system design are complimented with advances in RF module design. Integral to our systems designs and also sold as building block modules, Empower's latest PA modules are a "minimal touch" design which incorporate latest devices, circuit topologies and thermal management techniques.

→	**SKU 1163**	125 W	20 - 520	MHz
→	**SKU 1193**	100 W	20 - 1000	MHz
→	**SKU 1199**	100 W	1000 - 3000	MHz
→	**SKU 1191**	100 W	2500 - 6000	MHz

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ACPR figures have been characterized for single and quad-carrier W-CDMA signals after linearization (see ***Figure 20***). The CEiP outphasing PA achieves 20 W with 61 percent PAE for a single carrier W-CDMA signal with a PAR of 7.1 dB. ACPR is better than 54 dBC. For the quad-carrier (20 MHz) W-CDMA with a PAR of 9.6 dB 11 W is achieved with PAE >53 percent and ACPR close to 48 dBC which can be improved with advanced DPD.

Acknowledgment

The authors wish to acknowledge the help and support of Melina Apostolidou, Keith Finnerty, Jan Vromans, Rik Jos, Fred van Rijs, Michel de Langen, Thomas Roedle, Lex Harm, Jawad Qureshi, Jordan Svechtarov and the prototype line from NXP.

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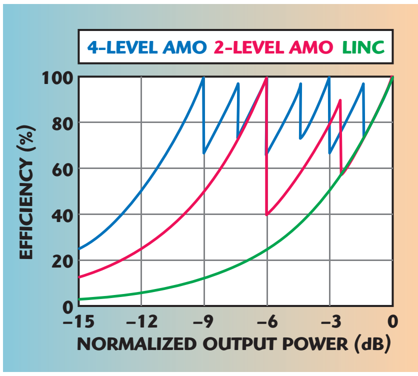

▲ *Fig. 21 Theoretical efficiency of AMO modulation with four amplitude levels, compared to two level AMO and "one level" outphasing (or LINC – LInear amplification with Nonlinear Components).*

ASYMMETRIC MULTILEVEL OUTPHASING POWER AMPLIFIER DESIGN

Ray Pengelly
Cree RF Products, Durham, NC

Higher efficiency PAs must be accompanied by the wider bandwidth and high linearity demands of 4G (and future) wireless signals. To address this issue, recent startup Eta Devices Inc. is commercializing a technology developed at MIT: Asymmetric Multilevel Outphasing (AMO). AMO combines the high linearity of outphasing with efficiency-enhancing, multi-level, discrete switched drain bias. Discrete switched drain biasing is the key to supporting wide bandwidths while maintaining high efficiency, and provides an advantage over traditional envelope tracking. ***Figure 21*** illustrates how AMO achieves efficiency improvement over outphasing alone.

In any outphasing system, the maximum efficiency is determined by the performance of the PAs. In its high power amplifier designs, Eta Devices uses GaN HEMT devices from Cree Inc., which have demonstrated practical peak drain efficiencies exceeding 80 percent.

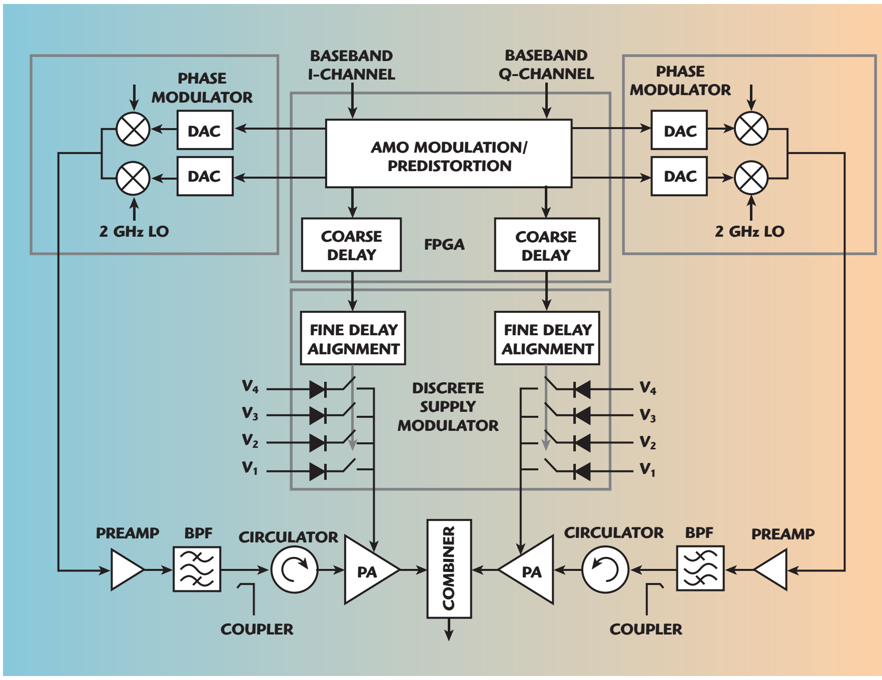

Fig. 22 The AMO test transmitter block diagram.

AMO Operation

Two well-known methods for achieving linear amplification with nonlinear power amplifiers are outphasing and envelope tracking (ET).

Outphasing basically uses two phase modulated amplifiers operating at constant amplitude. The input signal is converted to the proper phases and presented to the amplifiers, with outputs combined so that reinforcement and cancellation of the phase components results in a signal that accurately replicates the input. In practice, outphasing requires a power combiner that provides a consistent load for each PA, isolation between the amplifiers, and high power handling capability. These characteristics can be difficult to maintain over wide bandwidth.

Envelope tracking splits the signal into separate phase angle and amplitude components. The PA operates in saturated mode, typically one of the switching modes such as Class-E, F or inverse Class-F. Phase modulation is applied to the RF drive while the drain voltage is modulated with the amplitude envelope, thus phase and amplitude are both restored at the output. ET, despite its popularity, is greatly challenged by the increasing bandwidth requirements of 4G and WLAN standards. The crux of the problem is the DC supply modulator, which must handle a lot of power, be extremely efficient, be highly linear, be high resolution, inject very little noise into the system, and support wideband modulation.

The design challenges of outphasing and ET are addressed by Asymmetric Multilevel Outphasing (AMO), which combines their most desirable features. The amplitude modulation of ET is simplified to discrete steps instead of a wide bandwidth, linear analog range. With multiple drain voltage steps, outphasing then has a series of smaller operating ranges, which maintains high PA efficiency while reducing performance demands on the power combiner.

AMO solutions do require non-traditional digital predistortion (DPD) solutions, which are at the core of Eta Devices' intellectual property. Although non-traditional, the necessary computational resources do not differ from that of traditional DPD, thus there is no hidden cost associated with increased digital complexity.

GaN Devices and Transmitter Design

PA performance determines the maximum system efficiency of outphasing, ET and AMO. Presently, the highest efficiency production devices are fabricated using GaN processes. For example, the Cree CGH40010 GaN HEMT devices[1] used in a pro-

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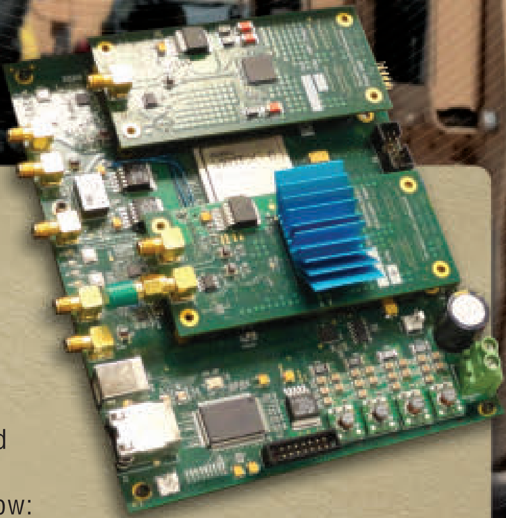
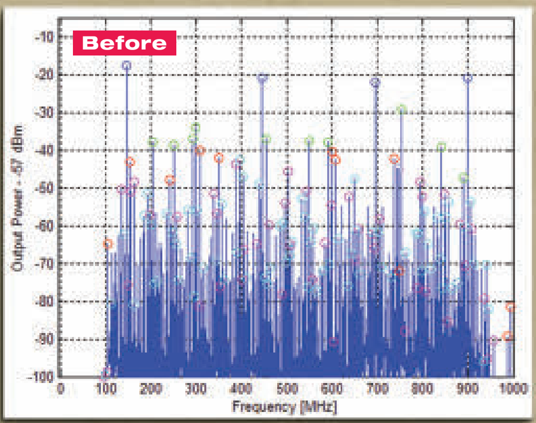
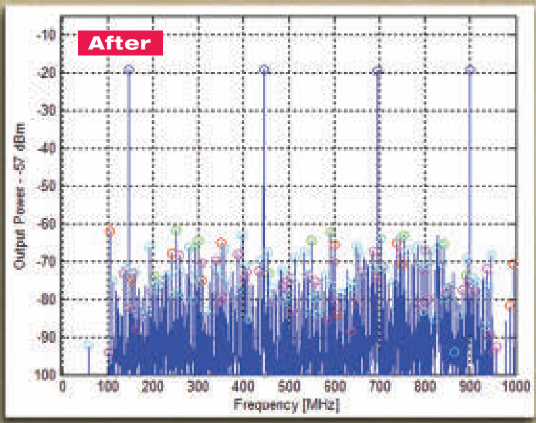


Aethercomm introduces a full GHz instantaneous bandwidth Digital Pre-Distortion (DPD) linearizer that operates from DC to 3 GHz. To demonstrate its effectiveness, Aethercomm stimulated a 10 year old first generation highly non-linear GaN amplifier with four CW tones randomly spaced from DC-1 GHz & the amazing results are shown below:





Linearizer Performance

- Direct RF linearization at the RF band
- 1 GHz instantaneous BW
- Operates from DC-3 GHz
- Easily translated from 3-6 or 6-9 GHz
- Works for CW or modulated passband multi-tones
- Harmonics and IMD's ameliorated by 20-30 dBc or greater

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Tel 760.208.6002 • sales@aethercomm.com • www.aethercomm.com totype developed at MIT[2] is specified at 65 percent (3.6 GHz) and >70 percent (2 GHz) typical efficiency at its maximum saturated output power. For AMO application, the PA is designed for good performance over the range of drain voltages to be delivered by the stepped-switching supply modulator.

A complete AMO transmitter is illustrated in ***Figure 22***. Baseband I and Q signals are delivered to a DPD and modulation signal processor implemented with a FPGA. In this evaluation system, DPD is implemented with a lookup table constructed from measured static nonlinearity of the transmitter for the various DC levels at the PA.

Outphasing channel phase modulation data is delivered to digital-to-analog converters and phase modulators for the two PAs. The stepped amplitude modulation data, with coarse delay correction, drives the supply modulator circuit. RF preamplifiers provide the necessary drive levels, and at the output a combiner sums the PA outputs into a single RF signal.

Performance Summary

Combining the desired attributes of outphasing and envelope tracking achieves much higher performance than could be obtained with either method alone. ***Figure 23*** shows efficiency versus bandwidth performance for the four-level AMO test transmitter. The advantages of the AMO system architecture using Class-E GaN PAs, combined with the latest DPD implementation, deliver an average modulated drain efficiency of 70 percent at 1 MHz bandwidth, with only a slight reduction to 68 percent at 20 MHz bandwidth.

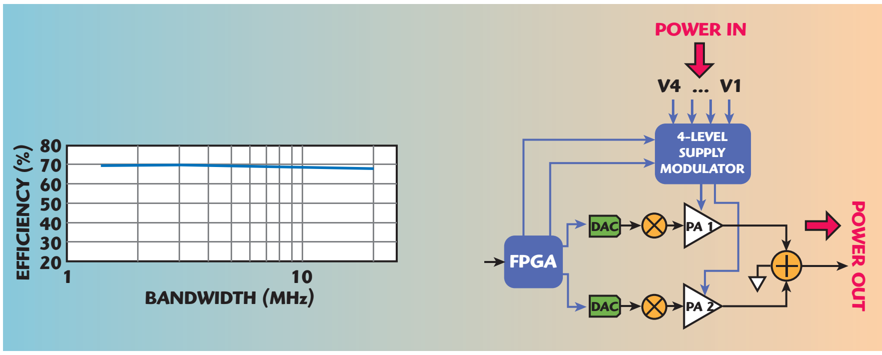

Fig. 23 Efficiency versus bandwidth at 2.14 GHz, 100 W peak power, 7 dB PAPR and ACPR > 45 dBc. Supply modulator losses are included in the efficiency measurement.

While this transmitter has 70 percent modulated drain efficiency at maximum output power, the performance at backoff is arguably more important. This is because it is normal to operate well below the maximum average power. Eta Devices' system only loses 10 percent of efficiency for 10 dB backoff from the maximum average power. For a signal with a 7 dB PAPR, this is actually a 17 dB backoff from peak power.

For more information on this technique, read "GaN Devices and AMO Technology Enable High Efficiency, Wide Bandwidth Wireless Transmitters" in the March 2014 issue of *Microwave Journal*.

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Raymond S. Pengelly *gained his BSc. and MSc. degrees from Southampton University, England in 1969 and 1973 respectively. He worked for Plessey Co. in the UK, Tachonics Corp., Compact Software and Raytheon Commercial Electronics. Since August 1999, he has been employed by Cree Inc. in Durham, NC. Initially, he was the general manager for Cree Microwave responsible for bringing Cree's wide bandgap transistor technology to the commercial marketplace. From September 2005 he became responsible for strategic business development of wide bandgap technologies for RF and microwave applications for Cree and most recently has been involved in the commercial release of GaN HEMT transistors and MMICs for general purpose and telecommunications applications. He has written over 120 technical papers and four technical books, holds 15 patents and is both a fellow of the IEEE and fellow of the IET.*

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PXIe Performance Vector Signal Analyzer

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Wireless communications is advancing at a fast pace, driven by the demand for higher data rates from an exploding number of users. Whether in commercial wireless or aerospace/defense applications, over-crowded frequency spectrum has forced engineers to resort to more complex signal and system design to transmit more data, more efficiently. Agilent Technologies, formed from Hewlett-Packard and soon to become Keysight Technologies, has played a critical role in enabling this progression through its development of test and measurement equipment. Since the invention of the audio oscillator in 1939, the company has advanced and evolved test and measurement equipment to meet increasingly complex engineering demands and is continuing to do so with the introduction of the M9393A PXIe performance vector signal analyzer, providing performance previously unseen in modular instrumentation.

▲ *Fig. 1 M9393A PXIe performance vector signal analyzer.*

The M9393A is a vector signal analyzer in a PXI form factor (see ***Figure 1***) with frequency up to 27 GHz and provides speed, accuracy and modular flexibility ideal for automated test. The M9393A's software enables consistent, fast, in-band and out-of-band analysis, covering EVM and ACLR, as well as harmonic and spurious measurements at speeds never seen before. The modular architecture of both the hardware and software are designed to provide an extensible, scalable solution that can evolve with signal analysis needs.

COMBINATION OF ACCURACY AND SPEED

With amplitude accuracy of ±0.15 dB and extremely fast frequency and amplitude switching speeds, the M9393A is specifically designed to reduce test time, while testing to the tightest tolerances in design validation and manufacturing. Using technology developed by Agilent for solid-state switches and attenuators, the M9393A provides best-in-class switching speeds with excellent amplitude accuracy, repeatability and reliability. Frequency synthesis allows the M9393A local oscillator (LO) to tune from any frequency to any other frequency in the entire 9 kHz to 27 GHz range in less than 150 µsec, while consistently providing excellent phase noise. Another unique Agilent innovation is the RF calibrator circuit that enables built-in automatic field calibration, eliminating errors inherent with external cabling, and ensuring excellent repeatability over time and temperature. The M9393A offers significant speed advantages through the absence of YiG-tuned filters, which further reduces amplitude errors, and also through solid state

attenuators, which ensure repeatable measurements without the risk of wearing out.

CLARITY AND CONFIDENCE IN RESULTS

As modulation formats become more complex, and test suites continue to expand, engineers are faced with the need to measure more without increasing cost, necessitating both measurement and development speed. Through a robust set of drivers and deep programmatic compatibility (including SCPI) with familiar X-Series measurement applications and the 89600 VSA software, the M9393A provides consistent, trusted results to decrease test development time. In addition to providing fast in-band measurements such as modulation quality and power, compatibility with the 89600 VSA software's new stepped spectrum analysis option also enables high-speed spectrum measurements. By stepping and stitching together FFTs across the entire frequency range of the analyzer, the software allows the M9393A to make traditional in-band measurements of known signals, and also out-of-band measurements of unwanted signals like harmonics and spurs. This "sweeping" functionality, along with the remarkable speed of the M9393A, provides best-in-class performance.

MODULAR EXTENSIBILITY WITH ROOM TO GROW

The M9393A has been developed to address the test challenges engineers face today and those they will face tomorrow. To keep pace with evolving test needs and to maximize equipment reuse, the M9393A and its software have been designed to be truly modular, delivering extensibility and scalability in terms of the size of the system (number of channels) and functionality. Consisting of four modules spanning five slots, up to four M9393A's can fit in a single 18-slot chassis, saving valuable rack and test space. User upgradeable options allow for fast, easy addition of capabilities, such as wider bandwidth, increased memory, and higher frequency range as needed. Access to intermediate points in the signal path is provided through front panel ports in order to facilitate incorporation of future modules or test equipment, taking microwave analysis scalability to the next level.

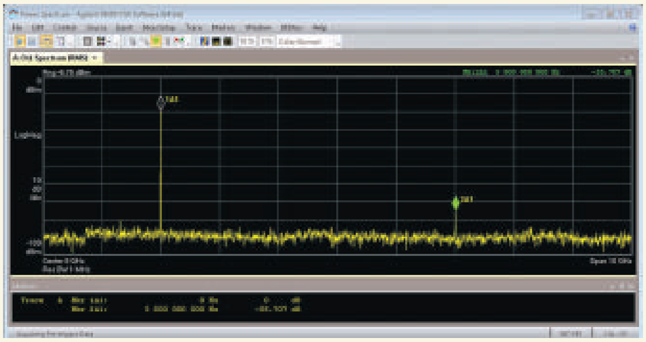
EVOLVING HIGH-PERFORMANCE SIGNAL ANALYSIS

The M9393A evolved from the proven designs of some of Agilent's best instruments, along with some of Agilent's newest innovations in microwave measurement technology. The M9393A's downconverter module incorporates the circuit design from the front end of the N9030A PXA signal analyzer. This flagship analyzer has earned respect in all industries for its accurate results, and its downconverter circuitry is now a core component in the M9393A. The unique internal calibrator from the Fieldfox handheld network analyzers, designed to hold tight specifications across all temperatures, has been included as well. With this internal calibrator, and some added enhancements, the M9393A contains an extremely stable and repeatable amplitude and phase reference over the entire operating temperature range.

RETHINK WHAT'S POSSIBLE

Testing the latest radio formats, the need to meet ever more stringent system requirements, while facing an increasing number of tests, shorter deadlines and continued support of legacy standards, mean that faster test times and lower test uncertainty are more critical than ever before when it comes to meeting throughput and yield demands. The M9393A is designed to make it possible for engineers to meet these challenges head-on by incorporating state-of-the-art technology from across Agilent with the M9393A's high-speed PXI backplane, providing the speed and accuracy you need.

With the fast tuning LO, 160 MHz analysis bandwidth, and high speed back-end processing, the M9393A allows extremely fast "sweeps," across the entire 27 GHz frequency range, in a fraction of a second. Even with narrow resolution bandwidths, the M9393A's "sweep" rates of several hundred GHz per second is the best "speed to dynamic range" of any PXI analyzer to date. These capabilities enable fast search and identification of low level signals over a broad frequency range, even when those signals are buried in noise.



▲ *Fig. 2 89600 VSA software provides fast spectrum analysis.*

As a device moves from design to validation to manufacturing, different test tools are required. Because the M9393A is compatible with Agilent's proven measurement science, including SystemVue ESL design software, the powerful 89600 VSA software and X-Series measurement applications, it provides consistency and confidence in measurement results across benchtop and modular signal analyzers, throughout the product development lifecycle (see ***Figure 2***). In addition to the extensive feature set, the M9393A benefits from a three year standard warranty, compliance with N7800A TME software for calibration and 52 service centers worldwide, providing Agilent experts to calibrate and service your product.

THE PERFORMANCE EDGE

The M9393A PXIe performance vector signal analyzer is Agilent's latest innovation, the evolution of decades of microwave measurement expertise, now in modular instrumentation. Together with Agilent's trusted measurement science, the M9393A provides confidence in test results from R&D to manufacturing to deployment. Core signal-analysis capabilities, along with hardware speed and accuracy, mean that the M9393A PXIe performance vector signal analyzer offers a solution that can be tailored to fit specific needs—today and tomorrow. Test with the M9393A and acquire the performance edge in PXI.

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The MoD, the Ministry of Transport and 'Elbit' Successfully Completed Series of Tests on the 'SkyShield' System

The Israel Missile Defense Organization (IMDO) in cooperation with the Civil Aviation Authority at the Ministry of Transport and the project's main contractor, Elbit Systems, have successfully completed a series of tests on the 'SkyShield' system that protects passenger aircraft against shoulder fired artillery.

The 'SkyShield' system, based on advanced laser technology that deflects missiles fired at aircraft deviating them from their trajectory, has been chosen by the Israeli Ministry of Transport to protect Israeli airlines planes.

> 'SkyShield' is considered to be the most advanced system of its kind in the world...

The tests, conducted in a test range in the south of Israel, were the most complex and sophisticated ever held in the State of Israel. The series of tests included a wide variety of threats that the SkyShield system would have to tackle in order to protect passenger aircraft.

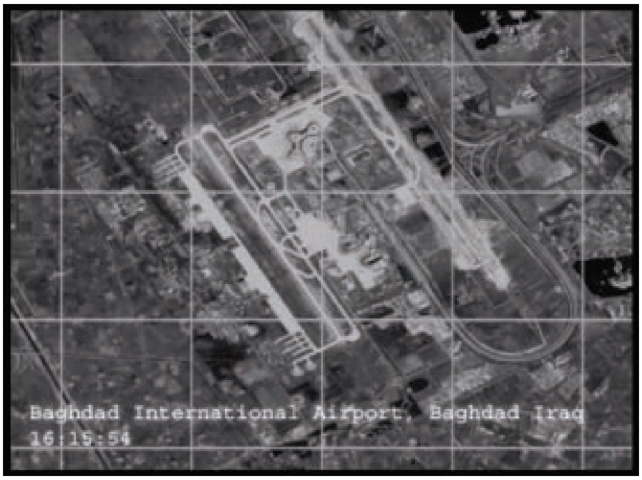
'SkyShield' is considered the most advanced system of its kind in the world and is programmed to protect aircraft automatically. The system, which boasts the highest reliability, combines advanced detection and deflection technologies that comply with the most stringent civil aviation regulations.

LM Team Surpasses Millionth Hour of In-Theater Airborne Surveillance

The Lockheed Martin-built and maintained Persistent Threat Detection System (PTDS) has surpassed one million airborne mission hours of providing around-the-clock, 360-degree monitoring and force protection for coalition forces in theater. Since 2007, Lockheed Martin has worked with deployed forces in Iraq and Afghanistan supporting the tethered aerostat surveillance system for the U.S. Army.

"PTDS has proven to be a great asset for soldiers, sailors, airmen and marines as well as our coalition partners serving in harm's way," said Lt. Col. Michael Parodi, U.S. Army product manager Meteorological and Target Identification Capabilities. "They have been instrumental in providing mission overwatch, detecting [improvised explosive devices] and assisting in the capture of numerous high value targets and weapons caches."

> "PTDS has proven to be a great asset for soldiers, sailors, airmen and marines as well as our coalition partners serving in harm's way."



Source: Lockheed Martin Aerostat. View video with layar app.

PTDS has proven to be extremely effective in providing real-time situational awareness to help troops identify IEDs and other threats, track insurgents and enhance overall readiness for the men and women in theater. From building and delivering 66 systems to the Army to providing ground station operations and manning the aerostats in country, the Lockheed Martin team has taken the warfighter mission as their own.

"Supporting soldiers with the most effective mission systems is our primary focus every day," said Mike Oates, vice president with Lockheed Martin Washington Operations for Army and Special Operations Force Programs. "Lockheed Martin is proud of the PTDS system and the Lockheed employees who served alongside soldiers to perform this vital combat surveillance mission."

With a very large coverage area and capability of remaining aloft 24/7 for weeks at a time in extremely challenging environments, PTDS provides an enduring force protection capability. Equipped with multiple sensors, PTDS gathers and distributes intelligence in support of real-time mission requirements.

Raytheon Continues to Drive GaN Evolution Through Cutting Edge Innovation

Raytheon Co. announced that under the DARPA Microsystems Technology Office (MTO) Wide Bandgap Semiconductor Program, the company has systematically matured GaN from basic material to transistors, MMICs, Transmit/Receive (T/R) Modules and finally Transmit/Receive Integrated Multichannel Modules (TRIMM), enabling game changing system performance for the DoD. This is the latest milestone for Raytheon's GaN technology which was honored by the Office of the Secretary of Defense in June for successful completion of a Defense Production Act Title III Gallium Nitride

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"Through our partnership with DARPA we continue to explore new ways to leverage GaN's limitless capabilities..."

production improvement program, culminating over a decade of Government and Raytheon investment in GaN RF circuit technology.

GaN technology significantly extends the warfighter's capability providing radar, electronic warfare, navigation, and communication systems with more affordable solutions and increased capability. "Raytheon continues to be a driving force in the evolution of GaN technology and it is exciting to be part of this new frontier that directly translates to the warfighter," said Joe Biondi, vice president of advanced technology for Raytheon's Integrated Defense Systems business. "Through our partnership with DARPA we continue to explore new ways to leverage GaN's limitless capabilities to increase performance and reliability of defense systems."

Raytheon, as part of the DARPA MTO Wide Bandgap Semiconductor Program, with the support of a Navy, Air Force and Army technology team, has achieved several first of their kind milestones:

- Demonstrated record setting X-Band GaN power amplifier MMIC performance. The higher efficiency and power of these MMICs enables more affordable systems with higher capability.
- Completed first ever X-Band GaN T/R module demonstrations. This involved extensive, successful design verification testing over a range of relevant operating conditions demonstrating the maturity of the GaN technology.
- Completed first ever X-Band GaN TRIMM demonstration which proved GaN in a relevant environment. This involved extensive testing in a relevant array environment including a 1,000 hour operating test in a laboratory pilot array and an insertion validation in a production radar, proving the TRIMM is ready for transition to production.

Source: Raytheon

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Europe Scores on Innovative but Regional Differences Persist

According to the European Commission's Innovation Union Scoreboard 2014 and the Regional Innovation Scoreboard 2014, Europe is closing its innovation gap with the United States and Japan but differences in performance between EU Member States are still high and diminishing only slowly. At a regional level, the innovation gap is widening, with the innovation performance having worsened in almost one fifth of EU regions.

The overall ranking within the EU remains relatively stable, with Sweden at the top, followed by Denmark, Germany and Finland – the four countries that invest most in research and innovation. The countries whose positions have improved the most are Portugal, Estonia and Latvia. Overall progress has been driven by the openness and attractiveness of the EU research system as well as business innovation collaboration and the commercialisation of knowledge as measured by licence and patent revenues from abroad. However, growth in public R&D expenditure was offset by a decline in venture capital investment and non-R&D innovation investment in companies.

> "We need to turn Europe's great ideas into profitable enterprises that bring jobs and sustainable growth."

Commissioner Johannes Hahn, responsible for Regional Policy, said: "We need to turn Europe's great ideas into profitable enterprises that bring jobs and sustainable growth. The new EU budget and the reformed Regional Policy offer a unique opportunity to foster innovation. More than 100 billion Euros of investment under European Structural and Investment Funds (ESIF) are going to be directed at research and innovation, as well as digital growth, small and medium sized business and developing green and efficient energy.

"Today's Scoreboards show that while some regions are clearly pushing forward, disparities exist. The new Regional Policy will address this head on: every one of Europe's 274 regions will have to develop a smart specialization strategy which will include innovation. Regions will have to build on their economic strengths and develop innovative ways to face global competition."

Anglo/French Partnership to Boost Defence

Defence and aerospace group NDI is bringing SMEs from the UK and France together to explore ways of collaborating. In partnership with the strategy and business development consultants Vanguard Intelligence, member organisation NDI is arranging a conference for SMEs and a range of bigger players from both countries, along with representatives and agencies from the two governments to explore business opportunities.

The conference, France and the UK – Doing Business Together, is being held at Down Hall Hotel Bishop's Stortford, Hertfordshire on June 4 and 5. It will bring together at least 80 SMEs to focus on three increasingly important industry capability areas – autonomy, automation and robotics.

> ...promoting exports success...

It is intended to mark the start of an ongoing engagement between companies in the UK and France, leveraging the potential of SMEs, strengthening the UK-France defence and security relationship and promoting exports success.

The NDI conference will seek to explore ways for business on both sides of the channel to capitalise upon the two countries' existing alliance and to foster broad-based business relationships between SMEs, prime contractors and government representatives across France and the UK.

The conference will also be relevant to those engaged in fields such as aerospace, space, transportation, automotive, marine, medical and energy; specifically to businesses with capabilities in areas including platform systems, propulsion and power systems, sensor and intelligence systems, control and handling systems and navigation and command systems.

Neosat Boosting European Telecommunications by Satellite

The European Space Agency (ESA) is forging ahead with the Neosat next-generation satcom platform, planning the first flights within five years. The goal is for European satellite builders to capture at least half of the world's satcom market in 2018–2030 through innovation and efficiency, generating €25 billion in sales.

Source: ESA

For More Information — **Go to mwjournal.com for more international news items**

> "Neosat will foster competitiveness of European satellite industry..."

The contract for Phase-B, which has been signed by ESA and prime contractors Airbus Defence and Space and Thales Alenia Space, covers selection of the equipment suppliers for the Neosat product lines. The two co-primes will run competitions between equipment suppliers for platform building blocks, based on an agreed single set of requirements.

The upcoming phase will include concurrent engineering activities to define the technical baseline of the new platforms and involve subcontractors in the UK, Sweden, Switzerland and Luxembourg.

Magali Vaissiere, ESA's Director of Telecommunications and Integrated Applications commented: "Neosat will foster the competitiveness of European satellite industry and strengthen Europe's position in the core satcom market for the next decade. This is a unique opportunity for Europe's suppliers, as 80 percent of European satellite platform equipment is procured from within ESA Member States. This will be worth €7 billion to those suppliers."

The contract for Phase-B is expected to last around 13 months. The subsequent Phase-C/D will start in 2015 for the development and manufacture of the first two prototype flight platforms, launch in 2018–2019 and in-orbit demonstration under a public–private partnership to be established with satellite operators.

ITEA ARTEMIS-IA Vision 2030 Presented to EU Commissioner

A delegation of representatives from ARTEMIS joint undertaking and EUREKA Cluster ITEA3 led by Heinrich Daembkes, president of ARTEMIS and Rudolf Haggenmüller, ITEA 3 chairman officially presented the ITEA ARTEMIS-IA high-level vision 2030: opportunities for Europe report to Neelie Kroes, vice-president of the European Commission and commissioner for the Digital Agenda.

> The delegation encouraged the commissioner to promote software innovation with the same passion as electronics.

The report estimates the global market of digital technology at $3,300 billion, corresponding to around 50 million jobs. Its key message is that European industry needs a balanced approach to electronics and software innovation.

The delegation encouraged the commissioner to promote software innovation with the same passion as electronics innovation. As a result, it was suggested that a high-level working session on concrete challenges for Digital Technology be organised and the list of challenges was identified.

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LZY-22+	0.1-200	43	16	32	1495	1470
ZHL-5W-1	5-500	44	8	11	995	970
• ZHL-100W-GAN+	20-500	42	79	100	2395	2320
• ZHL-50W-52	50-500	50	40	63	1395	1320
• ZHL-100W-52	50-500	50	63	79	1995	1920
LZY-1+	20-512	43	37	50	1995	1895
• ZHL-20W-13+	20-1000	50	13	20	1395	1320
• ZHL-20W-13SW+	20-1000	50	13	20	1445	1370
LZY-2+	500-1000	46	32	38	1995	1895
NEW ZHL-100W-13+	800-1000	50	79	100	2195	2095
ZHL-5W-2G+	800-2000	45	5	6	995	945
ZHL-10W-2G	800-2000	43	10	13	1295	1220
ZHL-30W-252+	700-2500	50	25	40	2995	2920
ZHL-30W-262+	2300-2550	50	20	32	1995	1920
ZHL-16W-43+	1800-4000	45	13	16	1595	1545
ZVE-3W-83+	2000-8000	36	2	3	1295	1220
ZVE-3W-183+	5900-18000	35	2	3	1295	1220

Listed performance data typical, see minicircuits.com for more details.

** To order **without** heat sink, add **X** suffix to model number (example: LZY-22X+).*

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

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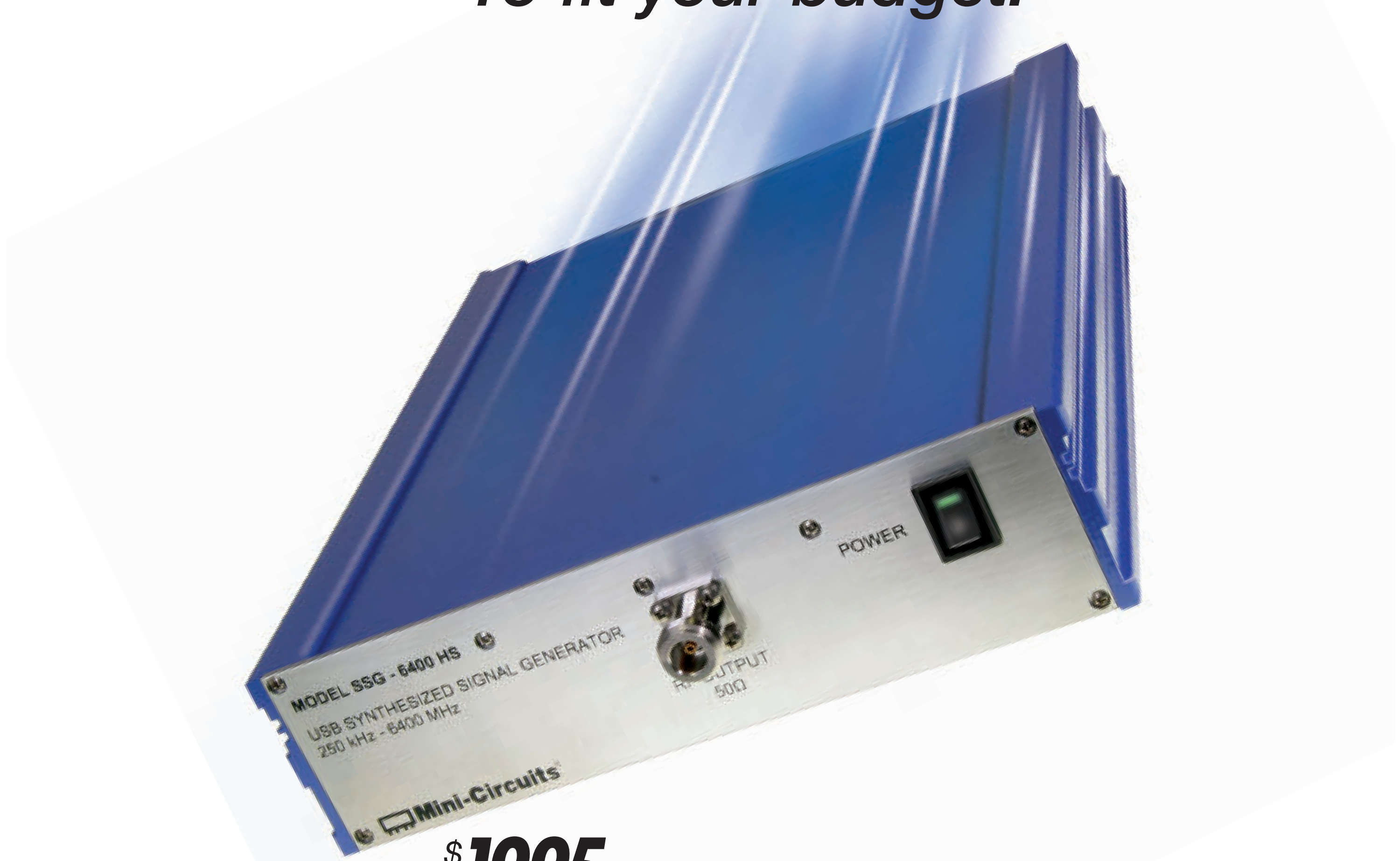

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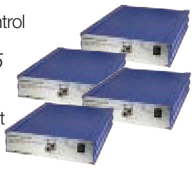

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Over 800M Smartphones Using Indoor Location by 2018

iBeacons are fast becoming the foot soldiers of indoor location in retail, bringing awareness and adoption, but it is just one of over 10 indoor location technologies competing in this $5 billion space. A host of new, higher-accuracy, "infrastructure-free" technologies are forecast to change the face of and use case for indoor location in the future.

> "With over 800 million smartphones actively using indoor location for applications by 2018, it will be as standard as GPS is today."

In ABI Research's report "Indoor Location Technologies," the evolution of each of these technologies is considered. Senior analyst Patrick Connolly said, "We see huge growth for infrastructure-based technologies like Wi-Fi and iBeacons, with BLE deployments forecast to break 20,000 by 2015, largely focused on retail. But the arrival of high-accuracy handset-based technologies like sensor fusion, LED, magnetic field and a host of others, will also enable a whole new set of consumer applications and services around ambient intelligence, social networking, corporate/enterprise, fitness/health, mobile advertising and gaming. With over 800 million smartphones actively using indoor location for applications by 2018, it will be as standard as GPS is today."

VP and Practice Director Dominique Bonte added, "iBeacons and BLE location make indoor easy and cheap, but that also opens the door to a host of new competitors. Those at the forefront are already aggressively pursuing new, sub-meter handset-based technologies. This will give the edge in both the retail and consumer spaces."

View video with layar.

DOT to Require V2V Communications on All Light Vehicles

The U.S. Department of Transportation's National Highway Traffic Safety Administration recently announced that it is going to create a formal path forward for vehicle-to-vehicle communication for light vehicles. This means that NTHSA will start regulatory proposals on how this technology could become mandatory in the future.

Through the technology, vehicles would be able to talk with each other and exchange information to prevent crashes and relay basic speed and position information.

"Vehicle-to-vehicle technology represents the next generation of auto safety improvements, building on the lifesaving achievements we've already seen with safety belts and air bags," says U.S. Transportation Secretary Anthony Foxx. "By helping drivers avoid crashes, this technology will play a key role in improving the way people get where they need to go while ensuring that the U.S. remains the leader in the global automotive industry."

The DOT launched a safety pilot for V2V communications in Ann Arbor, MI, in August 2012 that tied 3,000 vehicles together in the biggest ever road test of the technology. The agency concluded that safety applications using the technology can address "a large majority of crashes involving two or more motor vehicles," according to a press release.

> "V2V crash avoidance technology has game-changing potential..."

Currently under development are applications that could warn drivers of imminent crashes, but that do not intercede by automatically driving the vehicle out of those situations. NHTSA said in a release, however, that it is considering more active safety solutions in the future that will blend with V2V solutions.

Global LTE Subscriptions to Exceed 2B in 2019

Worldwide LTE-related subscriptions reached 229.7 million in 2013, and will continually grow at a CAGR of 43.6 percent between 2013 and 2019, to exceed 2 billion. By the end of 2013, LTE-TDD subscribers accounted for 5 percent of the LTE market, while 94.2 percent of the LTE market was taken up by LTE-FDD.

"Among the LTE subscription growth, Asia-Pacific contributes the most with a 49 percent market share. The second greatest contributor is North America with an 18 percent share," comments Marina Lu, research associate at ABI Research. "The large population base in Asia combined with rapid LTE network deployment and cost-competitive smartphones has accelerated the remarkable subscriber adoption."

All the major mobile operators are showing their commitments to carrier aggregation capable LTE-Advanced technology, which can better handle the anticipated explosion in mobile data traffic with greater bandwidth. ABI Research forecasts that LTE-Advanced subscribers will grow to 750 million in 2019 accounting for 37.3 percent of overall LTE subscribers. North America will be the most aggressive LTE-Advanced market, followed by Asia-Pacific and Western Europe. "Remarkably, the South Korean Operators, SK Telecom and LG U+, commercially launched LTE-Advanced networks in June 2013 and by the end of 2013, SK Telecom gained more than 1 million LTE-Advanced subscribers, which equates to 10 percent of all its LTE subscribers," adds Jake Saunders, VP and practice director.

For More Information

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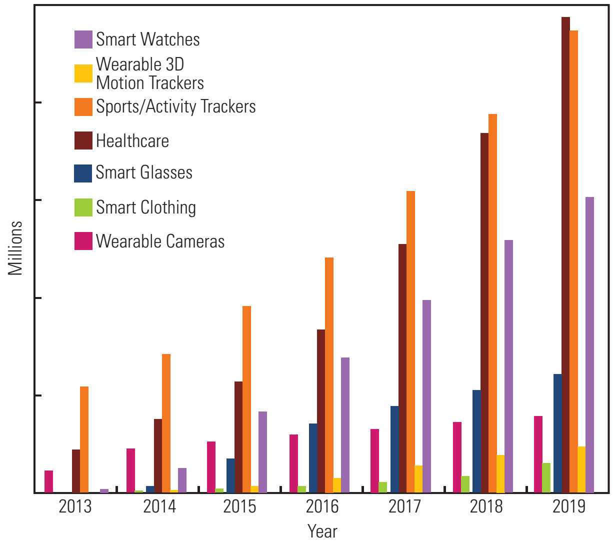
90M Wearable Computing Devices Will Be Shipped in 2014

Wearable technology will be characterized by the diversity of products, but only the product categories with a clear use-case and therefore target audience will succeed. ABI Research projects the wearable device sales volumes in 2014 to come from healthcare and sports and activity trackers. While the commercial launch of several smart glass products, including Google Glass, will continue to drive interest in the wearable space, it will not be a significant commercial success in 2014.

"The next twelve months will be a critical period for the acceptance and adoption of wearable devices," says senior analyst Joshua Flood. "Healthcare and sports and activity trackers are rapidly becoming mass-market products. On the flipside, wearable devices like smart watches need to overcome some critical obstacles. Aesthetic design, more compelling use cases, battery life and lower price points are the main inhibitors. How vendors approach these challenges and their respective solutions will affect the wearable market far in the future."

> "The next twelve months will be a critical period for the acceptance and adoption of wearable devices..."

Global Wearable Computing Devices
World Market, Forecast: 2013–2019



Source: ABI Research

Chipset vendors are beginning to pave the way with interesting wearable reference designs that will allow non-technology OEMs and brands to quickly jump upon the wearable device bandwagon and bring diverse, innovative, unique, and stylish solutions.

Around the **Circuit**

Laura Glazer, Staff Editor

MERGERS & ACQUISITIONS

RF Micro Devices Inc. and **TriQuint Semiconductor Inc.** announced a definitive merger agreement under which the companies will combine in an all-stock transaction. To reflect the nature of this transaction as a merger of equals, the new company will have a new name and shared leadership team. The boards of directors of both RFMD and TriQuint have unanimously approved the transaction. The merger will create new growth opportunities in three large global markets – mobile devices, network infrastructure and aerospace/defense.

M/A-COM Technology Solutions Inc. announced that it has acquired **Nitronex LLC**, a leader in the design and manufacture of GaN based RF solutions, for approximately $26 million in cash. The acquisition of Nitronex is expected to provide MACOM with fundamental and innovative GaN-on-Silicon epitaxial and pendeoepitaxial semiconductor process technology and materials for use in RF applications.

AMETEK Inc. has acquired **VTI Instruments**, a leading manufacturer of high-precision test and measurement instrumentation, for $74 million. VTI, acquired from an investor group led by Merit Capital Partners and Alerion Capital Group, has annual sales of approximately $38 million. Its headquarters is in Irvine, CA and it has additional facilities in Cleveland, OH and Bangalore, India.

Aeroflex Holding Corp. announced the acquisition of **Shenick Network Systems**, a leading edge provider of virtual testing for next generation software defined networking. Aeroflex expects the acquisition to be neutral to its fiscal 2014 financial results and accretive to its fiscal 2015 financial results.

COLLABORATIONS

Saab and the **Kalyani Group**, one of India's leading high-technology multinationals, have entered into a strategic alliance to partner and address key Indian Army air defence projects, including the VSHORAD and SRSAM requirements. The teaming combines Saab's many decades as a leading developer and supplier of proven high-technology radar and missile systems, with the rich engineering and manufacturing capabilities of Kalyani. Saab is offering a system based on the RBS 70 NG missile system for VSHORAD, while for the SRSAM requirement the company is offering a unique combination of its Giraffe AMB 3-D radar and the BAMSE advanced ground based air defence missile system.

Texas Instruments (TI) and **Nokia Solutions and Networks** (NSN) announced their collaboration on NSN's next generation of indoor small cell base stations. Based on NSN's Flexi Zone suite of products, the new indoor small cell base stations are expected to support a record 400 active indoor users, compared to 32 users supported today, in a power over Ethernet envelope. Furthermore, by utilizing TI's KeyStone SoCs to power the next generation indoor FlexiZone small cells, NSN is able to offer a macro parity leading solution.

MIMOtech, a specialist in high capacity point-to-point radios, has announced a strategic partnership with **CSG Science & Technology Co. Ltd.** (CSG Hefei), under which CSG Hefei has acquired an undisclosed amount of MIMOtech's share capital. CSG Hefei is a supplier of integrated access devices for last-mile bandwidth via fiber and copper. The two companies will collaborate on marketing the MIMOtech range of ultra high capacity packet radios for last mile backhaul.

Gowanda Electronics, a designer and manufacturer of precision electronic components and inductors for power, RF, and high frequency applications, is teaming up with its recently acquired sister company, **TTE Inc.**, to provide a broader range of electronic components to the global design engineering community. TTE Inc. designs and manufactures RF and microwave filters for critical markets including defense and test & measurement.

MIMOon GmbH, an LTE software vendor for small cells and terminals, and **NuRAN Wireless**, a supplier of mobile and broadband wireless solutions, have announced a cooperation to deliver LTE small cell base stations. NuRAN Wireless is developing an LTE base station which integrates MIMOon's physical layer, protocol stack and advanced scheduler software products, which have been licensed by leading small cell product developers around the globe. MIMOon is the only software vendor to offer complete LTE software from physical layer to protocol stack for both base stations as well as for terminals.

NEW STARTS

National Instruments announced that it is the first vendor to execute a Manufacturing Test License (MTL) agreement with **Broadcom Corp.** The MTL agreement authorizes NI to provide manufacturing test solutions and modifiable application source code to Broadcom® wireless LAN and Bluetooth device customers. The Broadcom® MTL agreement is a new license and validation program, providing test equipment vendors, such as NI, with access to Broadcom WLAN and Bluetooth software tools and Broadcom technical support resources. The program is designed to provide Broadcom OEM customers with validated test systems that reduce time-to-market and improve manufacturing efficiency and product quality.

TEGAM Inc. was recently awarded Patent No. 8,610,069, "Coaxial to Dual Co-Planar Waveguide Launcher for Microwave Bolometry." This patent describes a new way to construct bolometers—a type of microwave power sensor that uses thermistors—that makes them more accurate and easier to assemble. Specifically, the patent describes a sensor with a dual-coplanar sensor architecture that launches a microwave signal from coaxial airline to a unique arrangement of coplanar waveguides, arranged symmetrically on both sides of a thin dielectric substrate. The characteristic impedance

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2-WAY								
CSBK260S	20 - 600	0.28 / 0.4	0.05 / 0.4	0.8 / 3.0	25 / 20	1.15:1	50	377
DSK-729S	800 - 2200	0.5 / 0.8	0.05 / 0.4	1 / 2	25 / 20	1.3:1	10	215
DSK-H3N	800 - 2400	0.5 / 0.8	0.25 / 0.5	1 / 4	23 / 18	1.5:1	30	220
P2D100800	1000 - 8000	0.6 / 1.1	0.05 / 0.2	1 / 2	28 / 22	1.2:1	2	329
DSK100800	1000 - 8000	0.6 / 1.1	0.05 / 0.2	1 / 2	28 / 22	1.2:1	20	330
DHK-H1N	1700 - 2200	0.3 / 0.4	0.1 / 0.3	1 / 3	20 / 18	1.3:1	100	220
P2D180900L	1800 - 9000	0.4 / 0.8	0.05 / 0.2	1 / 2	27 / 23	1.2:1	2	331
DSK180900	1800 - 9000	0.4 / 0.8	0.05 / 0.2	1 / 2	27 / 23	1.2:1	20	330
3-WAY								
S3D1723	1700 - 2300	0.2 / 0.35	0.3 / 0.6	2 / 3	22 / 16	1.3:1	5	316
4-WAY								
CSDK3100S	30 - 1000	0.7 / 1.1	0.05 / 0.2	0.3 / 2.0	28 / 20	1.15:1	5	169S

◦ With matched operating conditions

HYBRIDS RoHS

Model #	Frequency (MHz)	Insertion Loss (dB) [Typ./Max.] ◊	Amplitude Unbalance (dB) [Typ./Max.]	Phase Unbalance (Deg.) [Typ./Max.]	Isolation (dB) [Typ./Min.]	VSWR (Typ.)	Input Power (Watts) [Max.]	Package
90°								
DQS-30-90	30 - 90	0.3 / 0.6	0.8 / 1.2	1 / 3	23 / 18	1.35:1	25	102SLF
DQS-3-11-10	30 - 110	0.5 / 0.8	0.6 / 0.9	1 / 3	30 / 20	1.30:1	10	102SLF
DQS-30-450	30 - 450	1.2 / 1.7	1 / 1.5	4 / 6	23 / 18	1.40:1	5	102SLF
DQS-118-174	118 - 174	0.3 / 0.6	0.4 / 1	1 / 3	23 / 18	1.35:1	25	102SLF
DQK80300	800 - 3000	0.2 / 0.4	0.5 / 0.8	2 / 5	20 / 18	1.30:1	40	113LF
MSQ80300	800 - 3000	0.2 / 0.4	0.5 / 0.8	2 / 5	20 / 18	1.30:1	40	325
DQK100800	1000 - 8000	0.8 / 1.6	1 / 1.6	1 / 4	22 / 20	1.20:1	40	326
MSQ100800	1000 - 8000	0.8 / 1.6	1 / 1.6	1 / 4	22 / 20	1.20:1	40	346
MSQ-8012	800 - 1200	0.2 / 0.3	0.2 / 0.4	2 / 3	22 / 18	1.20:1	50	226
180° (4-PORTS)								
DJS-345	30 - 450	0.75 / 1.2	0.3 / 0.8	2.5 / 4	23 / 18	1.25:1	5	301LF-1

◊ In excess of theoretical coupling loss of 3.0 dB

COUPLERS RoHS

Model #	Frequency (MHz)	Coupling (dB) [Nom]	Coupling Flatness (dB)	Mainline Loss (dB) [Typ./Max.]	Directivity (dB) [Typ./Min.]	Input Power (Watts) [Max.] ◦	Package
KFK-10-1200	10 - 1200	40 ±1.0	±1.5	0.4 / 0.5	22 / 14	150	376
KDS-30-30	30 - 512	27.5 ±0.8	±0.75	0.2 / 0.28	23 / 15	50	255 *
KBS-10-225	225 - 400	10.5 ±1.0	±0.5	0.6 / 0.7	25 / 18	50	255 *
KDS-20-225	225 - 400	20 ±1.0	±0.5	0.2 / 0.4	25 / 18	50	255 *
KBK-10-225N	225 - 400	10.5 ±1.0	±0.5	0.6 / 0.7	25 / 18	50	110N *
KDK-20-225N	225 - 400	20 ±1.0	±0.5	0.2 / 0.4	25 / 18	50	110N *
KEK-704H	850 - 960	30 ±0.75	±0.25	0.08 / 0.2	38 / 30	500	207
SCS100800-10	1000 - 8000	10.5 ±1.5	±2.0	1.2 / 1.8	8 / 5	25	361
KBK100800-10	1000 - 8000	10.5 ±1.5	±2.0	1.2 / 1.8	8 / 5	25	322
SCS100800-16	1000 - 7800	16.8 ±1.5	±2.8	0.7 / 1.0	14 / 5	25	321
KDK100800-16	1000 - 7800	16.8 ±1.5	±2.8	0.7 / 1.0	14 / 5	25	322
SCS100800-20	1000 - 7800	20.5 ±2.0	±2.0	0.45 / 0.75	12 / 5	25	321
KDK100800-20	1000 - 7800	20.5 ±2.0	±2.0	0.45 / 0.75	14 / 5	25	322
KEK-1317	13000 - 17000	30 ±1.0	±0.5	0.4 / 0.6	30 / 15	30	387

* Add suffix - LF to the part number for RoHS compliant version.
◦ With matched operating conditions

Unless noted, products are RoHS compliant.

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of the top and bottom coplanar waveguides is approximately twice the characteristic impedance of the coaxial airline, so the parallel combination of the two coplanar waveguides is the characteristic impedance of the coaxial airline.

Nutaq created a separate entity for its line of wireless end products, named **NuRAN Wireless**. Nutaq decided to create a separate entity which will be focused entirely on delivering best-in-class small cells wireless solutions to its customer base, which ranges from small private network operators to major Tier-1 mobile network operators. The increased focus will also accelerate the company's developments relative to LTE and TV White Space, for which trials are ongoing under experimental license from Industry Canada.

Gilomen Consulting is offering its services to maximizing trade show and event marketing success to increase sales for RF and microwave companies. Gilomen Consulting serves domestic and international clients with complete event program management and logistical support.

ACHIEVEMENTS

ThinKom Solutions announced that the ultra-low profile ThinSAT® 300 antenna has been successfully flight tested onboard Northrop Grumman's demonstrator aircraft, the Firebird. The antenna system was used to support intelligence, surveillance and reconnaissance (ISR) SATCOM mission capabilities while experiencing 2.5g maneuvers over the Mojave Desert. This demonstration proves that small ultra-low profile antenna systems can provide high quality sensor data through a commercial Ku-Band satellite network.

The **European Space Agency** (ESA) has announced that the in-orbit validation of Galileo has been achieved: Europe now has the operational nucleus of its own satellite navigation constellation in place – the world's first civil-owned and operated satnav system. In 2011 and 2012 the first four satellites were launched into orbit. In the following year, these satellites were combined with a growing global ground infrastructure to allow the project to undergo its crucial In-Orbit Validation (IOV) phase.

Exelis has successfully installed the latest operational software and certified mission data files for Exelis-built Advanced Integrated Defensive Electronic Warfare Suite (AIDEWS) systems in Chile, Oman, Poland, Pakistan and Turkey. AIDEWS is an EW self-protection system that shields F-16 fighter aircraft from advanced radio frequency threats. Exelis has provided AIDEWS systems, components and operational software to the five countries as part of a foreign military sales program conducted through Warner Robins Air Force Base.

CONTRACTS

Raytheon Co. has received a $655 million contract for new-production fire units of the combat-proven Patriot Air and Missile Defense System for Kuwait. These units are an addition to the Patriot fire units Kuwait currently owns to counter current and evolving threats. Awarded by the U.S. Army Aviation and Missile Command, Redstone Arsenal, AL, as a Foreign Military Sale agreement, the contract includes new Patriot fire units with increased computing power and radar processing efficiency, improved man-machine interface and reduced life-cycle costs.

Mercury Systems Inc. announced it received an $11 million follow-on order from a leading defense prime contractor for high performance microwave subsystems for an electronic warfare application. The orders were received in Mercury's fiscal 2014 second quarter, with deliveries currently expected to span 2015 through 2018.

Comtech Telecommunications Corp. announced that its Santa Clara, CA-based subsidiary Comtech Xicom Technology Inc. has been awarded a contract totaling $1.4 million from a major system integrator to supply rack-mount, high-power amplifiers (HPA). The HPAs will be used in an expansion of a system that relays military satellite communications around the world and that is already using similar Comtech Xicom HPAs.

Airbus Defence and Space has won a contract with **SES,** one of the world's leading satellite operators, for the design and construction of the latest addition to its fleet, the SES-10. The new satellite will be based on the ultra-reliable Eurostar E3000 platform and stationed over Latin America. SES-10 will be placed in geostationary orbit at 67° West, where it will provide SES with additional capacity for direct-to-home TV broadcasting and other telecommunication services for Mexico, Caribbean, Central America and South America. It will carry a payload of 50 high-power Ku-Band transponders.

Selex ES has been awarded a contract by the **Austrian Ministry of Defence** (Bundesministerium für Landesverteidigung und Sport – BMLVS), to provide a RAT31DL/M deployable air defence radar system and the relevant logistic support, with the contract including an option for a further radar system of the same kind. The system will enter operation in 2016. The RAT31DL/M system that is going to be provided will also include a 15 m high transportable and self-mounting tower. The new system will refresh Austria's fleet of existing radars which were provided by Selex ES during the 1980s, the company supplying five RAT 31 S medium range radars.

Anite has been selected to supply additional device testing systems to a major Chinese mobile operator for its TD-LTE device acceptance programme. The selection follows several years of close collaboration between the two parties and is a direct result of Anite's leading coverage of Global TD-LTE Initiative (GTI) validated TD-LTE network simulator interoperability test scripts.

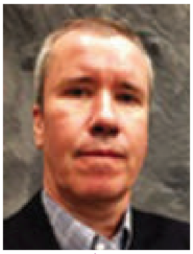
PEOPLE

Southwest Microwave is pleased to announce the appointment of **Donald Bradfield** as the new general manager for its Microwave Products Division. Bradfield joined Southwest Microwave after more than 30 years of design engineering and operations management of microwave components for the military/aerospace/hi-rel industries. Based at the company's Tempe, AZ facility, Bradfield will assume management of operations as well as oversee sales and business development activities for the Southwest Microwave's high performance connector products.

Around the **Circuit**

▲ *Jiro Hashizume*

Hesse GmbH announced that **Jiro Hashizume** recently joined the company to head up its new subsidiary, Hesse Mechatronics Japan Co. Ltd. Hashizume has 17 years of experience in technical support, software design and sales management in the semiconductor equipment industry. For the past five years he served as territory manager for Japan and Korea for Kulicke & Soffa Industries Inc. (K&S), where he gained extensive understanding of pre- and post-sales technical support, marketing and sales strategies to grow wire bonding equipment sales. Prior to his time at K&S, Hashizume worked for Orthodyne Electronics as senior field applications engineer.



▲ *Tom Butler*

RFMW Ltd. announced that **Tom Butler** has joined the organization as director of sales for North America. Butler has served in senior management positions where he has directed sales at local, national and international levels. With a successful track record at companies such as Crescend Technologies, TriQuint and RFMD, Butler brings a fresh approach to sales and market development for RFMW's highly qualified, technical sales organization. Butler graduated with a Bachelor of Science degree in electrical engineering from the University of Connecticut.

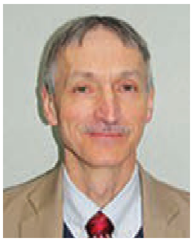
Diamond Antenna and Microwave Corp. announced that **David O. Thomas** has been named business development manager. He will be responsible for expanding opportunities at key U.S. accounts and developing markets in key Asian and South American countries. Thomas has more than 25 years selling and marketing microwave components, subsystems and systems into both the military and commercial markets. For the better part of the last 20 years, he has been selling microwave radio systems and subsystems (both portable and fixed) and satellite systems into the military, police and security markets as well as into the TV broadcast market.

Radio Frequency Systems (RFS) announced that wireless industry veteran and long-time RFS team member **Al Filoreto** has been promoted to eastern regional sales manager. In his new role, Filoreto's top priorities are to widen and diversify the company's customer base and to increase RFS' brand name recognition in the market. Filoreto has held positions in the wireless industry for more than 25 years and served in various sales roles at RFS since 2006, when he joined the company as a district sales manager. Before joining RFS, Filoreto worked for Motorola, Hutton Communications and American Tower.

San-tron Inc. has announced that they have rehired **Vincent Caputo** as senior product line manager for cable assemblies. Caputo brings over 16 years of RF/microwave experience to the position and first came to San-tron as a sales associate in 2004, and more recently served as eastern regional sales manager.

Around the **Circuit**


Tim Jensen


Glen Thomas

Indium Corp. announces that **Tim Jensen** has been named the senior product manager for engineered solders and **Glen Thomas** has been named product manager for PCB assembly solder paste. Jensen is responsible for the overall success of the product line, including sales volume, profitability, the range of products, and Indium Corp.'s strategic approach to the market. Thomas is responsible for managing the company's entire line of solder paste materials for PCB assembly.

OBITUARY


Michael Lally

Michael Lally passed away on January 26, 2014 at the age of 52. Mike was most recently a staff software engineer with RF Micro Devices in Billerica, MA. He specialized in developing software for RF and microwave engineering test systems and had a capacity for understanding much more than just test requirements. In a career in the microwave industry spanning over three decades, he also worked at M/A-COM, Raytheon's Research Division and Advanced Device Center, and ATN Microwave. He earned his BS from UMass-Amherst and his MS degree from Boston University.

REP APPOINTMENTS

Emerson Network Power announces **Con-Tek Marketing** (CTM) will represent Emerson Connectivity Solutions' Midwest Microwave and Semflex product lines in UT, WY and CO.

Res-Net Microwave Inc. has appointed **Youngewirth and Olenick Associates** as sales representative firm in Southern CA and NV.

TEGAM signed an agreement with **AR Europe** so that TEGAM RF instrumentation will be available from Amplifier Research subsidiaries throughout Europe.

PLACES

COMSOL Inc. announced the opening of a new office in Curitiba, Paraná to provide multiphysics simulation and analysis software for the Brazilian market.

Computer Simulation Technology (CST), Darmstadt, announces a new office in Warsaw, Poland, strengthening the sales and support channels for its electromagnetic (EM) simulation tools in the Baltic region.

Cost Effective 3D Glass Microfabrication for Advanced RF Packages

J.H. Flemming, R. Cook, S. Sibbet, C.F. Schmidt, K. Dunn and J. Gouker
3D Glass Solutions Inc., Albuquerque, NM

Microfabrication of glass micro-devices and circuits has been historically difficult at the part level, let alone in a high volume manufacturing (HVM) environment, due to low throughput, limited precision and accuracy, and reduced reliability, as well as limited process and design capabilities. A new photo-definable glass ceramic material has been developed that is processed in a three-step batch process enabling an HVM solution for glass microfabrication. Since the technology is based on a lithographic process, many design and process capabilities not typically associated with glass microfabrication are now possible, such as through glass vias (TGV) for I/Os, complex inductor line structures, high Q-factor architectures, and antenna air bridges on a single electrical substrate. The material's fine surface finish also enables an MCM capability with fully integrated thin film passive components such as resistors, capacitors and inductors.

Glass materials have many ideal properties for RF and microwave electronic packaging, including high strength, smooth surfaces for efficient signal distribution and excellent electrical characteristics; however, traditional glass manufacturing techniques (e.g., deep reactive-ion etching [DRIE], sand blasting and laser processing) suffer from low throughput, low yield, limited precision and accuracy and limited design capabilities. This prevents even the most basic packaging features like through glass vias (TGV) from being used in high volume applications.

For these reasons, most RF and microwave electronic packages are produced using materials such as laminates and solid ceramics. These are unsuitable for many applications, however, because circuit integration is constrained by flatness and warpage limitations; the inability to produce large scale through-substrate vias results in long interconnection paths between I/Os; high surface roughness prevents the use of small metal line widths; and many of these materials, such as alumina, are expensive to use and process.

TABLE I
SUMMARY OF RELEVANT RF MATERIAL CONSTANTS

Young's Modulus	81 GPa
Electrical Resistivity	10^{12} Ω
Coefficient of Thermal Expansion	10 ppm/K
Loss Tangent (3.3 GHz)	0.0086
Loss Tangent (10.2 GHz)	0.0106
Dielectric Constant (3.3 GHz)	6.58
Dielectric Constant (10.2 GHz)	6.575

With the newly developed APEX® Glass process, features such as TGVs, trenches and embedded microstructures (e.g., inductors and antennas) may be simultaneously microfabricated using a precise, rapid and cost effective batch manufacturing process. The ability to produce electronic packages that integrate these types of structures enables many types of packaging architectures across military, communications and portable consumer electronics industries.

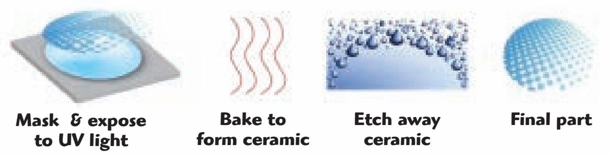
PROCESSING APPROACH

APEX Glass is a photosensitive glass-ceramic material capable of existing in both an amorphous glass state and a crystallized ceramic state. Leveraging the differences between these states allows designers to produce RF and microwave electronic structures not commonly associated with glass processing. ***Table 1*** lists several of its material characteristics.

The material is batch processed in three steps (see ***Figure 1***). First, a chrome-on-quartz mask is placed directly onto the glass wafer, without photoresist, and exposed to 310 nm light. During

this step, photo-activators in the glass become chemically reduced.

In the second step, the wafer is baked. The temperature is initially raised to a level that allows the photo-activators to migrate together forming nano-clusters and is then ramped up to a second level to facilitate coalescence of ceramic-forming ions around the nano-clusters. During this phase of the baking process, any previously exposed regions are converted into a ceramic state, where increased levels of exposure lead to more complete ceramic formation.



▲ *Fig. 1 APEX® Glass processing steps.*

TABLE II

TYPICAL PROCESSING CAPABILITIES AND TOLERANCES

Performance Metric	*Standard Specification*	*Standard Tolerance*
Material Thickness	100 to 1000 µm	± 15 microns
Surface Finish	10 to 250 nm Ra	±10%
TGV Diameter	>30 microns	± 10%
TGV Aspect Ratio (TGV Diameter: Wafer Thickness)	10:1	N/A
TGV Pitch	1.5 times TGV diameter	N/A
TGV Accuracy (across 150 mm)	5 microns	± 5 microns

In the final step, the wafer is etched in a dilute hydrofluoric acid solution (e.g., 10 percent), etching the ceramic state 60 times more preferentially than the glass state. In this manner, a wide variety of features, such as posts, wells, TGVs, trenches, blind vias and air bridges may be produced. The desired structure depth, or the amount of undercutting, is controlled by etch concentration, processing duration, bath temperature and etching direction.

The lithography-based patterning process produces accurate and precise manufacturing features (see ***Table 2***). For example, TGVs as small as 30 microns in diameter at pitches as small as 1.5 times the TGV diameter may be produced with micron-scale features and positional accuracy on the production substrate. ***Figure 2a*** shows an array of 60-micron diameter TGVs at a pitch of 150-microns. The differences between glass and ceramic etch selectivities enable the production of anisotropic etch profiles greater than 10:1 (TGV diameter: material thickness) as shown in Figure 2b. These anisotropic profiles allow for the efficient packing of electronic I/Os enabling densely packed TGV array (e.g., wide I/O) architectures. Figure 2c shows a cross-section of a fully copper plated TGV array.

Similar to other commercially available glass materials, its surface finish facilitates a number of surface modifications such as thin and thick film metallizations. A surface roughness of less than 40 nm is common for most RF and microwave applications and enables the production of sub-10 micron wide line widths for redistribution. ***Figure 3a***, for example, shows a redistribution layer of 10-micron lines on 20-micron pitch connecting to 50-micron TGVs. Furthermore, the fine surface finish of the material enables MCM capability with fully integrated thin film passive components such as resistors, capacitors and inductors. Figure 3b shows that thick layers (>10 microns) of copper and other metals may be electroplated onto the surface. Figure 3c shows a millimeter wave electronic circuit with 35-micron critical dimensions, demonstrating that the adhesion between electroplated metal and the glass surface is strong enough to withstand additional downstream processing such as post-electroplating wet etching to create air bridge architectures.

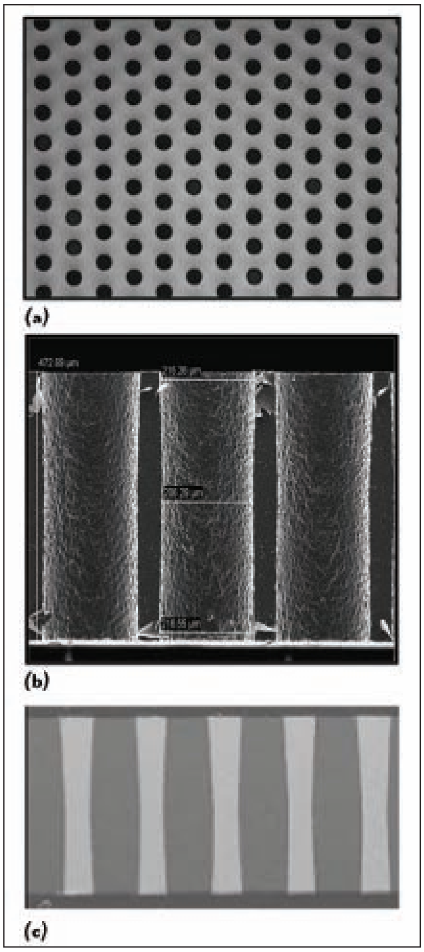
ADVANCED RF DESIGNS

The process enables complex RF electronics not typically associated with glass materials. In many applications, high Q-factor architectures are necessary for efficient, low power communications. For these applications, it offers several degrees-of-freedom in design and production. ***Figure 4*** shows a high Q-factor millimeter-wave structure that consists of 120-micron wide, 6-micron thick, copper lines resting on 20-micron wide glass rails, with 25-micron wide copper lines free floating 100 microns above the underlying glass material. The entire circuit is surrounded by solid copper EMI features, grounded on the backside.

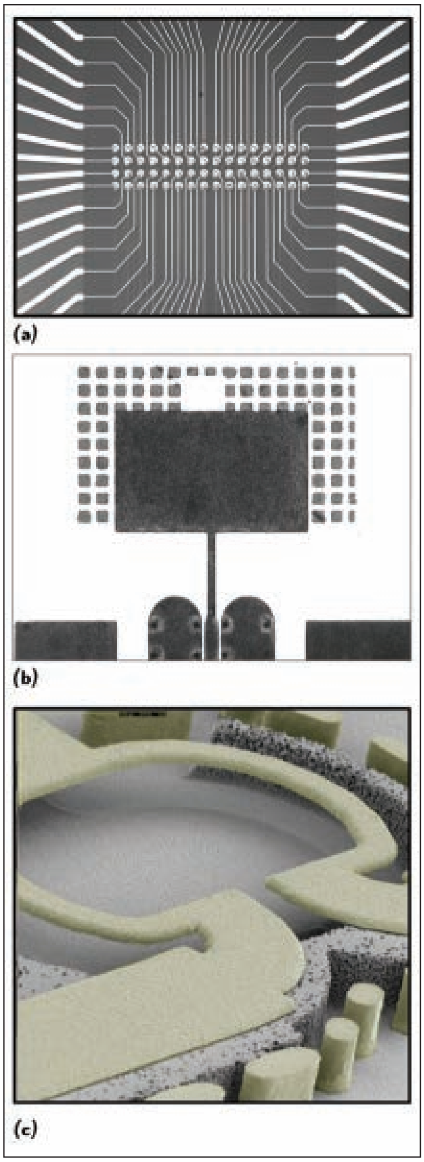
The package demonstrates three key design features:

Glass rails support surface metallization by providing rigidity for the metal lines to rest on while removing the majority of underlying glass material, enabling the metal lines to be surrounded by air. Support rails may be produced in a number of geometries, however, the central line architecture is the most common. Rails ranging from 10 to 100 microns have been demonstrated.

Air bridges of surface metal lines are used in a number of RF architectures. Air bridges of metal lines ranging from 10 to 1000 microns have been demonstrated. Air bridges may exist as undercut surface metal lines with the glass 150-microns below the metal line, or they may consist of free-floating metal lines spanning millimeters of space where no glass exist below the metallization.



▲ *Fig. 2 TGV array (a), 200-micron diameter TGVs demonstrating anisotropic etch (b), cross-section of 75-micron diameter, 800-micron thick copper plated (lighter color) TGVs (c).*



▲ *Fig. 3 Redistribution layer (a), 15-micron thick electroplated copper features (b), millimeter wave circuit with 35-micron air bridges (c).*

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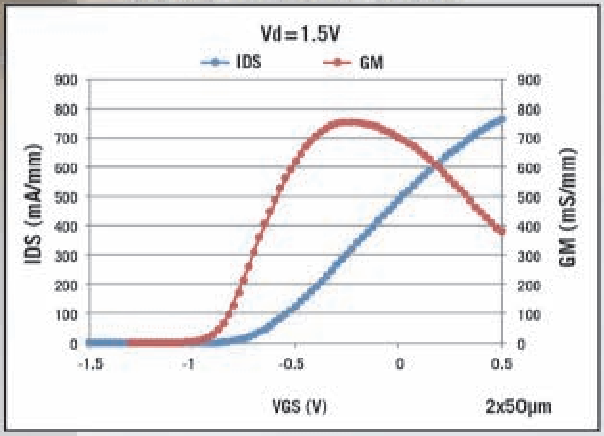
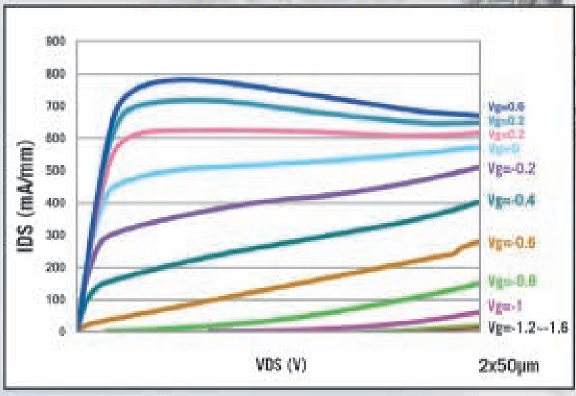
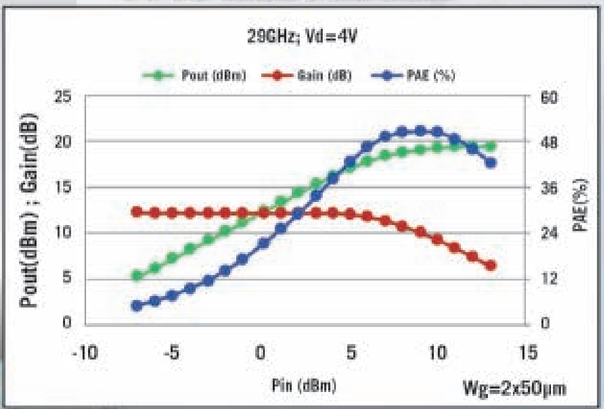


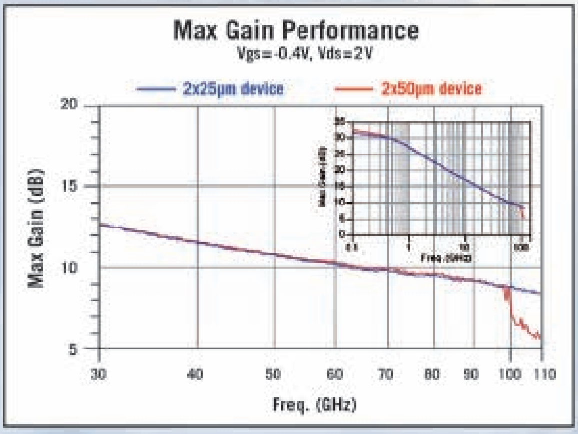
PP10 I-V Curves



PP10 Load Pull Data



PP10 Max Gain



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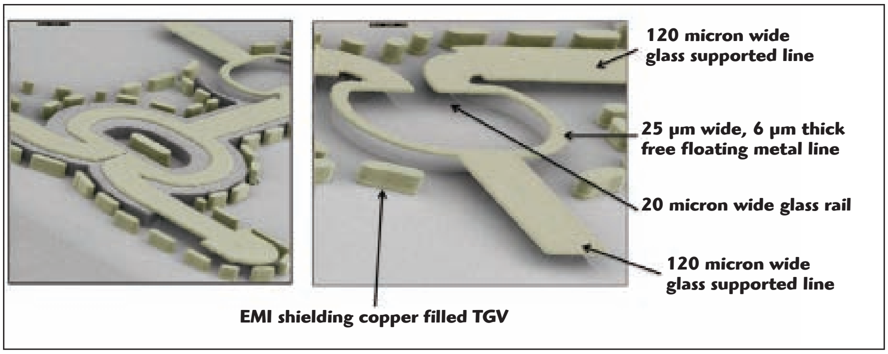
In-Chip EMI shielding structures, such as the through glass copper pillars may be built into almost any application to minimize unwanted RF radiation. EMI features are produced in a similar manner as TGVs for I/Os, however, whereas I/Os are typically round and used to connect the top of the substrate to the bottom of the substrate, EMI features may take on a variety of shapes and sizes, as shown in Figure 3c, and are all grounded together on the bottom of the substrate. In Figure 4, 30-micron wide, 120-micron long (4:1, length: width ratio), solid copper EMI features are shown. EMI features with aspect ratios up to 8:1 may be produced in almost any RF circuit.



▲ *Fig. 4 High Q-factor millimeter-wave circuit surrounded by solid copper EMI features grounded on the backside.*

PROCESS FLOW

The example shown in Figure 4 is manufactured using the following standard wafer-level semiconductor process.

- Exposure using a 500 W OAI flood exposure tool with 300 to 320 nm narrow pass mirrors is performed at a power density of 20 mW/cm^2. A chrome-on-quartz lithography mask is used during the contact exposure, with no photoresist. Exposure of the glass includes all features to be etched, including TGVs for I/Os, TGVs for EMI shielding and regions to etch for undercutting of metal lines.
- The wafer is baked at 500°C for 75 minutes at a ramp rate of 6°C per minute and then at 575°C for 75 minutes at a ramp rate of 3°C per minute, converting all of the previously exposed regions to ceramic.
- A chrome hard mask is applied to all ceramic features on both sides of the wafer except I/O and EMI shielding TGVs. All TGVs are double sided etched in 10 percent HF acid.
- All TGVs for I/Os and EMI shielding are copper filled using standard electrolytic copper filling techniques. Copper plating overburden is mechanically polished using standard techniques.
- Surface metal structures are patterned using standard photolithography techniques. Briefly, a thin seed layer of copper is blanket deposited onto the surface of the wafer. Photoresist is applied to the wafer and patterned to the exact locations to represent the surface metal. Open metal features are electroplated with copper to a final thickness of 6-microns. Next, the photoresist is stripped and the unplated seed layer chemically removed exposing the underlying glass or ceramic material.
- The wafer is placed into a 5 percent HF acid and etched for approximately 15 minutes to form glass rails and air bridges, etching the ceramic at approximately 10-microns per minute. The desired depth of the etched relief is controlled by controlling the total etch time.

CONCLUSION

APEX Glass is a flexible and cost effective substrate for a number of RF and microwave applications by providing a material for batch manufacturing of wafer-level components with simple processing and low production costs. This new manufacturing approach enables fabrication of very complex RF electronics not typically associated with glass processes. These devices may include TGVs, air bridges, EMI shielding and glass support rails with small dimensions. ■

Synthesizers: Looking Beyond the Basics

Alexander Chenakin
Phase Matrix, A National Instruments Company, Santa Clara, CA

Fractional-N PLL synthesizers are among the most challenging of high-frequency designs. Many approaches have been developed to generate clean output signals, although techniques that achieve fine frequency resolutions often suffer from elevated spurs and phase noise. In this article, industry expert Dr. Alexander Chenakin reveals the anatomy of the fractional-N synthesis and discusses some new ways to go beyond the current technology limits.

A generic single-loop PLL synthesizer includes a tunable VCO that generates a signal in a desired frequency range. This signal is fed back to a phase detector through a frequency divider with a variable frequency division ratio N as depicted in ***Figure 1***. The other input of the phase detector is a reference signal equal to a desirable step size. The phase detector compares the signals at both inputs and generates an error voltage, which following filtering (and optional amplification) slews the VCO until it acquires the lock frequency given by $f_{OUT} = N f_{PD}$, where f_{PD} is the comparison frequency at the phase detector inputs. Thus, the frequency tuning is achieved in discrete frequency steps equal to f_{PD} by changing the division coefficient N.

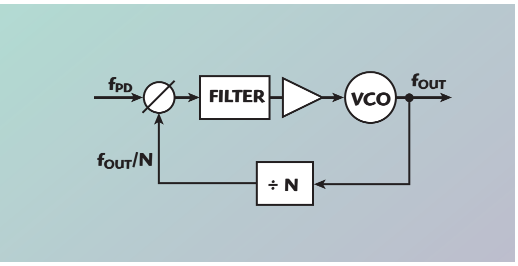
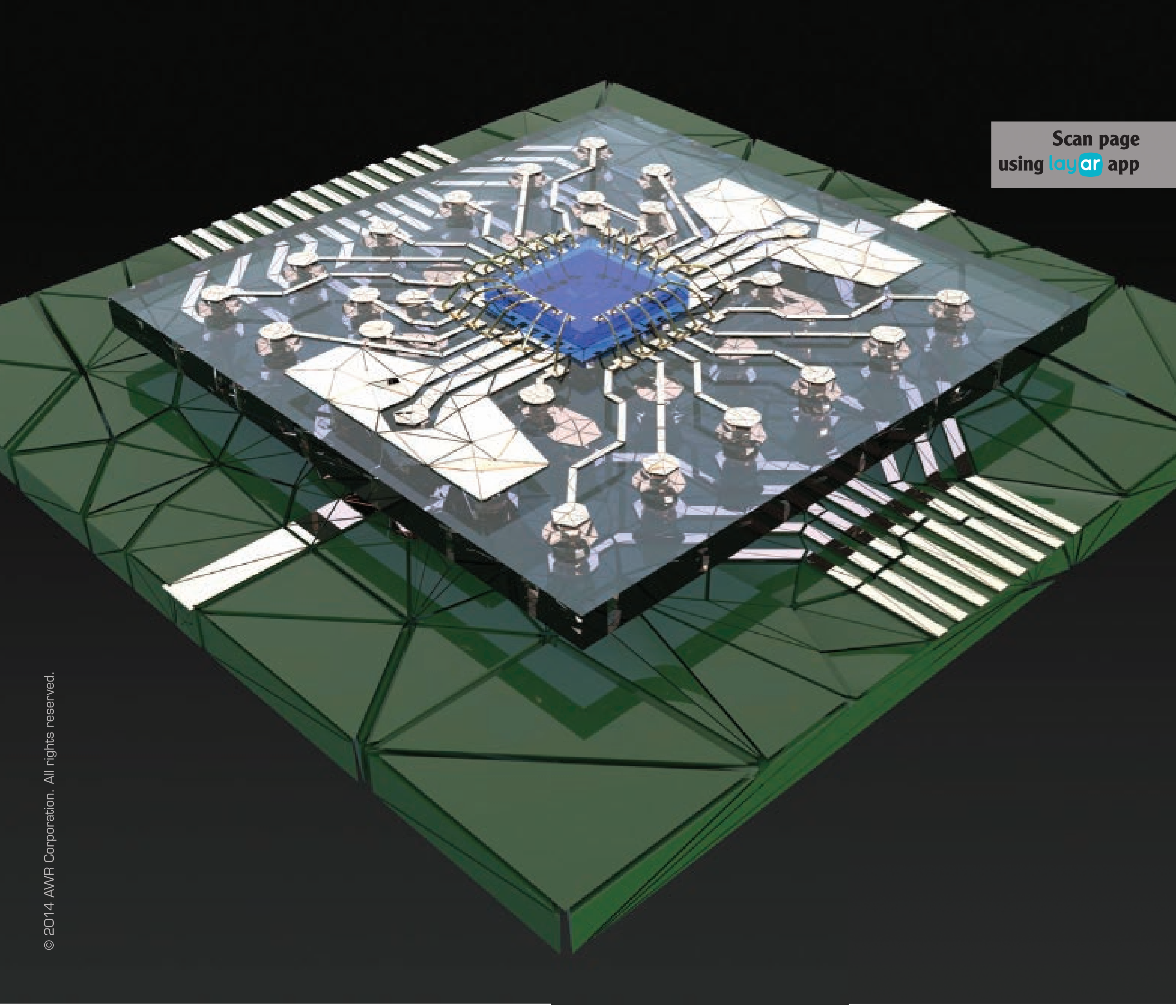


Fig. 1 Single-loop PLL synthesizer.

This simple PLL synthesizer exhibits various limitations and tradeoffs. The main impact on the synthesizer performance is due to large division ratios required to provide a high-frequency output with a fine resolution. Note that any noise generated by PLL components is degraded at 20logN rate, where N is the division ratio. In conventional integer-N PLLs operating at small step sizes, the division ratio is large because the step size must be equal to the comparison frequency at the phase detector. As a result, significant phase noise degradation occurs. Furthermore, the synthesizer switching speed is a function of its loop bandwidth and, therefore, is limited by the phase detector comparison frequency too.

CONVENTIONAL DESIGNS

Fractional-N synthesizers break this coupling between frequency resolution and other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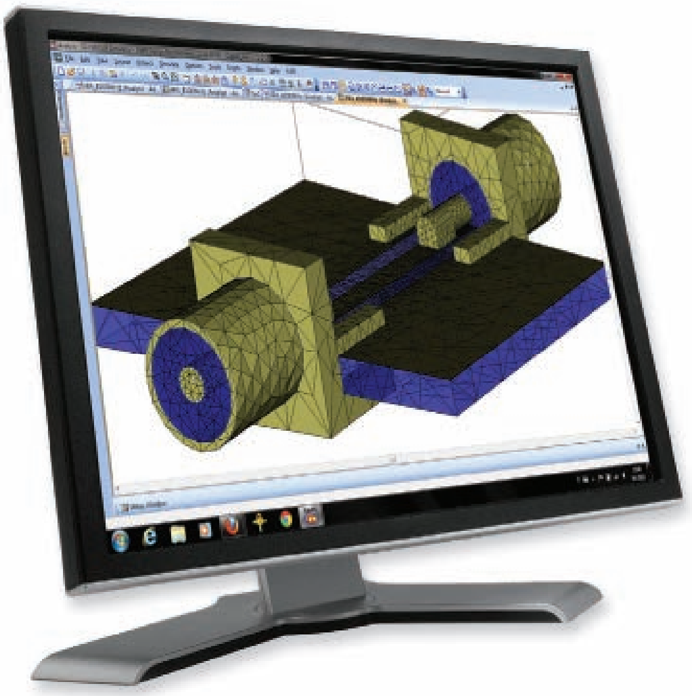
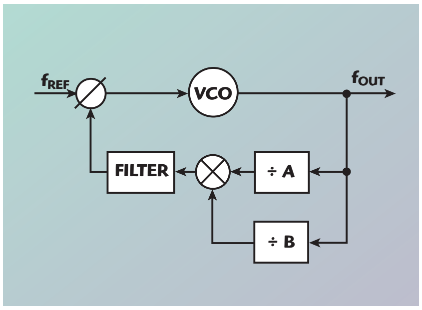




▲ *Fig. 2 Self-offset scheme.*

characteristics by using fractional division ratios and, therefore, allow a higher comparison frequency for a given step size. How are fractional division coefficients realized? In general, it is possible by alternating two division ratios (let's say, N and N+1) and averaging the output frequency over a certain period of time. Another way to look at this process is to calculate the number of pulses delivered by such a divider for a given time interval. Obviously, the average division coefficient will be between N and N+1 depending on how many pulses are processed by each divider.

The biggest concern associated with this scheme is that the instant frequency at the fractional-N divider output is not constant. An abrupt change in the division coefficient leads to a phase discontinuity that produces a voltage spike at the phase detector output. Since the frequency division change occurs periodically with the same rate, it appears as discrete spurs in the synthesizer's output spectrum. Suppression of the resulting spurs requires that the PLL filter bandwidth has to be sufficiently small, which is not always possible.

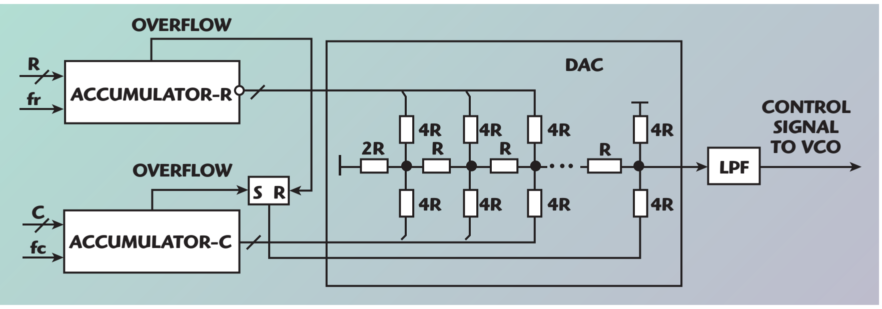
There are many techniques to reduce fractional-N spurs.[1-11] In general, this can be accomplished by adding or subtracting a voltage at the phase detector output during the frequency division change. Another method is based on using a multi-modulus divider that allows a larger number of division coefficients. In this case, we should expect a larger number of spurs of smaller amplitude. The multi-modulus divider is often accompanied by a delta-sigma modulator. The delta-sigma technique is well known in communication systems and has been used extensively for analog-to-digital conversion. The fundamental idea of utilizing ΔΣ-modulators is to shape the quantization noise in such a way that a smaller amount of noise power remains within the utilized signal bandwidth.

The same idea can be successfully applied to fractional-N frequency synthesis applications by randomizing frequency spurs and pushing them towards higher offset frequencies where they can be easily filtered by the loop filter. Moreover, a ΔΣ-modulator can also reshape the residual noise spectrum so that it has more power at higher frequency offsets. Accompanied by a properly designed loop filter, this leads to better spurious and phase noise characteristics. No perfect compensation, however, is possible. Thus, in spite of various improvements, the main disadvantage of the fractional-N technique is the excessive spurious levels produced by phase errors inherent in the fractional division mechanism.

SELF-OFFSET SCHEME

From the first glance, alternating frequency division coefficients seems to be a "natural" way to obtain fractional-N values. This is not necessarily true. Fractional division coefficients can be realized by other means that can avoid changing division ratios on the fly. An interesting scheme (called a "self-offset loop") has been presented by Sadowski.[12] The scheme utilizes a mixer in the PLL feedback path as depicted in ***Figure 2***. The mixer inputs are generated internally within the same PLL, therefore, no separate offset frequency source is required. Two frequency dividers (having division ratios A and B) divide the VCO output frequency to generate the required mixer inputs. It is easy to show that $f_{out} = f_{REF}\frac{AB}{A \pm B}$, thus, this scheme allows fractional division coefficients.

Let's examine how this circuit works. Imagine that we need to synthesize a signal at 119 MHz using a 10 MHz reference. If we use a conventional integer-N PLL approach, first we would need to divide the reference down to 1 MHz at the phase detector input. Then we would generate the required output by setting the division ratio in the PLL feedback path



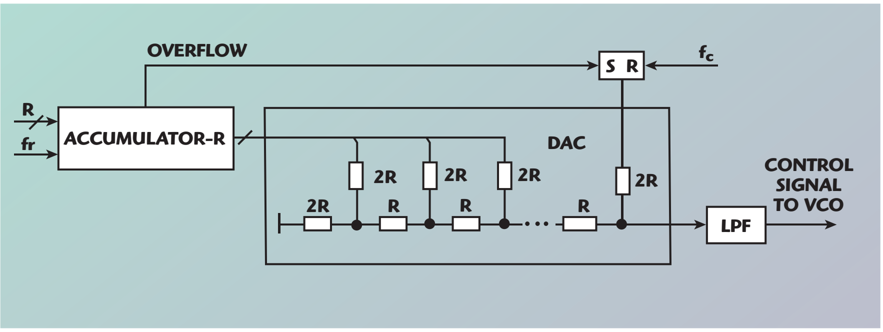
▲ *Fig. 3 Phase comparison with unequal frequency inputs and analog processing.*

to 119. This results in over 41.5 dB phase noise degradation. We can obtain the same output frequency in the self-offset scheme by setting division coefficients to A=17 and B=7. The dividers generate two mixer inputs at 7 and 17 MHz, respectively, thus, their difference (filtered at the mixer output) of 10 MHz is compared with the reference frequency. Note that we have essentially realized the fractional division ratio of 11.9 that results in substantial phase noise improvement compared to the conventional integer-N PLL. A disadvantage of such a structure is the need to select properly required division coefficients and filter out undesired mixer products.

PHASE COMPARISON WITH UNEQUAL INPUTS

Conventional wisdom suggests that the heart of any PLL should be a phase detector that compares two equal frequencies at its inputs to close the loop. Bosselaers looked at this from a slightly different angle.[13] He has proposed a circuit that consists of two accumulators clocked by the reference fr and signal fc frequencies, respectively. It also includes an arithmetic unit that digitally adds and subtracts current states of the accumulators. The result is transformed by a DAC into analog equivalent to control a VCO. When the total of the additions of the number R equals to the total of the subtractions of the number C over a period of time, the output frequency will be set to fc = fr R/C, where R and C are numeric values of the codes at the control inputs of corresponding accumulators. In general, the R and C values are not equal; therefore, the circuit provides the opportunity for phase comparison of unequal, fractionally-N related frequencies. The main drawback of this idea is that there is an uncertainty state when fc and fr pulses coincide. This results in a glitch and, thus, significant degradation of the signal spectrum.

Koslov has further improved this concept by processing the accumulator outputs with analog means to avoid the accumulator output uncertainty issue.[14] There are two identical accumulators R and C clocked by fr and fc signals, respectively. The accumulator outputs (one of them is inverted) are summed in a special DAC represented



▲ *Fig. 4 Phase comparison using a single accumulator.*

by a resistive ladder network as shown in ***Figure 3***. The most significant bit of the DAC operates from an RS-flip-flop switched by the overflow pulses coming from the accumulators. This scheme can be further simplified[15] by eliminating one of the accumulators, as depicted in ***Figure 4***. The second accumulator is excluded since its control code is fixed and, thus, its function is reduced to sending the signal pulses to the input of the RS-flip-flop.

PHASE SPLITTING

Synthesizer characteristics can be significantly improved using the idea of phase splitting.[16] To illustrate the concept, let's assume that there are voltage glitches in a PLL circuit (as shown in ***Figure 5***) represented by short pulses on the diagram A. Let's move these pulses by 1, 2 and 3 clocks and then sum them together with equal weights of 1/K (where K is 4 in this case) as illustrated on the diagram B of the same figure. Obviously, the amplitude of the resulting pulses is decreased four times although its average DC power remains the same. The diagram C shows the case when the shifts are 2, 4 and 6 clocks and the diagram D corresponds to the shifts of 8, 16 and 24 clocks, respectively. Note that in the latter case not only the amplitude but repetition frequency changes (increases). Thus, it may be easier to filter out these glitches.

This concept requires several partial phase detectors that are properly phased in respect to each other. One practical implementation called phase digital synthesizer is presented in references 17 and 18. The proposed solution consists of two channels (representing the reference and signal paths) that include accumulators (R-Acc and C-Acc) and phase splitters (R-PS and C-PS) as depicted in ***Figure 6***. The phase splitters drive partial phase detectors constructed with RS-flip-flops and a DAC as discussed earlier. For additional spur compensation, some least significant bits of the accumulators are optionally connected to R2R-sections of the DAC. In the signal path, they may be only required to select a preferable combination of codes R and C to tune out some troublesome spurs such as integer boundary spurs. The outputs of the partial phase detectors are pro-

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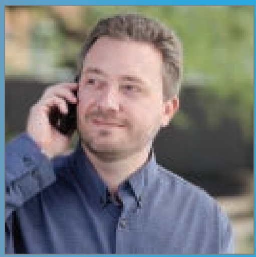

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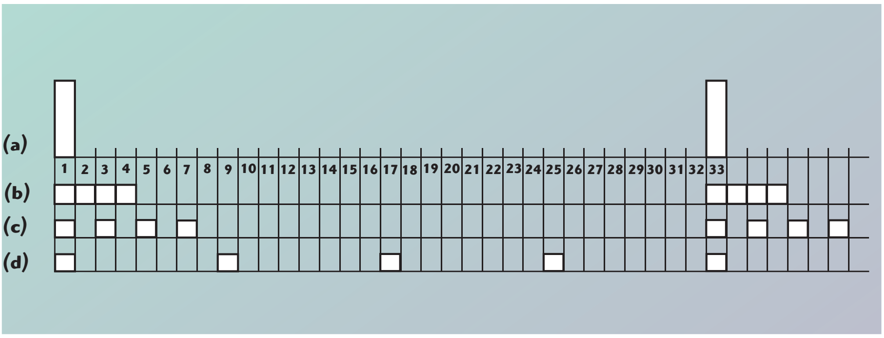

▲ *Fig. 5 Phase splitting concept.*

cessed in a DAC that generates a VCO control voltage. An ideal DAC would have only a DC component (for controlling the VCO frequency) and two saw-tooth components with frequencies fr and fc, which are filtered out by the loop filter. In reality, some spur degradation occurs due to DAC errors.

The essence of the presented phase digital synthesizer is that the control signal of the PLL is formed by a multi-phase comparator with phase splitting of the reference and VCO signals into a large number of partial channels. Another interesting feature is that phase comparison takes place directly at the clock frequencies, thus reducing frequency multiplication within the loop. Overall, spectral purity characteristics heavily depend on the number of partial phase detectors as well as DAC accuracy. The analysis presented in reference 18 shows quite superior performance compared to conventional fractional-N techniques. The solution is particularly well suited for implementation as an IC that allows constructing a large number of partial channels for better spectral characteristics. Building this circuit on a single chip can support the on-going demand for low-cost, high-performance frequency synthesizers.

This article highlights just a few interesting ideas that can potentially move current technology barriers. Can they be practically used? Some ideas thrive while others die. According to statistics, not more than 2 percent of patents are implemented in practice. Much of the value of looking at a problem from another person's point of view is that it helps us recognize and compensate for our own biases. Changing a perspective is a very valuable tool to develop new products. ■

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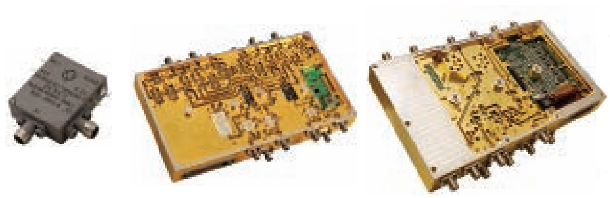

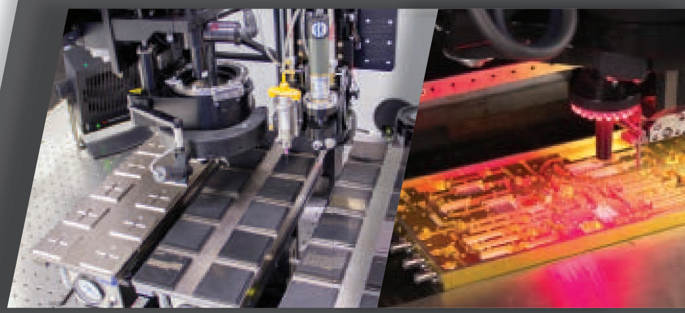

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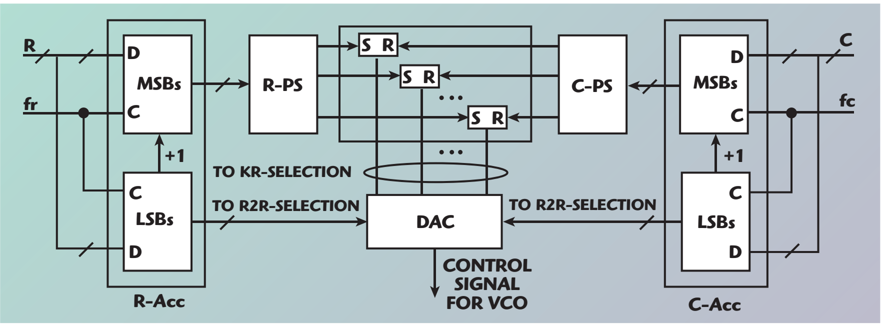

▲ *Fig. 6 Phase digital synthesizer.*

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OCXO Solutions Based on IHR Technology

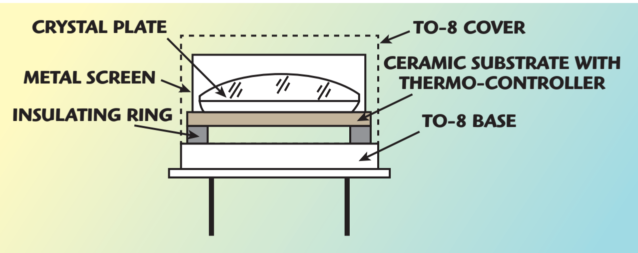
Igor Abramzon and Vadim Tapkov
Magic Xtal Ltd., Omsk, Russia

Changes in ambient temperature significantly affect crystal oscillator frequency stability due mainly to the frequency vs. temperature characteristic of the crystal resonator. Frequency stability of the oscillator can be greatly improved by using an oven-control system that accurately maintains the temperature of the resonator and its sustaining circuitry. But very high stability of an oven-controlled crystal oscillator (OCXO) is attained at the expense of a relatively large size/high power oven to maintain the temperature of a packaged resonator, while oscillator circuitry is poorly isolated from the environment. Although there have been improvements in the basic performance of high-end OCXOs over recent years, the power consumption and packaging size of even the most advanced designs have remained at about 1 W and 5 cm^3.

In the late 70s, an alternative OCXO concept was proposed based on the internally heated resonator (IHR) that integrates the heating system with the crystal plate within the resonator's vacuum-sealed package. Elimination of the bulky external oven and improved thermal isolation of the internal heating structure from the environment promised a radical reduction in power consumption, size and warm-up time. Nevertheless, its adoption has been delayed by a few practical challenges:

- Providing uniform heating of the crystal plate in a small resonator volume with sufficient mechanical durability and low environmental thermal loss.
- Sustaining a deep vacuum within the IHR volume.
- Minimizing the effect on frequency of the external, unheated, circuitry.

This article outlines methods used to address these challenges and realizes a new class of high performance OCXOs.



▲ *Fig. 1 Typical construction of an IHR built in a TO-8 package.*

INTERNALLY HEATED RESONATOR CONSTRUCTION

A standard TO-8 cold-weld holder, commonly used for packaging of conventional high precision crystals, is chosen to ensure reliability of the vacuum seal and accommodate a 10 mm crystal plate along with the integrated heating system. Typical construction of the IHR is shown in ***Figure 1***. It contains a supporting structure mounted on the TO-8 base, made

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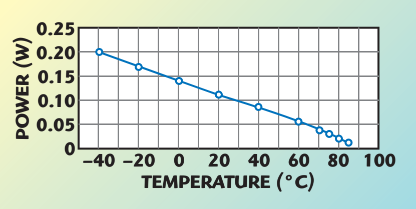
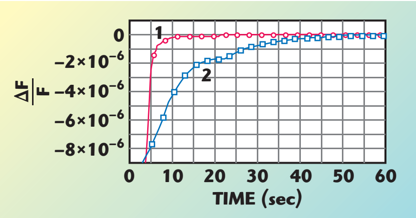


▲ *Fig. 2 IHR heating power vs. ambient temperature (internal temperature = 90°C).*

▲ *Fig. 3 Directly heated IHR.*



▲ *Fig. 4 IHR warm-up time using direct heating (1), using indirect heating (2).*

of low thermal conductivity materials for thermal isolation of the oven system above it. The integrated oven is implemented on a ceramic substrate bearing the whole thermo-control circuitry with the heater elements and the temperature sensor. The heated substrate provides accurate and uniform warming of the crystal plate at a fixed temperature via mounting clips and a metal screen over the plate surface. This IHR concept is called an indirectly heated resonator, because the heating elements are separated from the plate surfaces. This reduces the sensitivity of the crystal resonant frequency to changes in ambient temperature from coupling of weak thermal flows inside the oven structure to the environment. Due to near perfect thermal isolation of the integrated oven by a deep vacuum inside the TO-8 package and low conductivity of the supporting elements, the IHR design consumes very low power even at low ambient temperatures (see ***Figure 2***).

TABLE I

IHR OCXO PERFORMANCE

OCXO Characteristics	DIP8 Compatible MXO37/8	DIP14 Compatible MXO37/14	Hermetically Sealed MXO37/R
Operational frequency range	8 to 150 MHz	8 to 300 MHz (above 150 MHz with internal multiplication)	
Power consumption at 25°C	< 180 mW, 125 mW special option		
Voltage supply	3.3 V, 5 V		
Frequency stability at 10 MHz in (-40° to 85°)C range	to 10 ppb	to 5 ppb	to 0.5 ppb
Aging at 10 MHz per: day year 10 years	 0.2 ppb 20 ppb 0.2 ppm		
Allan variance at τ=1s, (E-12)	10	5	3
Phase-noise level dBc/Hz at:	at 10 MHz	at 100 MHz (fundamental)	
1 Hz offset 10 Hz offset 1 kHz offset 10 kHz offset	-105 -135 -160 -170	- 70 -100 -160 -170	
Warm-up time	60 s – typical, 30 s – special option, 15 s – DHR option		
Output waveform	CMOS, sine wave		

An alternative IHR concept called directly heated resonator (DHR) is shown in ***Figure 3***. Warming of the crystal plate is accomplished with film heaters deposited directly on the plate surfaces along with the temperature sensor. Strong thermal coupling of the film heaters to the plate surfaces results in extremely fast warm-up of the plate (exceeding 10°C/s), although there are significant thermal gradients produced in the plate during heating. Nevertheless, an optimal choice of heater geometry and use of a stress-compensated SC-cut plate enables the set frequency to be achieved in less than 10 s to 0.1 ppm (i.e., steady state) with sufficient start-up power (see ***Figure 4***).

OSCILLATOR CIRCUITRY

Sustaining circuitry of miniature OCXOs using the IHR concept must contain a minimum number of electronic components to fit onto the smallest PC boards; ensure steady excitation of the crystal using the SC or other double-rotated cut at the main C-mode, suppress the unwanted B-mode; ensure the lowest phase-noise level and highest spectral purity of the output signal; and, being outside the heated volume, have a minimal influence on oscillator frequency over wide variations of ambient temperature.

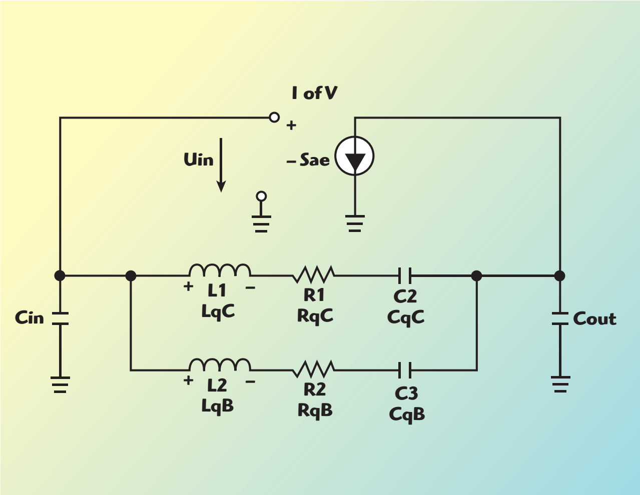
Among these requirements, effective suppression of the unwanted B-mode by the oscillator circuitry is the most challenging, since common suppression techniques using LC filtering require additional components and accurate adjustment, while exhibiting noticeable temperature sensitivity that limits oscillator temperature stability. To avoid these issues, we employ an alternative method based on different start-up times of the B- and C-modes in the double-rotated cut crystals, a consequence of substantial differences in their equivalent electrical parameters.

The high frequency model of the sustaining circuitry at excitation of the dual-mode crystal is shown in ***Figure 5***. The rise of B- and C-mode amplitudes during start-up is governed by the expressions:

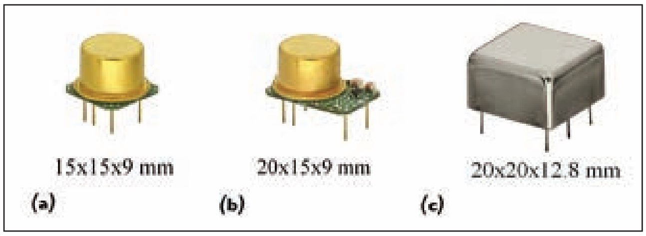
$$U_B(t) = U_{B0} \exp\left(\frac{\frac{K_0}{\omega_{KB}^2} - R_{qB}}{2L_{qB}} t\right) \quad (1)$$

$$U_C(t) = U_{C0} \exp\left(\frac{\frac{K_0}{\omega_{KC}^2} - R_{qC}}{2L_{qC}} t\right) \quad (2)$$

where R_{qB}, L_{qB} and R_{qC}, L_{qC} are equivalent resistance and inductance



▲ *Fig. 5 Oscillator equivalent circuit with a dual-mode crystal.*



▲ *Fig. 6 IHR OCXO families: MXO37/8 (a), MXO37/14 (b) and MXO37/R (c).*

of the B- and C-modes accordingly.

At a sufficiently high value of the gain factor (K_0), the equivalent inductance becomes a determining factor in the rate of amplitude rise. Due to a lower value of inductance for the C-mode (about 75 percent of the B-mode inductance in an SC-cut crystal) its amplitude grows faster, reaching steady state first and suppressing further B-mode growth. This is called "dynamic selection" due to the absence of special filtering elements. It requires minimal PCB space, produces no effect on temperature stability of the sustaining circuitry and needs no elaborate tuning. This technique provides excellent performance in OCXOs utilizing IHR technology.

REALIZATION AND PERFORMANCE

These designs are the basis for three new families of OCXOs (see ***Figure 6***). The smallest, MXO37/8, is a high stability OCXO with the oscillator circuitry built in a TO-8 package and mounted on a DIP8 compatible PC board. The MXO37/14 oscillator and associated electronic elements are packaged with the resonator in a TO-8 package, and with the rest parts on a DIP14 compatible PC board. The MXO37/R oscillators are packaged in a 20 × 20 × 12.8 mm hermetically sealed case.

Even the smallest DIP8 oscillators exhibit high frequency stability and low phase noise at nearly the level of high-end conventional OCXOs, while the larger DIP14 series, accommodating more complex circuitry, provides better temperature stability and can operate at much higher frequencies owing to internal frequency multiplication stages. The larger volume in the MXO37/R series OCXOs allows for additional thermal compensation circuitry, increasing temperature stability to nearly the level of double-oven oscillators.

Table 1 summarizes performance achievable from the three OCXO families, demonstrating very high frequency stability and low phase noise in a miniature size with extremely low power consumption. Such properties make these OCXOs excellent solutions for a variety of current applications as well as new developments.

CONCLUSION

IHR technology has proved to be a powerful enabler for development of a new kind of reference oscillator with excellent frequency stability, low phase noise, small size and low power consumption. Covering a wide range of customer needs, these devices offer an alternative to conventional high-end OCXOs. Potential applications include advanced battery supplies and portable equipment, such as high-end mobile radio, GPS, rescue or geodesic beacons, drone electronics and instrumentation. ■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A Tunable Dual-Band 6 Bit Digital Phase Shifter Using DGS and Stubs

Zheng Liang Lv and Shuxi Gong
Xidian University, Xian, China

Shiwei Zhao and Xiang Zhang
Shanghai Radio Equipment Research Institute, Shanghai, China

This tunable dual-band phase shifter uses a defected ground structure (DGS) and stubs. Its frequency can be tuned by changing the length and width of the stubs and the dimensions of the DGS. The resulting circuit has improved insertion loss and return loss with reduced phase variation, as verified by measurement.

Phase shifters are essential components in transmit/receive phase array antenna elements. While there are well known transmission line phase shifter approaches with sufficient performance, such as all-pass filter (APF) networks and vector addition,[1,2] they generally lack tunability. MEMS and varactor-tuned substrate integrated waveguide (SIW) are used to achieve tunable performance; however, these methods introduce increased design complexity.[3,4] The composite right-/left-handed transmission line (CRLH-TL) structure is also used,[5,6] with the penalties of increased physical size and insertion loss.

Providing advantages such as circuit size reduction and spurious response suppression, the DGS has been used successfully in the design of microwave circuits, such as filters, power dividers, couplers, amplifiers and oscillators.[7,8] Modern communication systems require dual-band bandpass filters (BPF) with low insertion loss, high selectivity and compact size, driving an increased interest in dual-band filters employing the DGS structure.[9,10]

This article describes the design of a 6 bit digital phase shifter using a DGS in the form of a rectangular ring and incorporating open and short-circuited stubs to create a tunable dual-band phase shifter. The length and width of the stubs (upper layer) and the dimensions of the rectangular ring (bottom layer) are adjusted to achieve the desired center frequencies and bandwidths.

ANALYSIS

The configurations of the conventional and proposed structure are shown in ***Figure 1***. The proposed structure includes two layers. In

the upper layer are two equal length parallel stubs: one open and the other short-circuited. In order to improve its operational bandwidth, the device employs impedance transformers at its input and output ports. When these matching circuits are ignored, the reflection coefficient (Γ) and the transmission coefficient (T) across the plane are by given by[11]

$$\Gamma = \frac{1-(1+jb)}{1+(1+jb)} = \frac{-jb}{2+jb}; T = 1+\Gamma \quad (1)$$

where b is the normalized susceptance of the stubs connected in parallel with the main microstrip line given by

$$b = \frac{Z_0}{Z_s}\left[\tan\left(\theta_s \times \frac{f}{f_0}\right) - \cot\left(\theta_s \times \frac{f}{f_0}\right)\right] \quad (2)$$

where θ_s and Z_s are the electrical length and impedance of the stubs at the design frequency f_0. Measured against the reference microstrip line, the differential phase shift is given by

$$\Delta\phi = \phi_2 - \phi_1 = \theta_r \times \frac{f}{f_0} - \arctan \quad (3)$$

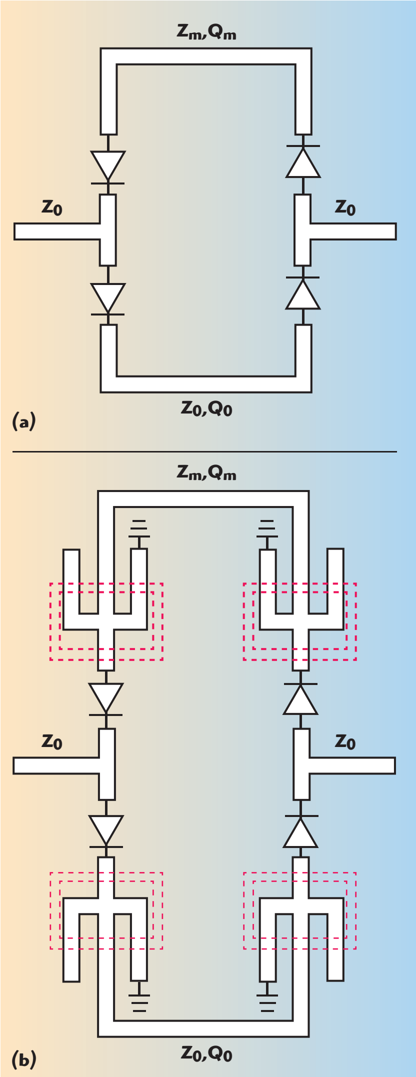
$$\left\{\frac{Z_0}{2Z_s}\left[\tan\left(\theta_s \times \frac{f}{f_0}\right) - \cot\left(\theta_s \times \frac{f}{f_0}\right)\right]\right\}$$

where θ_r is the electrical length of the reference microstrip line at frequency f_0.

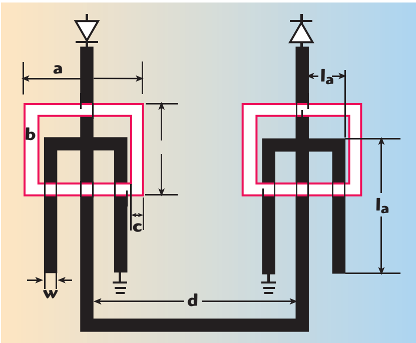
DESIGN

The schematic of the rectangle ring DGS and stubs is shown in ***Figure 2***. The upper resonator is implemented using open and shorted stubs and the lower resonator is a DGS in the shape of a rectangular ring. The upper and lower metals are separated by the substrate. The interaction that takes place between the stubs and the DGS is not conventional, so the classical design approach cannot be applied here.

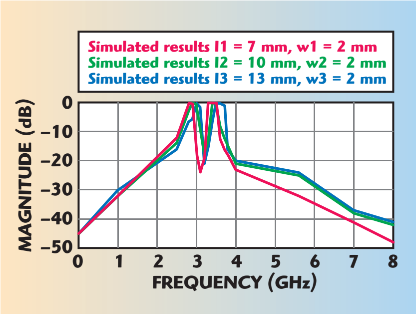
The length and width of the DGS and stubs are a, b, l and w, respectively (l is the sum of l_a and l_b, where l_a is 1.5 mm). In addition, the width of the slot between the outer rectangle and inner rectangle is c, while the distance between two rectangular rings is d. The frequency can be tuned by adjusting the length and width of the DGS and stubs. The circuit is designed for Rogers 5880 substrate material. Electromagnetic simulation software (HFSS) is used to determine the physical dimensions. With a, b, c and d at 15, 5, 2 and 20 mm, respectively, the



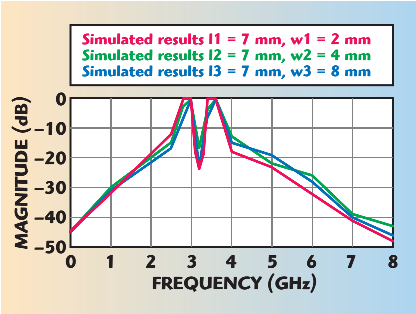
▲ *Fig. 1 Conventional (a) and proposed phase shifter (b).*



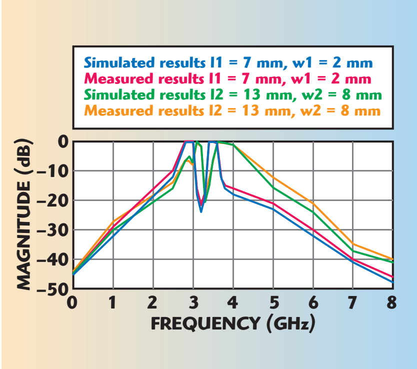
▲ *Fig. 2 Schematic of the DGS rectangular ring and tuning stubs.*



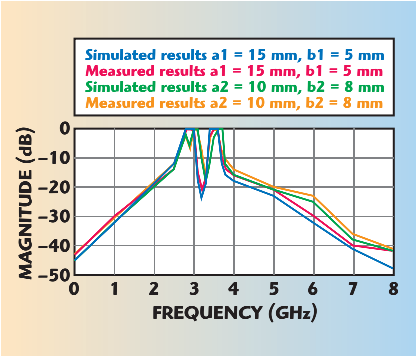
▲ *Fig. 3 Simulated |S_{21}| for different stub lengths.*



▲ *Fig. 4 Simulated |S_{21}| for different stub widths.*



▲ *Fig. 5 Simulated and measured |S_{21}| for different stub lengths and widths.*



▲ *Fig. 6 Simulated and measured |S_{21}| for different DGS lengths and widths.*

simulated |S_{21}| with several different stub lengths and widths is shown in ***Figures 3*** and ***4***. This shows the narrowing and shifting of the passbands lower in frequency with decreasing stub length and width.

FABRICATION AND MEASURED RESPONSE

The circuit is fabricated on Rogers 5880 substrate material using the Microsemi LSP 1000 PIN diode as the phase switching device. Simulated and measured values of |S_{21}| for the 45° phase shifter bit are shown in ***Figure 5*** for the DGS dimensions a, b, c and d equal to 15, 5, 2 and 20 mm, respectively. The effect of different lengths and widths of the DGS rectangular ring are shown in ***Figure 6***.

The measured insertion loss, return loss and phase variation for a 6 bit digital phase shifter are shown in ***Table 1***. The insertion loss varies from 0.3 to 0.5 dB and the return loss varies from 48 to 52 dB within the passbands, while the phase variation is controllable to within ±3 degrees. A photograph of the fabricated 6 bit digital phase shifter is shown in ***Figure 7***.

TABLE I

PHASE SHIFTER MEASURED PERFORMANCE

Frequency (GHz)	2.8	2.9	3	3.1	3.2	3.4	3.5	3.6
$\|S_{21}\|$ (dB)	–0.2	–0.3	–0.3	–18	–21	–0.5	–0.3	–0.3
$\|S_{11}\|$ (dB)	–48	–49	–51	–5.8	–4.3	–51	–48	–52
Phase Variation (degrees)	6.6	6	6.5	–20	–18	5.2	1	2.1

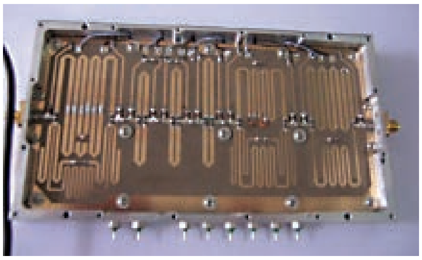


Fig. 7 Photograph of the phase shifter employing tuning stubs and DGS.

CONCLUSION

A tunable 6 bit digital phase shifter employing open and shorted stubs and a DGS rectangular ring achieves tunable dual-band performance by adjusting the length and width of the DGS and stubs. The result is improved insertion loss and return loss with reduced phase variation, as verified by measurement. ■

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Flexible Device Lineups for TD-LTE and FDD-LTE

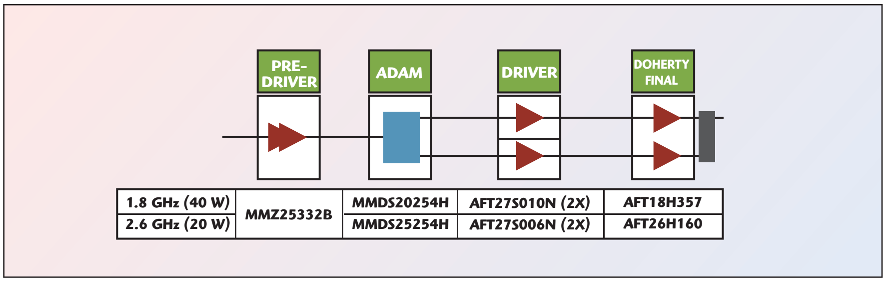
Freescale Semiconductor Inc.
Tempe, AZ

RF power amplifier designers often face the prospect of creating and optimizing a circuit for one set of frequencies and RF power levels; then attempting to revise it to cover other combinations of frequency and power. The best strategy to achieve this goal is to use the smallest number of different transistors to minimize redesign and overall cost. To accommodate this increasingly common requirement, Freescale® Semiconductor Inc. has introduced predriver, driver and asymmetric Doherty final-stage power transistors within its Airfast™ family that make this easier to achieve in TD-LTE and FDD-LTE cellular base stations. To complement the Airfast devices, the company has also introduced the industry's first module that can significantly reduce the time and effort required to align asymmetric Doherty amplifiers in production.

Two lineups, one at 1.8 GHz and one at 2.6 GHz, with similar circuit architectures illustrate how these devices can be employed in real-world applications. The circuits each include a predriver driver, and final-stage amplifier, along with the Advanced Doherty Alignment Module (ADAM).

The lineups for both frequency ranges are shown in ***Figure 1***. The first lineup is designed for use in a 2×40 W or 4×40 W MIMO base station in the 1.8 GHz band, the most popular FDD-LTE band in the world. The second lineup is applicable for the second most popular band, 2.6 GHz. This band is especially popular in North America and China where 8×20 W MIMO solutions are often employed. In the 1.8 GHz lineup, the MMZ25332B predriver is followed by the MMDS20254H ADAM module, two AFT27S010N drivers and the AFT18H357 final-stage amplifier. The 2.6 GHz lineup employs the same predriver, the MMDS25254H ADAM model, two AFT27S006N 6 W drivers and a 160 W AFT26H160 final-stage amplifier.

The predriver in all cases is the MMZ25332B GaAs MMIC, which is in the company's family of 5 V DC drivers and pre-drivers that includes 1, 2 and 3-stage amplifiers with RF output levels ranging from 250 mW to 4 W that are housed in compact over-molded plastic packages. The performance of the MMZ25332B can be optimized for any frequency between 1500 and 2700 MHz and is well suited for multi-band power amplifiers, as a driver for



▲ *Fig. 1 Device lineups for a 40 W amplifier operating at 1.8 GHz and a 20 W amplifier operating at 2.6 GHz. Both lineups use the same predriver and vary in the ADAM module, driver and final-stage amplifier dictated by operating frequency and RF output power.*

DPD-corrected Doherty power amplifiers, and as a final-stage amplifier in uncorrected small cell base stations.

The drivers include the 6 W AFT27S006N and 10 W AFT27S010N that are housed in PLD-1.5W over-molded plastic packages. The AFT27S006N delivers 22 to 24.3 dB gain with 0.05 dB gain flatness and 18 to 22 percent efficiency. The AFT27S010N has 21 to 24.3 dB gain with 0.2 dB gain flatness, and 21 to 25 percent efficiency. Both drivers cover the full cellular infrastructure frequency range of 700 to 2700 MHz.

The two final-stage amplifiers used in this illustration are the AFT26H160-4S4 160 W, 1.6:1 asymmetric Doherty device that provides 15.5 dB of gain and greater than 45.5 percent drain efficiency at 32 W of average output power between 2496 and 2690 MHz. The AFT18H357-24S is also a 1.6:1 asymmetric in-package Doherty device that delivers 360 W of peak RF power between 1805 and 1995 MHz with average power of 63 W, 50 percent efficiency, and 17.2 dB of gain. ***Table 1*** summarizes the key amplifier specifications.

The ADAM module placed between the predriver and driver stages can provide unique benefits for manufacturers. Designed specifically with Freescale's in-package asymmetric Doherty power amplifiers in mind, it can ensure consistent performance throughout an amplifier manufacturer's production line, while improving yield and providing tighter parametric distributions that increase system efficiency. It can also be adjusted in the field to optimize the amplifier for traffic loading, changes in frequency, operating temperature, or any other environmental condition.

The three current ADAM models include the MMDS09254H, MMDS20254H and MMDS25254H that collectively cover frequencies between 700 and 2700 MHz. They operate from a single 5 V DC supply, draw about 12 mA, and accept commands via a TTL/CMOS/SPI digital interface designed for 1.8 or 3.3 V DC logic. The devices are housed in 6×6 mm QFN surface mount plastic packages.

An ADAM module can optimize Doherty bandwidth, improve DPD correction and full-band efficiency, and enable consistent asymmetric Doherty performance of any Freeescale in-package Doherty amplifier. The devices incorporate a 90-degree directional coupler, digitally-selectable phased shifters, as well as programmable attenuators. All devices used in the reference lineups are in production and frequency-specific reference designs are available.

The lineup approach demonstrated by these examples allows RF power amplifier designers to save considerable design time and reduce their bill of materials by using a single predriver, the same architecture for each circuit and similar devices for ADAM, driver and finals based on frequency and power requirements.

Freescale Semiconductor Inc., Tempe, AZ, www.freescale.com/rf.

TABLE I

KEY AMPLIFIER LINE-UP SPECIFICATIONS

	MMZ25332B	MMDS09254H MMDS20254H MMDS25254H	AFT27S006N AFT27S010N	AFT26H160 AFT18H357
Type	GaAs HBT 2-stage driver	Advanced Doherty Alignment Module	Wideband Driver Transistor	Asymmetric Doherty Amplifier Module
Frequency Range (MHz)	1500 to 2700	700 to 1000 1800 to 2200 2400 to 2800	728 to 2700	2496 to 2690/ 1805 to 1995
RF Output Power (W)	2	--	6 10	32 average 160 peak 63 average 360 peak
Gain (dB)	27	--	22.5 21.5	17.2 15.5
Drain Efficiency (%)	--	--	21 (Class AB) 23 (Class AB)	45.5 (Doherty) 50.1 (Doherty)
Power Supply	5		28	
Package	3×3 QFN	6×6 QFN	PLD-1.5W over-molded plastic	NI-880XS-4L4S

STAN Circuit Stability Analysis Tool

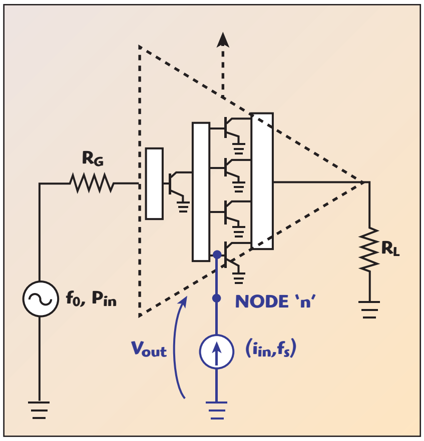
AMCAD Engineering
Limoges, France

Spurious oscillation is one of the major issues facing the designer of power amplifiers at microwave frequencies. This instability is due to the presence of feedback loops associated with high level gains even out of band. The appearance of these unwanted oscillations depends on the bias of the device (linear stability) or on the dynamic power applied at the input of the device (nonlinear stability). The possibility of obtaining information on the stability of an amplifier at the design stage is essential and even more critical for monolithic microwave integrated circuit (MMIC) technology for which adjustment after fabrication is impossible.

Different methods can be used by the designers to analyze the small-signal and large-signal stability of microwave circuits. Some of these methods are implemented in commercial simulators which facilitates their utilization as μ or K factor analyses which are intended for linear two-port devices and are not suitable for multi-device circuits. More rigorous small-signal analyses, valid for multi-device circuits, have been presented in literature but these methods can be quite arduous to implement in a commercial simulator especially for circuits with a great number of active elements.

For large signal conditions, the majority of commercial simulators lack the tools for the stability analysis of the circuit around a nonlinear steady state. Different techniques have been developed that are applicable to microwave circuits, but have the drawback of not being completely rigorous or too complex to be implemented in an industrial design flow.

To address these issues, the STAN tool offers a stability analysis technique for microwave circuits that is valid for small-signal and large-signal regimes. This patented technique, which has been developed by the University of Basque Country and the French Space Agency (CNES) is able to detect and determine the nature of oscillations, such as parametric oscillations in power amplifiers that can be, for example, a function of the input drive signal. Knowledge of the type of oscillation mode facilitates the insertion of stabilization networks, with a



▲ *Fig. 1 Small-signal sinusoidal current source connected at a particular node of the circuit for stability analysis.*

good balance between the required oscillation avoidance and maintaining the original circuit performance.

The stability analysis used is based on the pole-zero identification technique. This technique has the benefit of being applicable to DC, small and large-signal stability analyses within a similar methodology and, from the simulations obtained, in commercial CAD tools. ***Figure 1*** shows a small-signal sinusoidal current source connected at a particular node of the circuit for stability analysis.

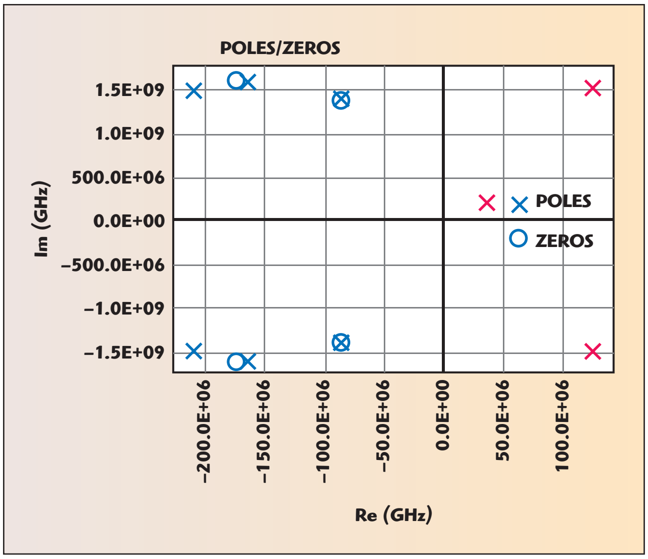
INTEGRATION IN CAD ENVIRONMENT

The first step is to select a node of the circuit to be analyzed and to connect a small current source to this node. Then a linear or a nonlinear simulation using a commercial simulator is performed in order to obtain the frequency response. Simulation templates are available for both Agilent ADS and AWR Microwave Office simulators to easily facilitate this implementation in the CAD environment.

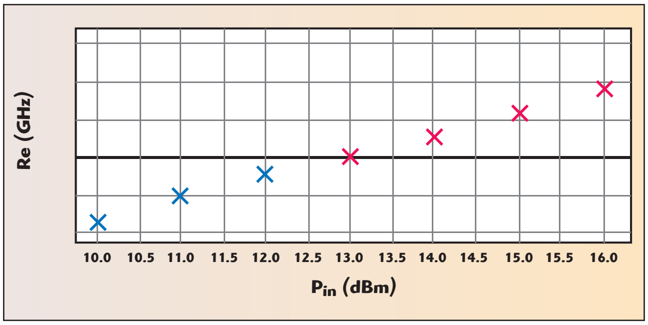
The second step is to identify the frequency response to obtain the transfer function and the associated poles and zeros. This step is done using the STAN tool which, starting from a text file exported from the simulator, enables easy identification and analysis of the results. ***Figure 2*** illustrates a pole-zero plot.

NODE SELECTION AND OSCILLATION

In simple circuits with a clear feedback structure (some amplifiers, oscillators, etc.) any node should serve for the analysis. However, for more complex circuits such as multi-stage power amplifiers, at least one analysis per stage is highly recommended.



▲ *Fig. 2 Pole-zero plot.*



▲ *Fig. 3 Poles versus input power showing an oscillation from 13 dBm of input power.*

Analysis at several nodes is not necessarily a drawback of the technique because relevant information about the nature of the oscillation and the place in which it is being generated can be extracted from such analysis. A multi-node simulation can be completed, and with the obtained results it is then possible to determine the kind of oscillation mode and its location in the circuit. This information will help the designer to define the most suitable stabilization strategy.

PARAMETRIC ANALYSIS

Multi-parameter analysis can also been performed, that is to say analysis sweeping a circuit parameter. This can be used for verification under various conditions or checking the critical resonances, sweeping the input drive power, the load impedance or any parameter inside the circuit. Tracking the evolution of critical poles allows a better understanding of the circuit dynamics and helps determine which parameter has an influence on the circuit stability. ***Figure 3*** plots poles versus input power showing an oscillation from 13 dBm of input power.

Parametric analysis is also extremely useful for the optimization of the stabilization networks. It facilitates finding the best trade-off between stabilization of the circuit and its RF performances.

NEW DESIGN APPROACH

Commonly used techniques for the stabilization of microwave circuits are empirical and can be too conservative. Designers often over-design their circuits, guard-banding designs by including excessive safety margins. Such over-designing leads to ICs that are more conservative than necessary in power, size and performance specifications.

Using the STAN tool from the early design stages leads to an enhanced approach in the design of RF and microwave circuits. STAN is used throughout the optimization process to help reduce the amount of stabilization networks that deteriorate the RF performances at the fundamental frequency of operation, while preserving similar stability margins. Thanks to the identification speed of the tool, it even opens up the possibility of performing Monte-Carlo stability analysis, in order to check the stability versus the manufacturing process variation.

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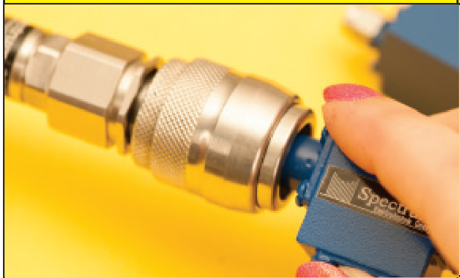
Procedure for how to use the N, TNC and 7/16 Push-On male. Push-On Connectors mate with any standard female connector of the same connector style

1. Convert your standard Assembly into a Push-On Assembly using the Nf to Nm Push-On Adapter

2. Put your fingers firmly onto the knurls of the “Lock Nut”

3. Push “Lock Nut” forward and engage the Push-On end of the Adapter with the mating female. Back nut must be released.



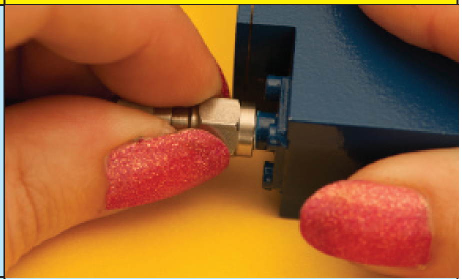
4. The Connection has been completed, easy and fast. The connector has been locked on safely.

5 . To unlock (when “Back Nut” is in unlocked mode) push the “Lock Nut” forward and stop reverse movement by setting your fingers onto the “Back Nut”.

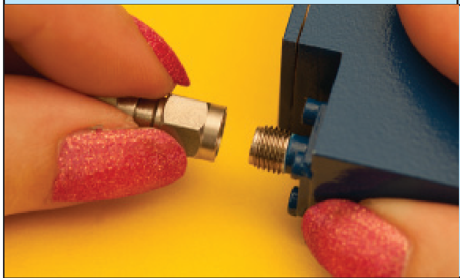
6. Keep fingers on “Back Nut” to ensure that “Lock Nut” cannot slide back and pull the connector off.

1. Convert your standard cable assembly into a Push-On Assembly by threadening the standard female side of the adapter onto the male connector of the assembly.

2. Your standard SMA male cable assembly is converted into an SMA male Push-On Assembly.



3. Just slide the Push-On SMA male Connector onto any standard SMA female. The connection is securely completed in seconds.

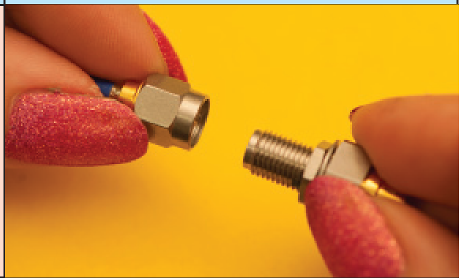


4. To disconnect, just pull the connector off.

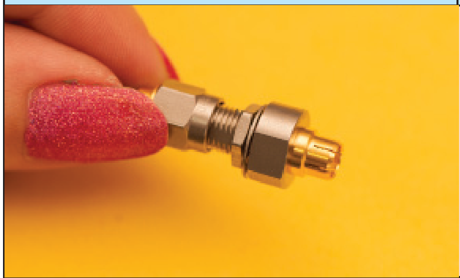
Spectrum
Elektrotechnik GmbH

www.spectrum-et.com
Email:sales@spectrum-et.com
Phone: +49-89-3548-040
Fax: +49-89-3548-0490

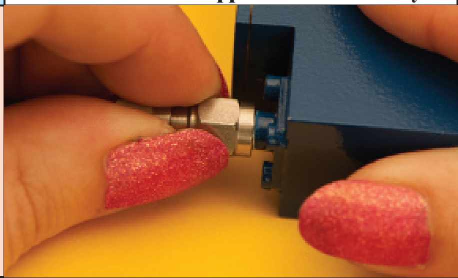
Procedure for how to use the SMA male and female Push-On connectors. SMA Push-On Connectors mate with any standard connector of the same but opposite connector style.



1. Convert your standard cable assembly into a Push-On Assembly by threadening the standard female side of the adapter onto the male connector of the assembly.



2. Your standard SMA male cable assembly is converted to a Push-On SMA female Cable Assembly.

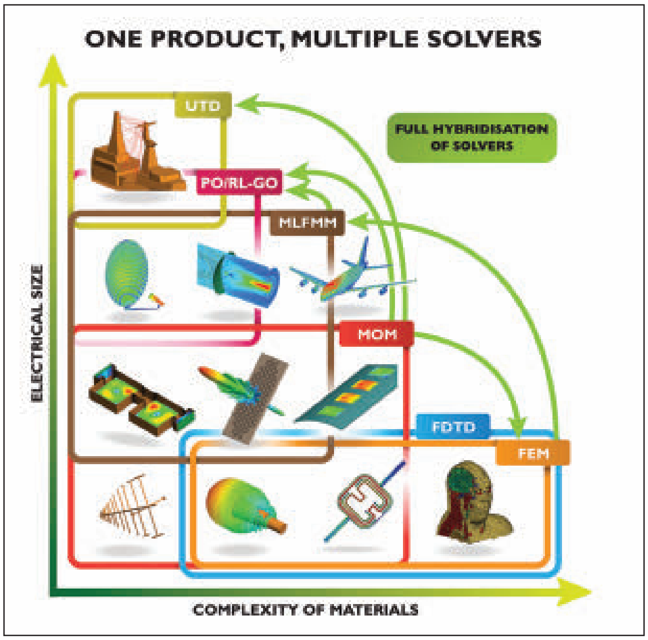


3. Just slide the Push-On SMA female Connector onto any standard SMA male. The connection is securely done in seconds.

4. To disconnect, just pull the connector off.

FEKO: The Power of Multiple Solvers

EM Software & Systems-S.A. (Pty) Ltd.
Stellenbosch, South Africa



▲ *Fig. 1 FEKO has pioneered the development of multiple CEM solvers, and the hybridisation thereof, enabling solutions for a broad scope of applications and seamless cross-validation.*

Today, more than ever before, electromagnetic (EM) simulation is embraced in the research and design of technologies ranging from RFID tags, to radar systems on ships and most things in between. Increasingly, simulation is applied as a means for digital prototyping early in the product development cycle. It also offers a virtual test platform for scenarios where measurement of the actual usage environment might be challenging or impossible, e.g., a cardiac pacemaker, or lightning striking an airplane. The challenge in these cases is how to generate dependable simulation results.

The FEKO approach is to provide all of the EM solvers in a single license, rather than licensing each solver individually. This broadens the scope of how customers are able to solve problems. The advantage of this approach is that, in the absence of measurements, a good correlation between simulation results using different solvers can give the user confidence and certainty in their models.

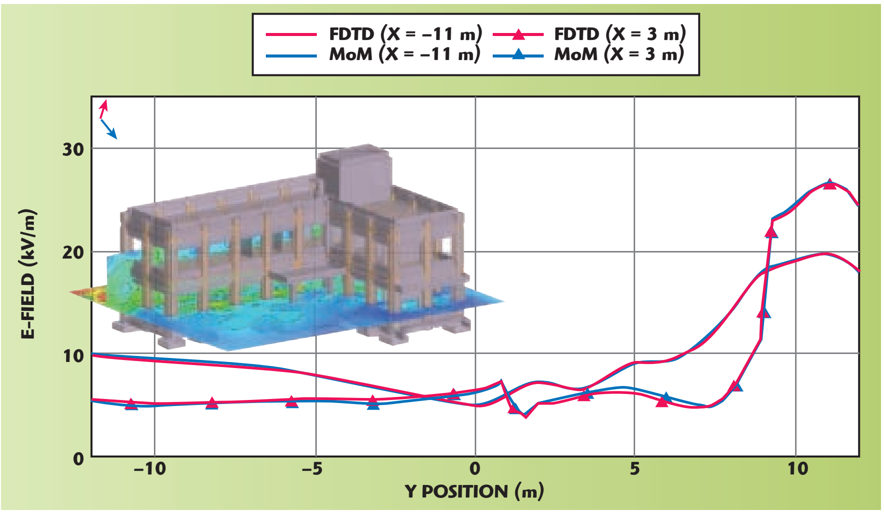
EMSS's belief is that no single computational EM (CEM) method is capable of solving the whole spectrum of problems which is why different CEM methods are normally applied to specific applications. By hybridizing different solvers, it is possible to further combine the advantages of these individual methods to solve an even broader scope of problems, as is illustrated in ***Figure 1***.

With the introduction of fully integrated finite difference time domain (FDTD) and multilevel fast multipole/physical optics (MLFMM/PO) hybrid solvers, FEKO's Suite 7.0 release will take the next step toward a complete solution. Examples follow to illustrate the features and capabilities of the new release.

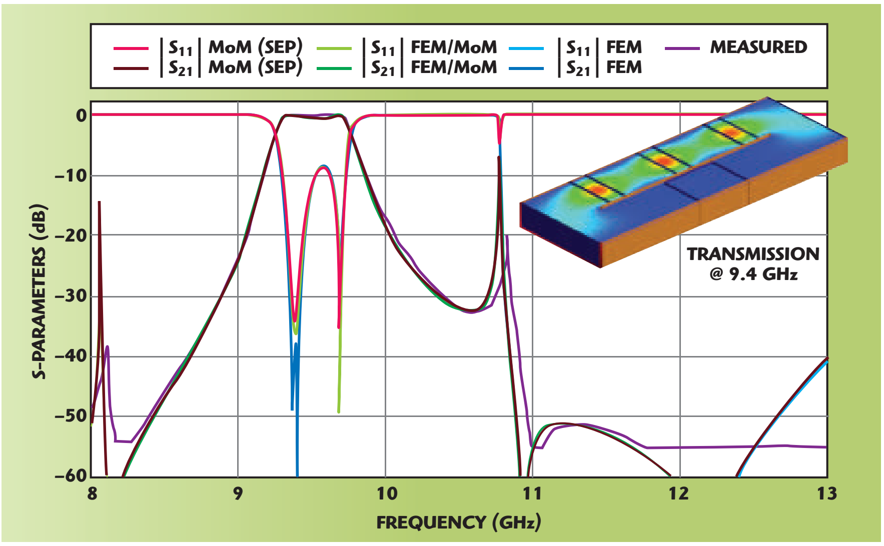
EMP AND LIGHTNING ANALYSIS

A scenario where making field measurements is challenging is the study of the propagation of an electromagnetic pulse (EMP) or a lightning strike on a building. Although the pulse waveforms for EMP and lightning are not the same, the nature of the problem is similar. The goal is to understand the transient fields in order to shield sensitive electronic equipment.

The building structure (see ***Figure 2***) is simulated with FDTD using a typical pulse. The cross-validation is done with the frequency domain method of moments (MoM) at specific frequencies within the spectrum of the pulse. Despite solving the complex geometry with time and frequency domain methods, the results agree very well.



▲ *Fig. 2 Comparison of FDTD and MoM results of the E-field for the two storey building. The field distribution is also shown at 50 MHz.*



▲ *Fig. 3 Comparison of the S-parameters for a dielectric resonator and the field distribution in the transmission band at 9.4 GHz.*

MICROWAVE FILTER DESIGN

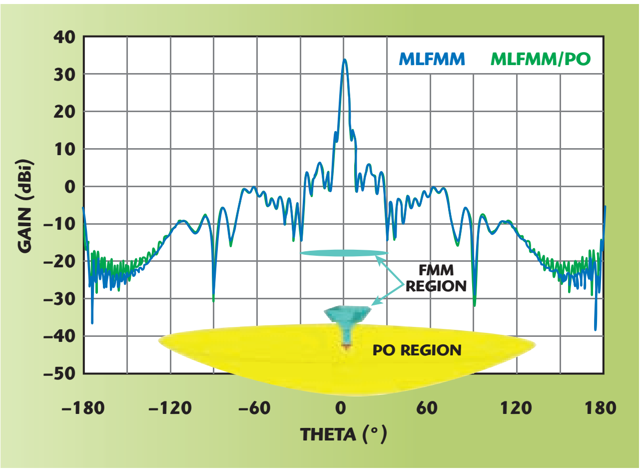
The design of microwave filters can be automated using optimization routines. In addition to understanding the structure, this is an attractive approach to reduce the number of prototype iterations. In this case, the S-parameters are calculated for a filter constructed from dielectrics in an evanescent-mode waveguide (see ***Figure 3***). The two parallel cut-off paths are realized by a partial H-plane bifurcation [Shigesawa, "Two-path cut-off waveguide dielectric resonator filters"].

The structure was simulated using the following three methods: MoM (using the Surface Equivalence Principle for the dielectrics), hybrid FEM/MoM (MoM applied to the waveguide and finite element method FEM to the dielectrics) and FEM only. Not only do the simulation results correspond exceptionally well with each other, but also with the measurements.

A CASSEGRAIN REFLECTOR

Designing electrically large reflectors to meet gain, beamwidth and sidelobe requirements is a challenging task, even more so when complex feed horns are used that require many unknowns in the MoM region. FEKO's new hybrid MLFMM/PO solver is ideally suited to this type of problem because of the huge memory saving offered by MLFMM (when compared to standard MoM).

A Cassegrain reflector with a main reflector diameter of 25λ, operating at 10 GHz, and a corrugated horn feed (see ***Figure 4***) is used to illustrate how this method can be applied–MLFMM for the horn and sub-reflector, PO for the main reflector with bi-directional coupling. The results are compared with the full-wave solution of the whole structure which is solved with MLFMM alone. There is excellent agreement between the full-wave solution, where the MLFMM is applied to the total structure, and the hybrid MLFMM and PO solution. It is only behind the reflector where small differences can be observed.



▲ *Fig. 4 Comparison of the gain of a Cassegrain reflector solved with MLFMM and hybrid MLFMM/PO.*

Simulations have also shown that ignoring the coupling between the feed, the sub-reflector and the main reflector can lead to significant inaccuracies. Using the radiation pattern of the horn and sub-reflector as a feed has been shown to be extremely efficient approximation, but care should be taken with unaccounted for coupling effects.

SPECIALIZED IMPLEMENTATIONS

In addition to the broad range of solvers offered in FEKO, other specialized implementations are available. These include the multi-conductor transmission line (MTL) model which is used to study radiation/irradiation/bi-directional coupling for arbitrary cable cross-sections.

Many of FEKO's solution methods (MoM, MLFMM, FEM, etc.) may be used to compute the external fields and currents that couple to or from such complex cable bundles. Special solutions are available for the efficient analysis of thin dielectric sheets and periodic structures. This can be applied when solving frequency selective surfaces, finite arrays and antennas integrated into glass windscreens.

Characteristic mode analysis (CMA) allows the calculation of natural current modes supported by a structure. These modes give insight into the fundamental radiation and cross-coupling characteristics of the structure, which can then be used to obtain certain design objectives. For example, the position of an antenna on a structure can be chosen to excite a specific mode, which will in turn create a desired radiation pattern.

It is inevitable that the nature of the problems that need to be simulated will become increasingly more complex. Release 7.0 addresses current issues and FEKO intends to provide solutions to tackle new challenges in the future.

VENDORVIEW

FEKO is a product of EM Software & Systems-S.A. (Pty) Ltd., Stellenbosch, South Africa, +27 21 831 1500, www.feko.info.

TechBrief

Handheld Cable and Antenna Analyzer with Frequency Coverage up to 40 GHz

Anritsu Co.'s new Microwave Site Master™ S820E is the world's first handheld cable and antenna analyzer with frequency coverage up to 40 GHz. It brings best-in-class measurement capability to the field and allows for accurate measurements to easily be made on microwave communication systems anytime, anywhere. The Microwave Site Master S820E conducts one- and two-port measurements on coaxial or waveguide systems, and a future vector network analyzer (VNA) mode will offer S-parameter functionality in a compact, field-proven design.

The Site Master S820E has a dynamic range of 110 dB typical up to 40 GHz, and best-in-class frequency resolution of 1 Hz across the full range of operation. Patented RF interference rejection, up to +17 dBm, allows the analyzer to accurately measure in the harshest RF environments, and powerful processors deliver measurement sweep speed of 650 us/point. Standard one-port measurements include return loss, VSWR, cable loss, Distance-to-Fault (DTF), phase, and Smith Chart. Standard transmission measurement (one-path, two-port) is also included.

UNIQUE TWO-PORT MEASUREMENT CAPABILITY

Two-port transmission and swept cable loss measurements on long, embedded transmission systems can also be made with the S820E. External USB sensors up to 40 GHz can be connected to the analyzer to accurately measure loss in cables and waveguide assemblies where there is significant distance between each end of the assembly. The sensor may be easily extended up to 85 meters using passive USB extenders and Cat5e cable. Other lengths can be accommodated.

VNA MEASUREMENTS IN THE FIELD

Internally, the S820E is a four-receiver VNA architecture, and utilizes the same cutting edge NLTL (shock line) sampler technology as the premium Anritsu VectorStar™ VNA benchtop models to deliver unprecedented performance to 40 GHz in a handheld instrument.

VENDORVIEW

Anritsu Co., Richardson, TX, (972) 644-1777, www.anritsu.com.

MINIATURE FOOTPRINT

ULTRA WIDE BANDWIDTH VCO

0.3" x 0.3" x 0.08"

Model	Frequency Range (MHz)	Tuning Voltage (VDC)	DC Bias VDC @ I [Typ.]	Phase Noise @ 10 kHz (dBc/Hz) [Typ.]	Size (Inch)
DCO Series					
DCO50100-5	500 - 1000	0.5 - 15	+5 @ 34 mA	-100	0.3 x 0.3 x 0.08
DCO6080-3	600 - 800	0 - 3	+3 @ 15 mA	-105	0.3 x 0.3 x 0.08
DCO7075-3	700 - 750	0.5 - 3	+3 @ 12 mA	-108	0.3 x 0.3 x 0.08
DCO80100-5	800 - 1000	0.5 - 8	+5 @ 26 mA	-111	0.3 x 0.3 x 0.08
DCO8190-5	810 - 900	0.5 - 16	+5 @ 34 mA	-118	0.3 x 0.3 x 0.08
DCO100200-5	1000 - 2000	0.5 - 24	+5 @ 36 mA	-95	0.3 x 0.3 x 0.08
DCO1198-8	1195 - 1205	0.5 - 8	+8 @ 30 mA	-115	0.3 x 0.3 x 0.08
DCO170340-5	1700 - 3400	0.5 - 24	+5 @ 29 mA	-90	0.3 x 0.3 x 0.08
DCO200400-5 DCO200400-3	2000 - 4000	0.5 - 18	+5 @ 46 mA +3 @ 46 mA	-90 -89	0.3 x 0.3 x 0.08
DCO300600-5 DCO300600-3	3000 - 6000	0.5 - 18	+5 @ 35 mA +3 @ 35 mA	-80 -78	0.3 x 0.3 x 0.08
DCO400800-5 DCO400800-3	4000 - 8000	0.5 - 18	+5 @ 20 mA +3 @ 20 mA	-78 -76	0.3 x 0.3 x 0.08
DCO432493-5 DCO432493-3	4325 - 4950	0.5 - 11	+5 @ 22 mA +3 @ 22 mA	-88 -86	0.3 x 0.3 x 0.08
DCO450900-5 DCO450900-3	4500 - 9000	0.5 - 18	+5 @ 20 mA +3 @ 20 mA	-76 -74	0.3 x 0.3 x 0.08
DCO473542-5 DCO473542-3	4730 - 5420	0.5 - 22	+5 @ 20 mA +3 @ 20 mA	-88 -86	0.3 x 0.3 x 0.08
DCO490517-5 DCO490517-3	4900 - 5175	0.5 - 5	+5 @ 22 mA +3 @ 22 mA	-88 -86	0.3 x 0.3 x 0.08
DCO495550-5 DCO495550-3	4950 - 5500	0.5 - 12	+5 @ 22 mA +3 @ 22 mA	-83 -85	0.3 x 0.3 x 0.08
DCO5001000-5 DCO5001000-3	5000 - 10000	0.5 - 18	+5 @ 20 mA +3 @ 20 mA	-75 -73	0.3 x 0.3 x 0.08
DCO579582-5	5780 - 5880	0.5 - 10	+5 @ 20 mA	-90	0.3 x 0.3 x 0.08
DCO608634-5 DCO608634-3	6080 - 6340	0.5 - 5	+5 @ 20 mA +3 @ 26 mA	-85 -86	0.3 x 0.3 x 0.08
DCO615712-5 DCO615712-3	6150 - 7120	0.5 - 18	+5 @ 22 mA +3 @ 22 mA	-85 -83	0.3 x 0.3 x 0.08

Model	Frequency Range (GHz)	Tuning Voltage (VDC)	DC Bias VDC @ I [Typ.]	Phase Noise @ 10 kHz (dBc/Hz) [Typ.]	Size (Inch)
DXO Series					
DXO810900-5 DXO810900-3	8.1 - 8.925	0.5 - 15	+5 @ 32 mA +3 @ 32 mA	-82 -80	0.3 x 0.3 x 0.08
DXO900965-5 DXO900965-3	9.0 - 9.65	0.5 - 12	+5 @ 27 mA +3 @ 27 mA	-80 -78	0.3 x 0.3 x 0.08
DXO10701095-5	10.70 - 10.95	0.5 - 15	+5 @ 25 mA	-82	0.3 x 0.3 x 0.08
DXO11441200-5	11.44 - 12.0	0.5 - 15	+5 @ 30 mA	-82	0.3 x 0.3 x 0.08
DXO11751220-5	11.75 - 12.2	0.5 - 15	+5 @ 30 mA	-80	0.3 x 0.3 x 0.08
DXO14851515-5	14.85 - 15.15	0.5 - 15	+5 @ 30 mA	-74	0.3 x 0.3 x 0.08

Patented Technology

SYNERGY®
MICROWAVE CORPORATION

Phone: (973) 881-8800 | Fax: (973) 881-8361
E-mail: sales@synergymwave.com
Web: WWW.SYNERGYMWAVE.COM
Mail: 201 McLean Boulevard, Paterson, NJ 07504

1805 to 1880 MHz, 200 W Amplifier

Broadband Wireless has developed a linearized 200 W peak power amplifier operating in the 1805 to 1880 MHz band. Linearized output power is 50 W (80 W maximum) with ACPR (5 MHz W-CDMA at 7.5 dB PAR) of <–45 dBc at 5 MHz and < 50 dBc at 10 MHz. With a 10 MHz LTE waveform at 50 W, the ACP is <–45 dBc at 10 MHz offset. The RF gain is 45±0.5 dBm (adjustable) with ±0.5 dB gain over the frequency and temperature range. The noise figure is 12 dB.

The DC current at 28 V is 5.5 A maximum at 50 W average RF power with an operating base plate temperature from -30° to + 80°C. It is a packaged in a 8" × 4" package with SMA female connectors for RF, nine pin D-Sub female and two pin Molex 0428202222 for DC power. Harmonic level is -45 dBc with input/output return loss of 18 dB min. Broadband Wireless has produced this PA in bands from 700 to 2700 MHz.

Broadband Wireless supplies RF and microwave amplifiers to commercial and government customers in the telecommunications, defense and aerospace industries. They specialize in customized linear high efficiency RF power amplifiers for the communications industry.

Broadband Wireless,
Reno, NV
(775) 329-5544,
www.bwt-amps.com.

Ka-Band ITAR-Free Suite

TMS offers a complete suite of ITAR-free products for Ka-Band systems that have been specifically developed for both legacy and new designs. Both up and down converters have the ability to electronically switch between the commercial and military Ka-/K-Bands. Each converter has a number of functions that enable easy integration into legacy and new systems. These include either internal or external reference at both 10 and 50 MHz along with blanking and attenuation control. By combining these converters with the standard SSPA, a full transceiver can be configured to operate over the 29 to 31 GHz transmit band and the 19.2 to 21.2 GHz receive band with just three hermetically sealed modules.

The standard SSPA offers 16 W P1dB or 8 W linear output power over the full 29 to 31 GHz frequency range. The unit also includes extensive gain control and forward power monitoring. An internal BIT circuit monitors current, thermal and other critical parameters. TMS also offers a K-Band (19.2 to 21.2 GHz) LNA with a 1.3 dB noise figure over the full 2 GHz bandwidth. With a total weight of 0.5 lbs and small size, the unit is ideal for today's integrated, light weight Ka-Band terminals.

For the past 40 years, TMS has always offered a wide range of microwave modules specifically designed to meet demanding size, weight, power and cost applications for land, air and marine markets. Using unique chip and wire techniques, TMS offers rugged and reliable products suitable for the most demanding platforms. With extensive functionality built-in, TMS is able to offer these standard products that work with any modem. Each unit is designed to provide over 200 different configurations, many of which are auto-sensing. All these options are available from a single standard product, enabling last-minute configurations at the factory and thus shorter delivery times.

Teledyne Microwave Solutions, Rancho Cordova, CA, www.teledynemicrowave.com.

CatalogUpdate

LTE-Advanced Manufacturing Test

VENDORVIEW

The *Solutions for LTE-Advanced Manufacturing Test* application note provides an understanding of the requirements for LTE-Advanced carrier aggregation manufacturing test. It is the newest in the series of Agilent Power of Wireless application notes designed to provide a better understanding into the intricacies of the continuously evolving wireless industry, so you can accelerate your development of products. The series can be found at www.agilent.com/find/powerofwireless.

Agilent Technologies Inc.,
www.agilent.com.

EMC & RF Testing Product Catalog

VENDORVIEW

AR has just completed a brand new edition of its sought-after full line product catalog. It has supplemented its extensive line of RF and microwave power amplifiers. Please contact your local AR sales associate for a hard copy or visit the website at www.arworld.us/html/catalogRequest.asp for a free download, either in full or by section.

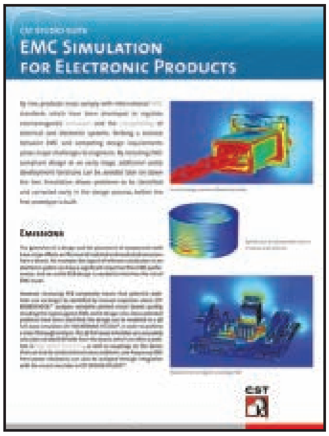
AR RF/Microwave Instrumentation,
www.arworld.us.

EMC Analysis for Cables and Connectors

VENDORVIEW

Electronic systems, including those with cables and connectors, are subject to electromagnetic compatibility (EMC) standards. Coupling of electromagnetic (EM) energy through cables is one of the common occurrences that can be easily analyzed using CST CABLE STUDIO®, a specialized EM simulation tool for cables. Including simulation in the design process allows problems to be identified and corrected before a prototype is built. Find out more in CST's brochure, *EMC Simulation for Electronic Products*.

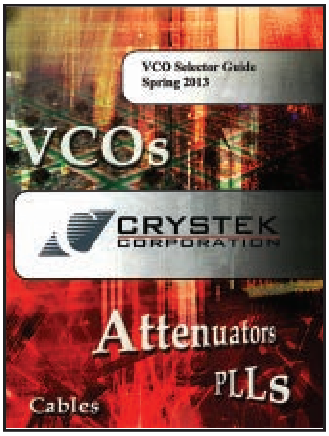
CST-Computer Simulation Technology AG,
www.cst.com.



Crystek VCO Selector Guide

Crystek's *VCO Selector Guide* highlights the company's line of VCO products, available in a wide variety of performance levels and packaging options. Besides VCOs, Crystek offers quartz crystals, XOs, TCXOs and VCXOs, as well as cables and accessories. Crystek Corp.® has been providing frequency products since 1958.

Crystek Corp.,
www.crystek.com.



"At a Glance" Brochures

VENDORVIEW

Empower RF Systems continues to add to its selection of continuously updated and downloadable "At a Glance" brochures which detail (in separate editions) an overview of the company, recommended products for key markets and new product introductions as they occur. Twelve different documents, organized and consistent in presentation of key information, can be accessed via the website. The "At a Glance" materials are especially useful for engineers, buyers and sales reps.

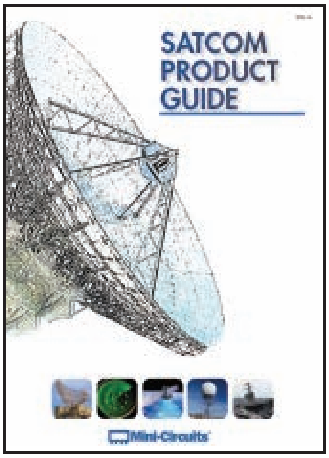
Empower RF Systems Inc.,
www.empowerrf.com.

SATCOM Product Guide

VENDORVIEW

Mini-Circuits is pleased to release its new *SATCOM Product Guide* featuring a full survey of components and assemblies for satellite and earth station systems. With selected models from over 20 different product types to 40 GHz, the guide provides key performance parameters for each product and serves as a handy reference for engineers evaluating parts for their design needs. Request your copy from the literature section of Mini-Circuit's website or email apps@minicircuits.com.

Mini-Circuits,
www.minicircuits.com.



New Waves: Amplifiers & Oscillators

FOR MORE NEW PRODUCTS, VISIT WWW.MWJOURNAL.COM/BUYERSGUIDE

FEATURING VENDORVIEW STOREFRONTS

TWT Pulse Amplifier

AR's new 10000TP8G10 TWT pulsed amplifier produces 10,000 W of peak output power over the 8 to 10 GHz frequency range with 70 dB gain for various EMC and microwave testing applications. Standard features include a built-in IEEE-488 (GPIB) interface, TTL Gating, VSWR protection, gain control, RF output sample ports, auto sleep, plus various monitoring circuits.

AR RF/Microwave Instrumentation,
www.arworld.us.

Low Noise Amplifier

Custom MMIC introduced the CMD167, a highly efficient, ultra low noise GaAs MMIC amplifier that operates from 10 to 17 GHz and is ideally suited for EW and communications systems where small die size and low power consumption are needed. At 14 GHz, it delivers greater than 15 dB of gain, with an output 1 dB compression point of +11 dBm and a noise figure of 1.8 dB. It has a 50 Ω matched design, thereby eliminating the need for external DC blocks and RF port matching.

Custom MMIC,
www.custommmic.com.

Power Amplifier

Hittite launched a new GaAs PHEMT MMIC distributed PA covering the DC to 40 GHz frequency range. The amplifier provides 13 dB of gain, 33 dBm output IP3 and +22 dBm of output power at 1 dB gain compression while requiring 175 mA from a +10 V supply. The HMC5805LS6 exhibits a slightly positive gain slope from 8 to 32 GHz, making it ideal for EW, ECM, radar and test equipment applications. The amplifier I/Os are internally matched to 50 Ω.

Hittite Microwave Corp.,
www.hittite.com.

GPSDO

Jackson Labs Technologies announced the availability of its breakthrough product DROR-II, a 10 MHz/5 MHz/1 PPS GPS-disciplined atomic frequency and timing reference (GPSDO). The DROR-II is a ruggedized frequency and timing reference with a cesium vapor atomic oscillator followed by a precision SC-cut crystal double-oven oscillator and an actively vibration-compensated VCXO oscillator, with specific emphasis on ultra low phase noise performance under extreme vibration and acceleration such as could be encountered in aircraft, tracked vehicles and wheeled vehicles.

Jackson Labs Technologies Inc.,
www.jackson-labs.com.

Wideband Amplifier

Mini-Circuits' GVA-60+ amplifier features a frequency range from 10 MHz to 5 GHz, optimized to deliver incredibly flat gain (20 ±0.3 dB), high IP3 (29 to 40 dBm), and an input return loss of 17 to 20 dB with no external matching for VHF/UHF/IF applications and more. Performance like this, with a typical output power of 19.5 dBm on a 5 V/92 mA DC supply, makes the GVA-60+ ideal as a driver in complex waveform up-converter paths and linearized transmit circuitry.

Mini-Circuits,
www.minicircuits.com.

Wideband Amplifier

QuinStar Technology Inc. introduced QPW-71803014-S1, an E-Band power amplifier. The QPW model of E-Band amplifiers come with some of the widest industry frequency ranges,

such as 71 to 86 GHz, a gain of 30 dB and output power available up to +30 dBm depending on the frequency range and bandwidth. The wide bandwidth of these amplifiers makes them ideally suited for broadband MMW communications systems and other broad spectrum systems applications.

QuinStar Technology Inc.,
www.quinstar.com.

Ultra Low Noise Oscillators

Rakon launched a new series of oven controlled, voltage controlled SAW oscillators (OCSO). Using advanced SAW technology and new circuitry design, the OCSOs are ideal for applications that require high frequency and ultra low phase noise. The LNO1280B1 and LNO2000B1 enable frequencies of 1280 MHz and 2 GHz, respectively. They are based on Rakon's high performance SAW oscillator cores at 320 MHz and 500 MHz, combined with Rakon's low noise, active frequency quadruplers. The technology enables an exceptional phase noise floor and very low broadband jitter.

Rakon Ltd.,
www.rakon.com.

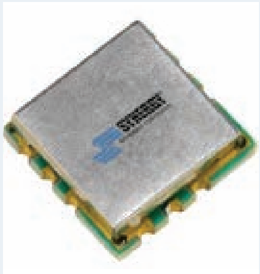
GaAs E-PHEMT MMIC

AE510 is a new state-of-the-art PHEMT MMIC, based on GaAs Enhancement Mode PHEMT which provides low current draw and

very low noise. The AE510 push-pull amplifier is designed for many applications including CATV and FTTH systems operating in the 30 to 2700 MHz range, an ideal solution for broadcasting applications for its high gain and low distortion. With RFHIC's vertical integration and patented manufacturing processes, the AE510 is also one of the most cost effective parts for the price.

RFHIC,
www.rfhic.com.

Miniature Footprint Oscillator

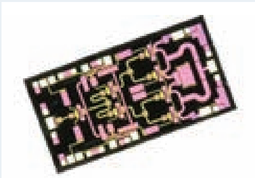


This C-Band miniature surface mount VCO model DCO680700-5 delivers a powerful performance. This optimized fundamental frequency planar resonator design covers the band of 6.76 to 7 GHz with just 0.5 to 5 V of tuning. The 5 V supply voltage (Vcc) draws only a maximum current of 35 mA while achieving a superb low phase noise of -88 dBc/Hz at 10 kHz offset. It also gives a strong output power of 0 dBm as a minimum with excellent harmonic suppression of 32 dB (typical).

Synergy Microwave Corp.,
www.synergymwave.com.

Ka-Band GaN HPA

TriQuint's TGA2594 is a Ka-Band power amplifier fabricated on TriQuint's 0.15 µm GaN on SiC process. Operating between 27 and 31 GHz, it achieves 5 W saturated output power



with an efficiency of 28% PAE, and 23 dB small signal gain. Along with excellent linear characteristics, the TGA2594 is ideally suited to support both commercial and defense related satellite communications. To simplify system integration, the TGA2594 is fully matched to 50 Ω with integrated DC blocking caps on both I/O ports.

TriQuint Semiconductor Inc.,
www.triquint.com.


Mini-Circuits
YAT

New**Products**

Components

SAW Duplexer

VENDORVIEW

The AM1950-2140SD345 SAW duplexer is designed for wireless applications and has very low ripple and insertion loss along with high rejection. Passband 1 is 1940 to 1960 MHz and Passband 2 is 2130 to 2150 MHz. Rejection is up to 52 dB, insertion loss is less than 2.2 dB in either passband, in-band ripple is 0.6 dB, isolation is at least 43 dB, return loss is greater than 16 dB, and power handling ability is 10 dBm.
Anatech Electronics Inc.,
www.anatechelectronics.com.

Phase Shifter

Model P2P-68T-5 is a broadband digitally controlled PIN 360° diode phase shifter operating from 6 to 18 GHz. This device offers up to 0.088° resolution with 12 bits of TTL compatible binary logic and switches in less than 500 nSec. Across the entire band, phase accuracy is ±10°, amplitude balance ±1.0 dB, and VSWR 1.9:1 in 50 Ω. Input power is up to +15 dBm CW or 1 W max. The operating temperature range is extended from -55° to +85°C.
G.T. Microwave Inc.,
www.gtmicrowave.com.

Reactive Splitters

VENDORVIEW

Dr. D.A.S© prescribes MECA's low PIM (-160 dBc typical) compact reactive splitter for DAS applications. Covering 1.7 to 2.2 GHz makes them ideal for space restricted areas where the traditional T styles simply won't fit. IP67 rated. Made in USA - 36 month warranty.
MECA Electronics Inc.,
www.e-meca.com.

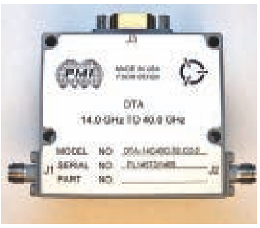
Waveguide Modules

Pasternack introduced new 60 GHz waveguide transmitter/receiver modules and development system. The 60 GHz frequency range is highly desirable to engineers and developers wanting to experiment with transmitting high-bandwidth data at extremely high speeds. Existing solutions currently available are expensive and difficult to integrate into systems. Pasternack's solution is equally effective at a fraction of the cost due to its silicon-germanium (SiGe) construction, making it practical for a wide range of configurations and budgets.
Pasternack Enterprises Inc.,
www.pasternack.com.

Programmable Attenuator

VENDORVIEW

PMI Model No. DTA-14G40G-32-CD-2 is a 10 bit programmable attenuator with step resolution as low as 0.04 dB which provides over 32 dB of attenuation over the frequency range of 14 to 40 GHz. This model is offered in a slim line housing measuring 2.0" × 1.8" × 0.5" with 2.92 mm female connectors and operates on a single +15 V DC supply with only 40 mA of current consumption typically.



Planar Monolithics Industries Inc.,
www.pmi-rf.com.

Notch Filter

VENDORVIEW

Reactel part number 22R7-1580.5-X80S11 is a highly selective cavity notch filter that eliminates GPS, GLONASS, COMPASS and BeiDou signals simultaneously while allowing a passband up to 3000 MHz. Reactel manufactures a wide variety of notch filters which are perfect for co-location interference; please contact the factory with your specifications.

Reactel Inc.,
www.reactel.com.

DC-to-DC Converters

VENDORVIEW

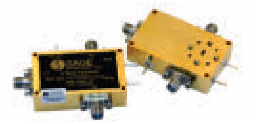
Richardson RFPD Inc. announced availability and full design support capabilities for a large portfolio of high-isolation DC-to-DC converters from RECOM Power Inc. Designed specifically for insulated-gate bipolar transistor (IGBT) systems, the converters' asymmetric outputs of +15 and -9 V make them ideal to power IGBT drivers, replacing the need for two converters. The devices are available with input voltages of 5, 12 and 24 V DC and offer up to 6.4 kV DC/1 sec isolation.

RECOM Power Inc., distributed by Richardson RFPD Inc.,
www.recom-power.com.

E-Band Transceiver Module

VENDORVIEW

Model SSC-7737731200-1212-C1 is a compact and cost-effective E-Band transceiver module operating in the frequency range of 76 to 78 GHz. The module is designed and fabricated for emerging automotive ACC radar applications. It can be used as an FMCW transceiver for speed and distance measurements or radar target simulators for testing. Thanks to the built-in ×4 active multiplier, the required local oscillator frequency is 19.0 to 19.5 GHz at +5 dBm.

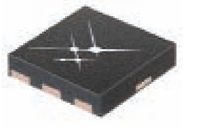


SAGE Millimeter Inc.,
www.sagemillimeter.com.

SPDT Switch

VENDORVIEW

RFMW Ltd. announces design and sales support for Skyworks' SKY13446-374LF, a high isolation SPDT switch covering 0.1 to 6 GHz. Targeted at WLAN applications in the 2.4 to 2.5 GHz and 4.9 to 5.9 GHz bands, the SKY13446-374LF offers 38 and 30 dB typical isolation. Low insertion loss improves transmit signal efficiency. Excellent EVM performance is attributed to linearity of 32 to 33 dBm P1dB. The SKY13446-374LF incorporates two control voltages for Tx/Rx switching and is packaged in a 1.5 × 1.5 mm QFN.



Skyworks Solutions,
distributed by RFMW Ltd.,
www.skyworksinc.com.

Waveguide High Pass Filter

Spacek Labs model HPF-700 is a waveguide high pass filter in WR-12 waveguide. This filter series is designed with a sharp cut off close to the passband. This filter will pass all of E-Band down to 71 GHz with an insertion loss of

NewProducts

1.5 dB typical and 2 dB max. The reject band is </= 68 GHz, with 20 dB rejection at 68 GHz and 40 dB at </=67 GHz. Spacek Labs offers this HPF series of filters up to 110 GHz.
Spacek Labs Inc.,
www.spaceklabs.com.

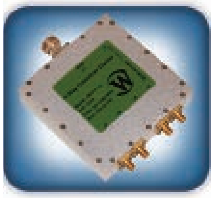
Coaxial Circulator

Model F2585-0203-67 is an octave band SMA connectorized circulator covering 1.35 to 2.7 GHz frequency range. It features 0.6 dB insertion loss, 17 dB reverse isolation and 1.35:1 VSWR, and can handle 50 W of CW power. The package size of the circulator is 2.0" × 1.949" × 0.748".

Wenteq Microwave,
www.wenteq.com.

4-Way Combiner/Divider

VENDORVIEW



Werlatone's newest addition to its 20 to 1000 MHz family of products is the Model D9317. This 200 W CW, 4-way combiner operates with less than 0.7 dB insertion loss, and a minimum of 15 dB isolation. Measuring just 3.75" × 3.75" × 0.9", the D9317 is ideal for combining four 50 W modules. The unit has an operating temperature of -55° to +85°C and can be supplied with all SMA female connectors.
Werlatone,
www.werlatone.com.

Cables & Connectors

P-SMP Interconnection

The P-SMP board-to-board interconnection provides excellent continuous power handling of up to 200 W at 2.2 GHz. It is built as a three components concept: two PCB or panel types, assembled with an adaptor – 'bullet'. The minimum distance of the P-SMP interconnection is 12.6 mm. Typically one PCB board is equipped with a snap-on PCB type – the 'limited detent' type – the second PCB board with a slide-on version, is the 'smooth bore' type. Excellent RF capabilities make P-SMP connectors ideal for applications up to 10 GHz.

IMS Connector Systems,
www.imscs.com.

Antenna

C-Band Antenna

mWAVE Industries' model RPD4-48-N, a 4' dual linear polarized 4.40 to 5.25 GHz antenna, utilizes a self supporting monopod feed support for reduced blockage. The antenna comes standard with a mount for pipes. It was designed for use in the C-Band telemetry industry but can be used for any other communications requirement within the operating band and capabilities of the antenna. The RF inputs are Type N female connectors and are located behind the vertex of the main reflector.

mWAVE Industries LLC,
www.mwavellc.com.

Test Equipment

Waveform Generators

VENDORVIEW

Agilent's 33600A Series, which comprises four different one- and two-channel models, can generate waveforms up to 120 MHz at a 1 GSa/s sampling rate. The waveform generators provide the lowest jitter (less than 1 ps jitter, or 200× better than previous generation direct digital synthesis generators) and lowest total harmonic distortion in their class, giving engineers the ability to generate the exact signals they need. With total harmonic distortion less than 0.03 percent and non-harmonic spurs below -75 dBc, the 33600A Series offers clean signals that don't introduce noise.

Agilent Technologies Inc.,
www.agilent.com.

I/Q Analyzer

Narda Safety Test Solutions has equipped the second generation of its Interference and Direction Analyzer with I/Q analyzer functions. Based on the I/Q data, the device generates high resolution spectrograms, persistence spectrums and time domain displays that were previously only available from high cost laboratory instruments. Radio spectrum interference and impairments can thus be detected and analyzed on the spot.
Narda Safety Test Solutions,
www.narda-sts.com.

Envelope Tracking Power Amplifiers for Wireless Communications

Zhancang Wang

Higher peak to average power ratio requirements of modern communications systems have negatively impacted power amplifier efficiency over the years. Envelope tracking technology is seen as one of the most promising efficiency enhancement technologies for RF power amplifiers for newer 4G and beyond wireless communication systems. Therefore many organizations are investing and researching this topic that has a large potential reward in commercial and military applications.

Envelope Tracking Power Amplifiers for Wireless Communications is one of the first books on the market to offer a complete introduction, theory and design considerations on envelope tracking for wireless communications. It presents a full introduction and covers underlying theory and practical design considerations including high efficiency power amplifier architectures and devices; envelope tracking power amplifier basics; envelope generation and alignment; supply modulator for envelope tracking; power amplifier for envelope tracking; digital front end design for envelope tracking; and experimental methodologies and measurements for envelope tracking. One new method presented is nested and multi-nested envelope tracking to preserve the benefits of the combined hybrid supply modulator for higher efficiency.

Envelope Tracking Power Amplifiers for Wireless Communications covers many advanced design techniques for thorough coverage of envelope tracking and related subjects. Therefore it offers designers a full reference guide on the subject so is appropriate for engineers, designers and students interested in complete coverage of the subject. This book will publish in June 2014 but is on sale for pre-order at 25% off.

To order this book, contact:

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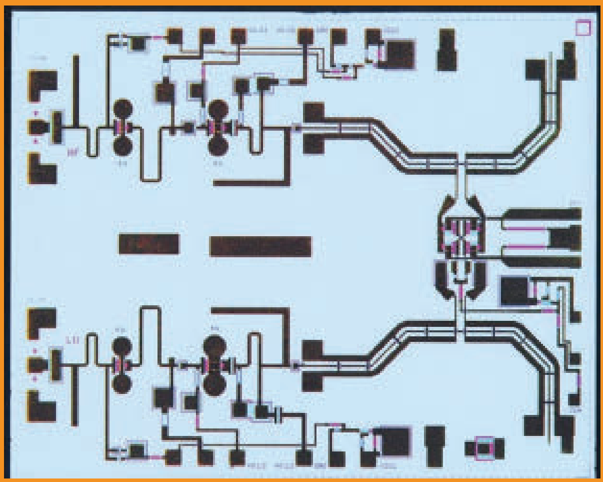
MMIC Amplifier [mim-ik · am-pluh-fahy-er]

A Monolithic Microwave Integrated Circuit Amplifier (MMIC amp) combines transistors and passive devices (resistors, capacitors, etc.) on the semiconductor substrate and is widely used in telecommunications to amplify microwave signals for transmission or improved signal processing at the receiver. The input and output impedances of a MMIC amplifier are frequently matched to a characteristic impedance of 50 ohms, making them easier to use by eliminating the need for external matching networks between cascaded devices.



1907 The DeForest audion, a thermionic vacuum tube, offers a means of electronically generating and controlling RF signals.

1925 Austro-Hungarian physicist Julius Edgar Lilienfeld files a patent in Canada, "Method and apparatus for controlling electric current," the first describing a device similar to a MESFET.

1947 AT&T Bell Lab scientists John Bardeen and Walter Brattain led by William Shockley invent the first transistor using gold point contacts applied to a crystal of germanium, thereby producing a signal with the output power greater than the input.

1958 Jack Kilby invents the integrated circuit at Texas Instruments for which he later wins the Nobel Prize in Physics (2000).

1967 The first GaAs MESFETs are realized, demonstrating superior performance over GaAs bipolar transistors. Plessey Research (Caswell) fabricates a 4 um gate length device that produces 10 dB gain at 1 GHz.

1975 Ray Pengelly and James Turner of Plessey publish "Monolithic Broadband GaAs FET Amplifiers," describing a single-stage amplifier that provided 5 dB of gain at X-Band using 1 micron optically-written gates.

1982 Jamison et al. present a MMIC amplifier using a planar spiral transformer. Strid and Gleason present a paper describing a DC to 12 GHz broadband amplifier using the travelling-wave (or distributed) amplifier technique.

1987 A 0.25 um GaAs LNA MMIC for DBS receiver becomes the world's first mass market product based on HEMT technology. The following year, worldwide production of HEMT receivers reaches 20 million/year.

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Model	Type	Frequency (MHz)	Power (W CW)	Insertion Loss (dB)	Isolation (dB)	Size (Inches)
D8265	2-Way	1-50	5,000	0.3	20	15.5 x 15 x 5.25
D2075	2-Way	1.5-30	6,000	0.2	20	15.5 x 11.75 x 5.25
D8969	2-Way	1.5-30	12,500	0.2	20	17 x 17 x 8
D6139	4-Way	1.5-32	5,000	0.25	20	13 x 11 x 5
D6774	4-Way	1.5-32	20,000	0.3	20	21 x 17.25 x 11
D6846	6-Way	1.5-30	4,000	0.35	20	3U, 19" Rack
D8421	8-Way	1.5-30	12,000	0.3	20	22.5 x 19.5 x 8.75
D7685	4-Way	2-100	2,500	0.5	20	14.75 x 13 x 7
D2786	4-Way	20-150	4,000	0.5	20	18 x 17 x 5
D6078	2-Way	100-500	2,000	0.25	20	13 x 7 x 2.25
H7521	2-Way (180°)	200-400	2,500	0.3	20	15 x 10 x 2
D7502	2-Way	400-1000	2,500	0.25	NI*	9.38 x 3.12 x 1.25

*NI = No Isolating Terminations

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