Vol. 53 • No. 9

September 2010

Microwave Journal®

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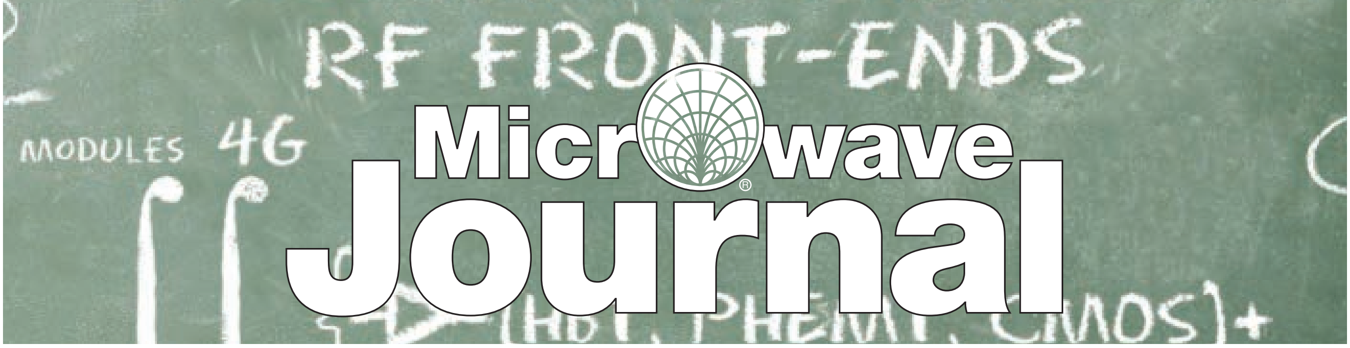

SEPTEMBER 2010 VOL. 53 • NO. 9

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

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

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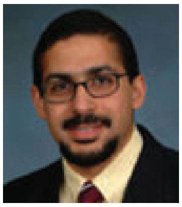
John Coonrod of **Rogers Corp**. provides technical advice and information about RF/microwave materials. His first entry covers FR-4 versus high frequency laminates in selecting a PCB material. Various experts from Rogers will cover high frequency material issues over the next several months. Read his advice, ask questions or add to the comments at http://mwexpert.typepad.com/rog_blog.

Executive Interview

Greg Peters, Vice President and General Manager of **Agilent Technologies**' Component Test Division, talks about the health of the microwave industry as viewed through the lens of test equipment procurement trends.

Expert Advice



Dr. Ali Darwish, adjunct faculty member at the University of Maryland and Besser Associates instructor, answers audience questions from his recent MMIC design overview webinar.

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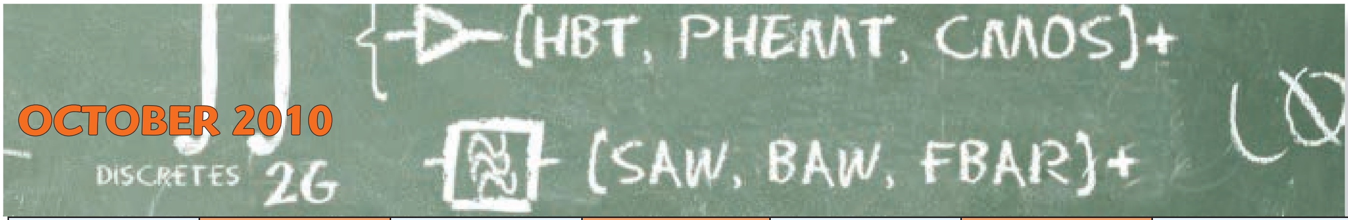

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26	27	28	29	30	1 **Sonnet User Meeting/EuMW** Paris, France	2
3	4	5	6	7	8	9
10	11	12	13	14 **AWR® 2010 Users Group Meeting** Munich, Germany	15	16
17	18	19 **MWJ/Besser Webinar: MIMO** Sponsored by AWR®	20	21	22	23
24 **MUD 2010**	25	26 **MWJ Webinar: MilSatCom Electronic Market Trends through 2020** Presented by Strategy Analytics	27	28 **Agilent Webcast: A Practical Approach to Verifying RFICs with Fast Mismatch Analysis**	29	30
31	1	2	3	4	5	6

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- October 7–9: **COMSOL Conference 2010** Newton, MA
- October 4–7: **BiPolar/BiCMOS Circuits and Technology Meeting** Austin, TX
- October 5–9: **MWP 2010 International Topical Meeting on Microwave Photonics** Montreal, Canada
- October 10–15: **AMTA 2010 Antenna Measurement Techniques Association** Atlanta, GA
- October 12–15: **IEEE International Symposium on Phased Array Systems and Technology** Waltham, MA
- October 18–21: 4G WORLD Chicago, IL
- October 21–24: **Microwave Update (MUD)** Cerritos, CA
- October 26–28: **EMC By Your Design: An EMC Practical Applications Seminar and Workshop** Northbrook, IL
- October 26–29: **Microwave Antenna Design, Testing and Wireless Propagation** Ottawa, Canada
- October 31–November 3: MILCOM San Jose, CA

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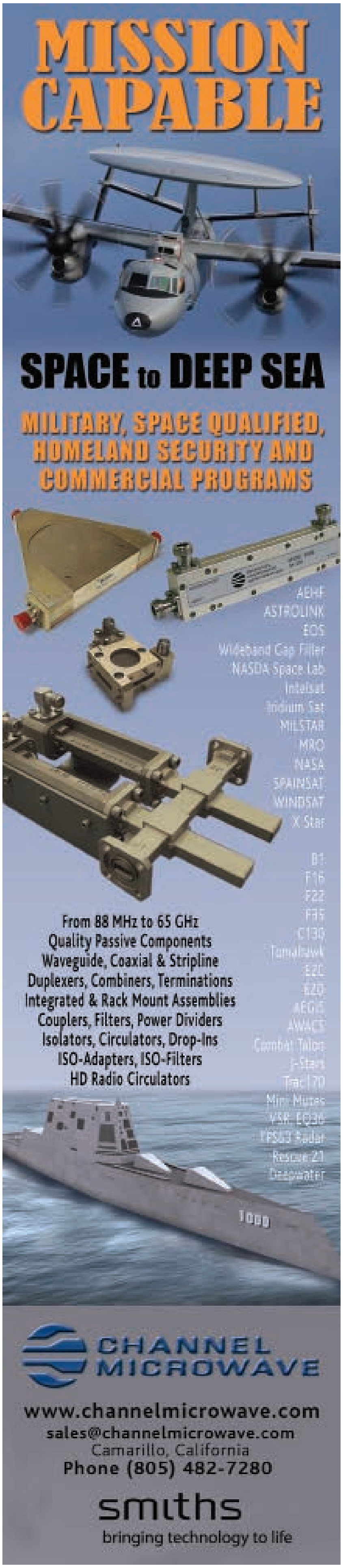

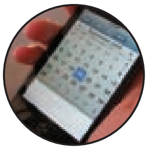

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4G World
October 18–21, 2010 • Chicago, IL
http://4gworld.com

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

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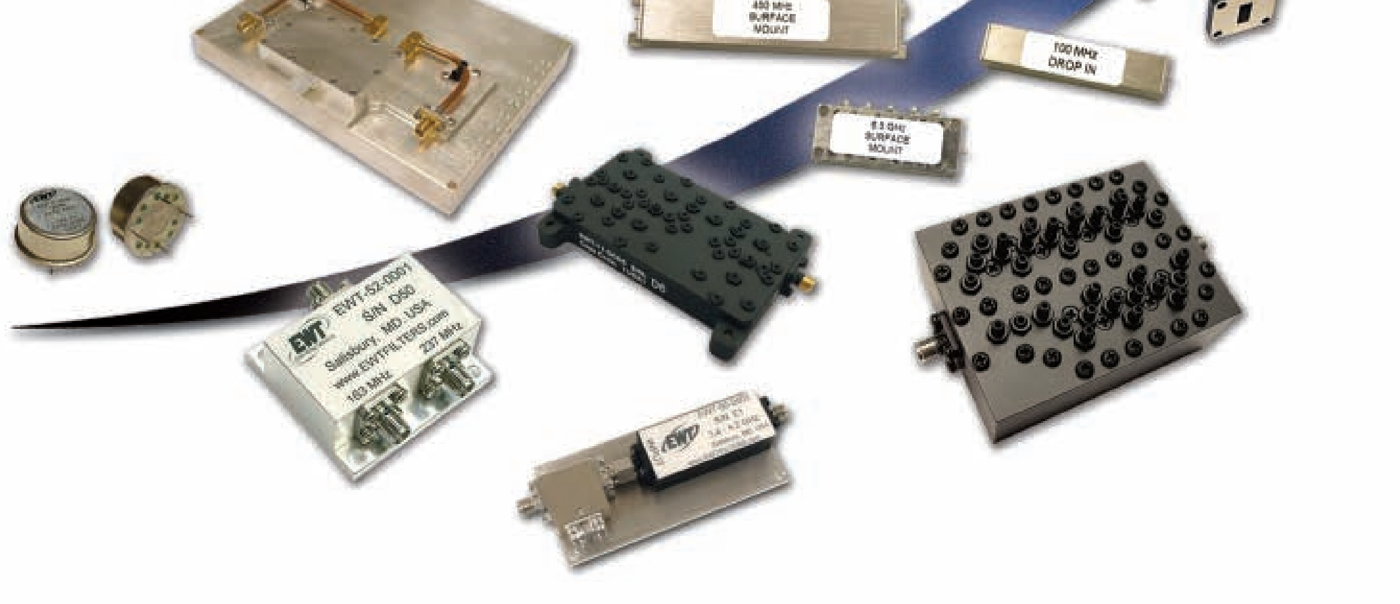

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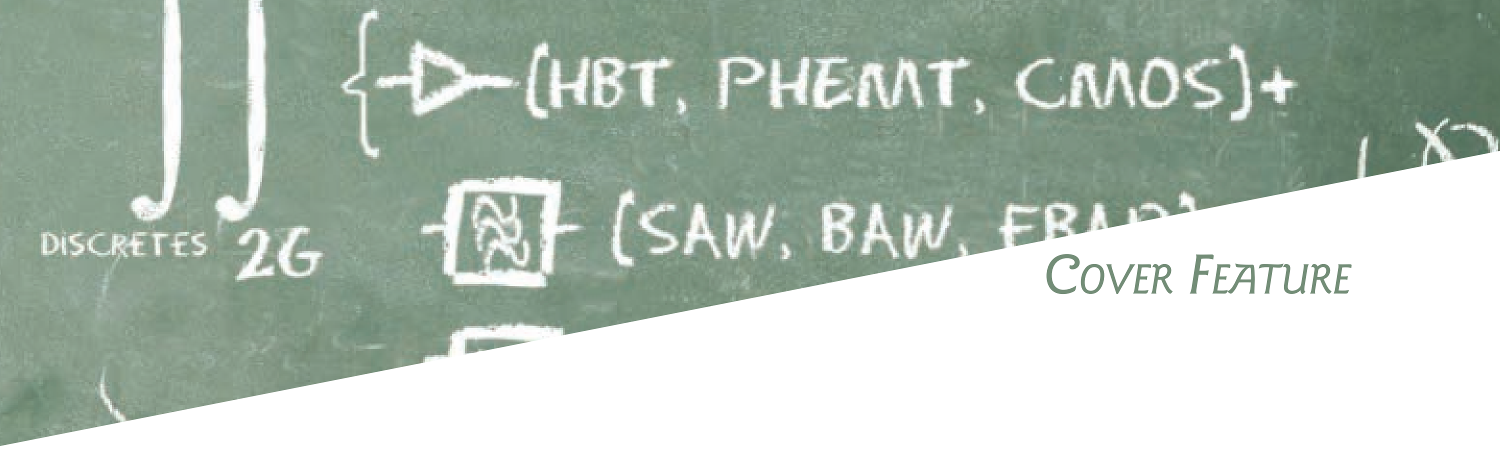


COVER FEATURE

THE ECONOMICS OF HANDSET RF FRONT-END INTEGRATION

In this article, the executives responsible for mobile device products at ***RFMD, Skyworks*** *and* ***TriQuint*** *talk to* Microwave Journal *about market dynamics and how they are influencing their companies' business and engineering decisions.*

The mobile device has come a long way from its humble beginnings as a cell phone. Today, it is becoming the primary means of communication for most people around the world; serving as both a voice and data connection, emulating many of the functions once reserved for the personal computer and ushering in a new class of personal media devices. In addition, mobile technology is playing a key role in new embedded wireless and machine-to-machine (M2M) communications. These are the trends impacting the mobile device industry, fueling its growth and ultimately defining the needs of the radio inside, which will be as diversified as the trends driving these applications.

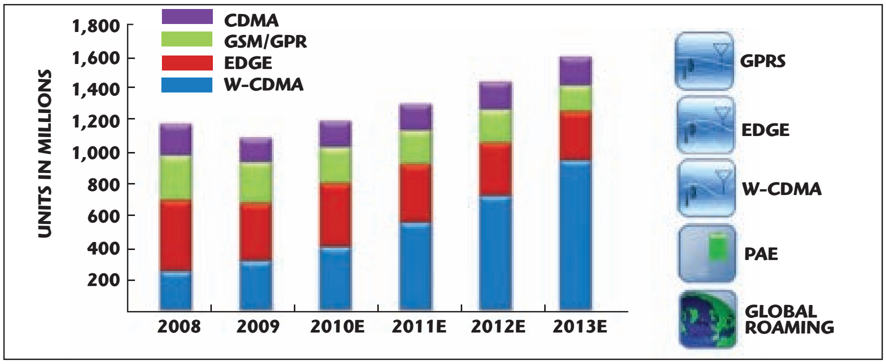
For example, an RF front-end solution covering a specific geographical region with a one or two band low-cost entry phone is considerably different than the front-end in a handset targeting global coverage with a high-bandwidth data/voice connection. The former calls for a high volume front-end with RF content at the $1 and below price point, while the later requires a multi-band, multi-mode radio with RF content that can run from $8 to $10.

MARKET DYNAMICS: 2G ENTRY, 3G EMERGING AND 3G/4G SMARTPHONE SECTORS

Worldwide mobile phone sales totaled 315 million units in the first quarter of 2010, a 17 percent increase from the same period in 2009, according to Gartner Inc. Industry analysts are forecasting handset unit volumes to grow approximately 10 percent this year to around 1.5 billion units (see ***Figure 1***). Smartphone sales, which reached 54.3 million units, increased 48.7 percent over the first quarter of the previous year.[1] The growth rate of Smartphones, which contain 3 to 6 times more RF dollar content than voice-only phones, is forecast to continue growing at 42 percent through 2010, and 35 percent in 2011, vastly outpacing middle-tier "feature" phones, which had relatively flat growth and should eventually be displaced by feature-limited 3G entry phones.

While Smartphone market growth has been phenomenal this year, 2G entry phones represent another sizable market opportunity. Ralph

DAVID VYE
Editor, Microwave Journal



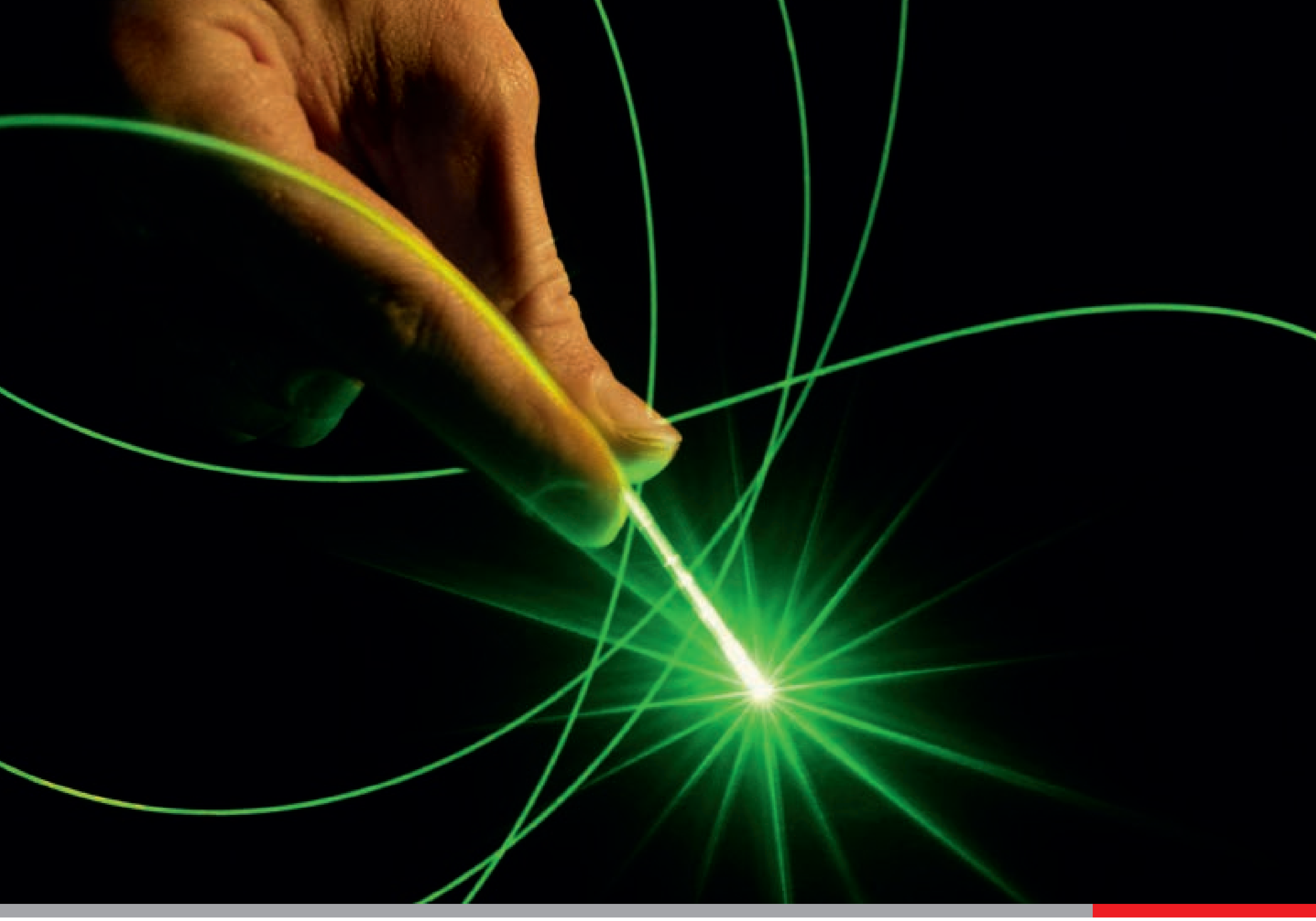
▲ *Fig. 1 Projection of mobile phone unit sales by standard.*

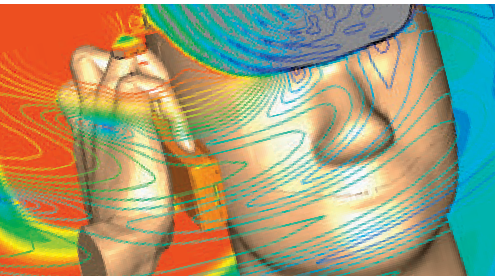
Quinsey, President and CEO of TriQuint Semiconductor, expects this market, which is mostly in China but increasingly includes India, to account for "500 to 600 million low-end, voice-only (2G—probably dual-band GSM) phones this year." Quinsey referred to this sector [2G and eventually 3G entry phone] as the second wave of market opportunity (behind the first wave of revenue growth represented by Smartphones).

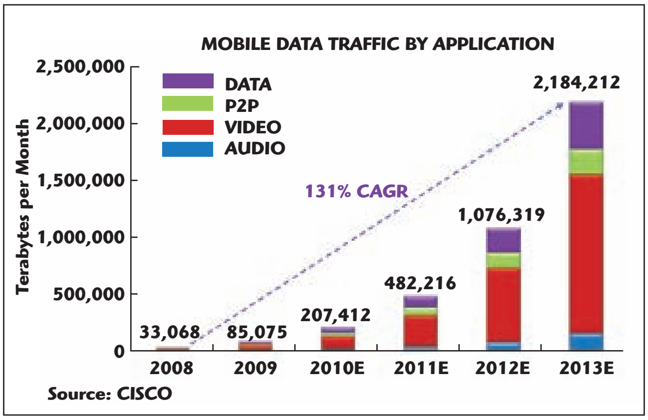
With voice-only entry phones exceeding new landline connections, Greg Waters, Executive Vice-President and General Manager of Front-end Solutions for Skyworks, said that "the company expects voice-only phones to continue to grow as they replace landline phones, with the cost of voice-only services continuing to drop. A combination of CMOS and GaAs technologies are required to continue to drive aggressive price points in this type of solution. Skyworks believes they have over 50 percent market share today in 2G and that their share will increase."

Eric Creviston, President of the Cellular Products Group at RFMD, confirmed that "2G has just done extremely well in the emerging market category. For this sector, the company developed a transmit module (PA and switch) focused on China and Korea handset manufacturers." The strength of this market was clearly evident when the company surpassed 100 million units in cumulative shipments of its 2G dual-band and quad-band transmit modules this past spring, less than one year into production shipments, putting the 71xx transmit module product family among the company's all-time most successful product launches. Creviston was not in agreement over which company enjoys the largest market share for 2G, believing that RFMD, at 40 percent, holds the largest market share.

> "In the past, people thought the emerging world would access the Internet through low-cost PCs, whereas now it is believed that many people will have their first experience with the Internet through a Smartphone." Quinsey, TriQuint







▲ *Fig. 2 Compound annual growth rate of mobile data traffic by application (courtesy of Cisco).*

By 2015, it is predicted that five billion people will be connected via communication networks, with well over half enjoying broadband access. The majority of new users will come from emerging markets and 3G/HSPA will be the core technologies to connect them to the Internet.[2]

In general, the 2.5G or "feature" phone category has not really been showing a lot of growth year over year. There is a strong likelihood that the 2.5G category will transition into a new, low-end 3G Smartphone category, one that is different than the current high-end phones with less RF content but a minimum of 2X content over 2G entry (voice-only) phones, (see unit sales by radio standard in Figure 1). Quinsey believes that access to the Internet is the "killer-application", a term repeated by Waters of Skyworks as he described the five year, 131 percent CAGR of mobile data traffic, driven largely by audio, video, P2P and data (see ***Figure 2***).

Creviston also sees the breakout 3G emerging markets as a very fast growth category: "What's behind all this is the need for higher and higher data throughput for mobile applications and economics are driving these finer segmentations. In other words, how cheaply can one provide as much data as possible to as many people as possible. While the 3G/4G or Smartphone category is growing very nicely, to around 250 million handsets, we believe the fastest growth will be the 3G entry category, which to a certain extent will replace the 2.5G, or EDGE feature phone."

Creviston went on to comment that, "the 3G emerging markets will be built around 1 to 2 bands of UMTS and then in some cases just GPRS for the 2G backward compatibility and in other cases EDGE. This is in contrast to the 3G/4G/Smartphone market that typically has 5 bands of UMTS and 4 bands of EDGE. So what vendors are trying to do (for the emerging market) is create a high volume solution for a very targeted region, such as a part of India, for example."

In February, RFMD released four new transmit modules designed specifically for 3G entry-level feature phones supporting one-to-two bands of W-CDMA and two-to-four bands of GSM/GPRS. Each module features a GSM/GPRS power amplifier (PA) and an integrated pHEMT switch to support stringent 3G linearity requirements.

Creviston shifted his attention to the connected device category (M2M and personal media). "This is not really a new segment but one that is growing very rapidly and becoming quite meaningful to all handset front-end suppliers. This segment includes usb data modems, which from an RF perspective are similar to a Smartphone or high-end multi-mode phone with the exception that they typically work at max power level." In contrast, a Smartphone communicating data at the edge of a cell site might be at max power, but they also have a lot of use in voice communication where the power is backed-off to preserve battery life, which leads to a wide spread of power ranges. This results in different design criteria between M2M and handset front-ends.

Will 2G and lower data rate technologies be used for M2M? Not necessarily. "Currently, the majority of M2M applications are at low data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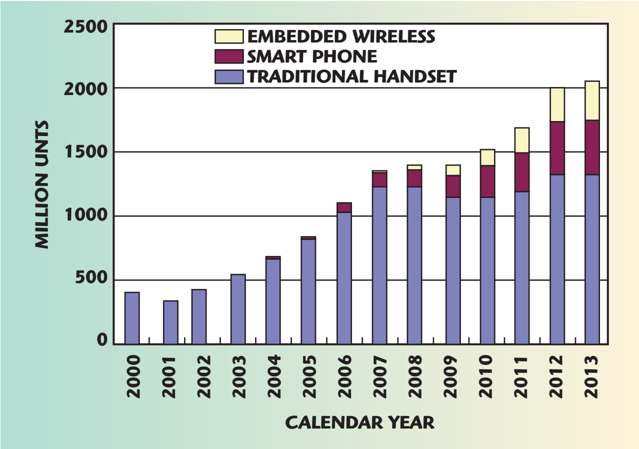


▲ *Fig. 3 Estimate of cellular terminal market (courtesy of Navian Inc.).*

rates, and are using CDMA and GSM for asset tracking or remote vending applications which require little data. But more and more applications are using high amounts of data such as video surveillance. So M2M, as a category, will also include 2G, 3G and 4G as well," remarked Creviston.

Quinsey referred to M2M as the third-wave of general mobile device trends "that will provide lift for the RF suppliers. M2M applications such as e-readers, remote health sensors, power grid management and security surveillance will need RF connectivity. Over the next decade, I see billions of wireless nodes, outstripping the demand for person-to-person communications in the long run."

Waters agrees that embedded RF may overtake cellular in pure volume in this decade. "Evolving mobile applications and network traffic that includes broadband data such as video is already calling for a shift in product architecture and will require new innovation and the best of CMOS and GaAs to improve battery life for high data rates. At the heart of the challenge is to find a way to support multiple bands and air interfaces that offer a small enough form factor while improving performance, battery life and heat dissipation. Skyworks is already beginning volume shipments of new products tailored for high speed data and video applications."

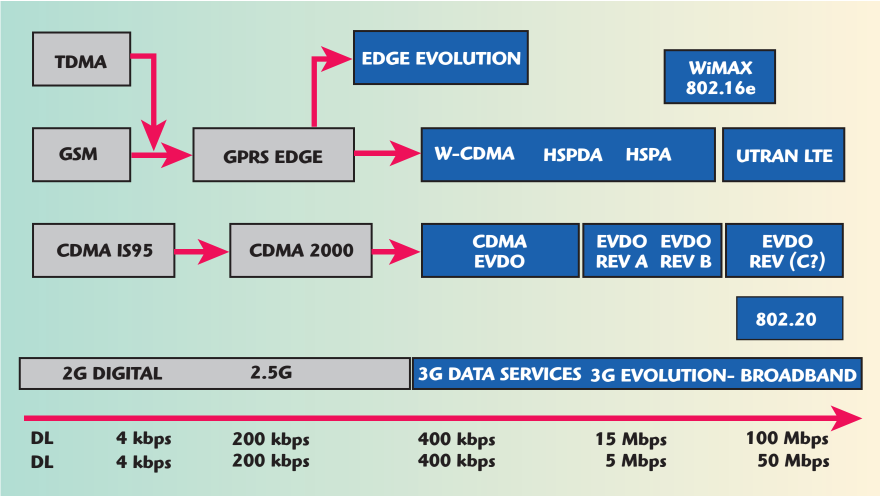
The projected contribution of each of these sectors on the cellular terminal market is shown in ***Figure 3***, indicating the growth expected from Smartphones and embedded wireless devices to the overall number of units sold.

STANDARDS AND MARKET DRIVERS OF FRONT-END TECHNOLOGY

The high-tier Smartphone market needs to provide simultaneous voice and data transmission with broadband functionality for multimedia and international roaming (which allows phone manufacturers to realize economy of scale) while maintaining support of existing networks. To do so, these UMTS (W-CDMA) terminals may support up to 15 frequency band allocations, backward compatibility with the earlier GSM standards, and support for additional non-cellular wireless interfaces such as WiFi, Bluetooth and GPS. All this requires additional RF content (amplifier, filtering and switching), which adds to the complexity of the RF front-end architecture.

Over the past 20 years, the handset radio has evolved from a nearly all-discrete solution toward highly integrated baseband and transceiver ICs and integrated RF front-end modules (FEM). RF functional blocks between the transceiver and antenna include filtering, amplification and switching (with impedance matching incorporated between components where needed). The electrical requirements for each component as well as the overall topology are dictated by the particular standards requirement and band support (see ***Figure 4***).

The increase in RF components as band support moves from single to dual, triple and quad bands in a time-division duplex GSM phone is shown in ***Figure 5***. Progressive integration might lead to a dedicated filter bank (e) or incorporation of the switch and filter into a single Antenna Switch Module (ASM) module (f). Individual band specific power amplifiers could also be combined into a power amp module (PAM).



▲ *Fig. 4 Evolution of cellular standard.*

Where time-division duplexed systems such as GSM rely on switching between receive and transmit functions, CDMA and W-CDMA use full-duplex communication with receive and transmit functions operating simultaneously at slightly different frequencies. The addition of a duplexer in the transmit/receive chain is one of the principle FE architecture differences between these standards. Traditionally, handset designers seeking to support multiple air interface standards in the same device have resorted to high-throw switching and stacked radio architectures, which can lead to front-end duplication of components. An FE diagram for a phone utilizing discrete components and supporting two GSM bands and one UMTS band is represented in ***Figure 6***. The BOM costs for W-CDMA handsets are typically double that for EDGE handsets and nearly triple those for GSM/GPRS devices.[4]

TRENDS IN FEM PARTITIONING

How front-end components are partitioned into modules is driven largely by economics and suppliers' access to technology. Handset OEMs need to lower the bill of materials and limit the amount of engineering they invest in RF design at the board level. Driving up the cost (and complexity) is the need to increase revenue potential by way of multi-band, multi-mode platforms with broader market appeal. Scale drives integration. In other words, the less specialized the phone's band requirements, the more cost effective it is to integrate multi-mode RF components into a module. Partitioning functional blocks based on standards requirements and reducing costs has led to a number of module products.

Common FE modules (see ***Table 1***) include:

- Antenna Switch Module (ASM): Antenna switch and low pass filters. The ASM appears mostly in low-end GSM handsets. Renesas is the only vendor using pin diode switches and LTCC; the other vendors use hybrid modules based on PHEMT MMIC or SOI switches and SAW or BAW filters.
- Switch Filter Module (SFM): For GSM phones, the SFM integrates the Rx bandpass filter and the ASM. Demand for this module should exceed that of the Tx module when combined with a duplexer module for the UMTS/GSM multi-mode market. It will likely become obsolete as duplexers are integrated directly into the Switch Duplex Module. Samsung, LG, Apple and Huawei are major customers of the SFM.
- Tx Module: ASM and PA module. This module is largely dominated by PA manufacturers who tend to have a cost advantage. This module is mostly adopted in GSM terminals, although Nokia uses this module in its UMTS/GSM handsets as well. The Tx module will likely lose out to the Switch Duplexer and multi-duplexer modules for UMTS/GSM and LTE/UMTS/

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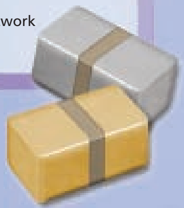

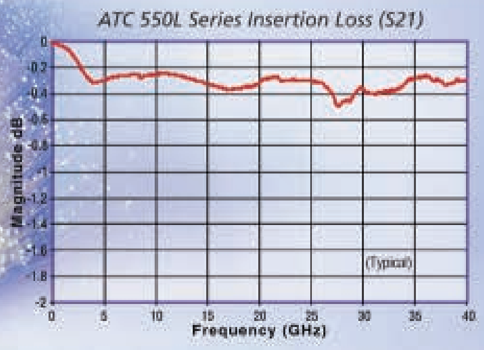

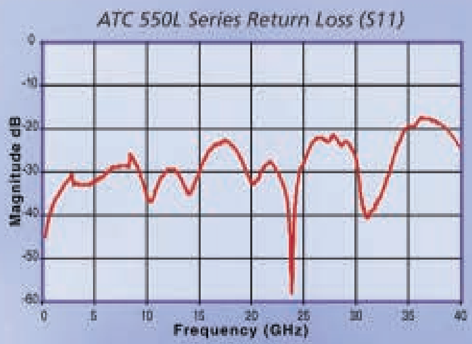

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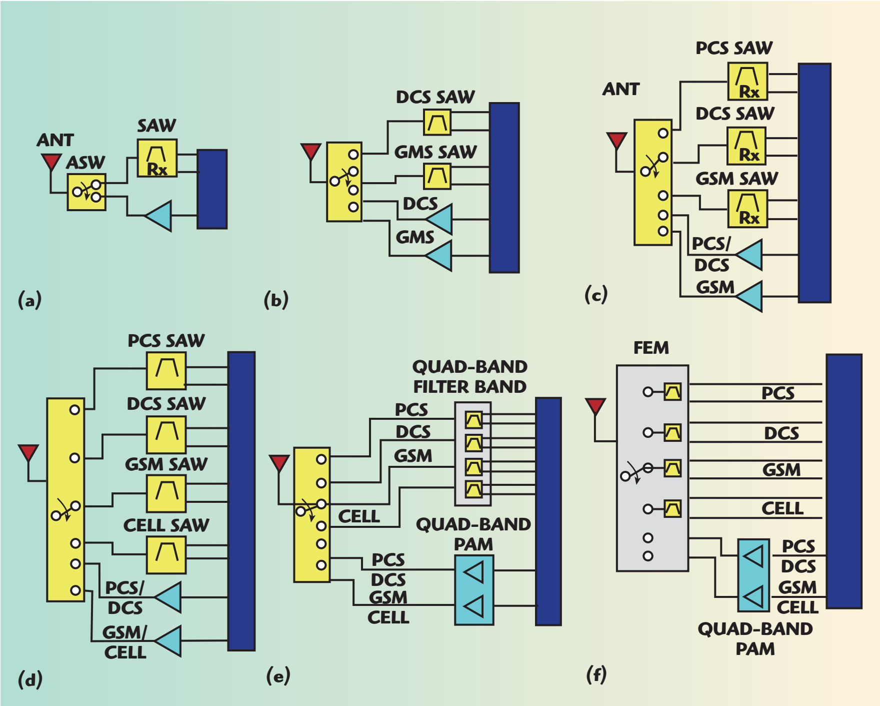
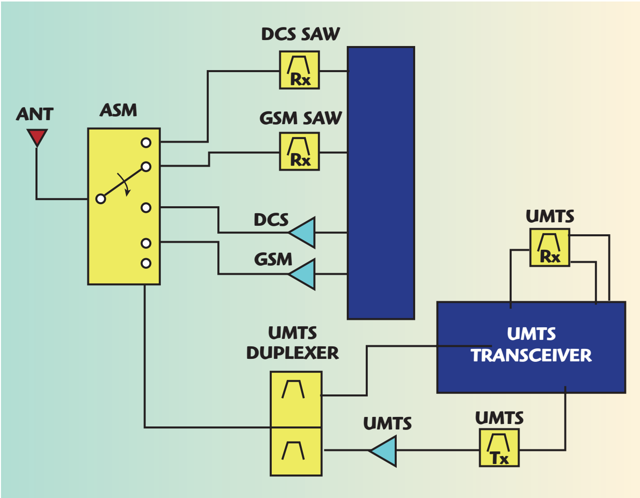


▲ *Fig. 5 FE diagram for (a) single, (b) dual, (c) triple, (d) quad band GSM;,(e) integrated FEM based on filter bank/PAM and (f) ASM/PAM.*

GSM platforms.

- PA-Duplexer Module: Mostly found in the iPhone 3G/3GS, Samsung Wave/Galaxy, Motorola's Droid, RIM's Bold, HTC's EVO and Huawei's WWAN Module/dongle. TriQuint believes that with the performance advantages and the flexibility that PA-Duplexer modules offer, this integrated solution will solve the large number of band combinations their customers have to provide while minimizing the use of board space. Yet, PA-Duplexer module shipments are expected to decrease as multi-mode PAs begin to ramp in the first half of 2011.
- Switch Duplexer Module (Antenna Switch and Duplexers): Nokia plans to expand adoption of this architecture for its multi-band handsets, which will likely entice other manufacturers.
- SFM and Duplexer Module (Switch filter module and Single Duplexer): This module is the level of integration expected for the future.



▲ *Fig. 6 UMTS and dual-band GSM handset front-end design.*

Table 2 lists the global suppliers of these various module types.

Figure 7 diagrams various ways in which integration has been adopted. For a single band UMTS/GSM phone, one common architecture will be based on partitioning around a Switch filter module, PA-Duplexer module (shown with single band UMTS) and dual band GSM PAs (see **Figure 8a**). On other occasions, the duplexer will be incorporated into the Switch Duplexer Module (see **Figure 8b**).

TABLE I
CONSTITUENT FUNCTIONS FOR FRONT-END MODULES[3]

FEMs \ Functions	Antenna Switch	TX LPF	Duplexer	BPF	PA
Antenna Switch Module	●	●	–	–	–
Switch Filter	●	●	–	●	–
Switch Duplexer Module	●	●	●	●	–
TX Module	●	●	–	–	●
Duplexer+PA Module	–	–	●	▲	●

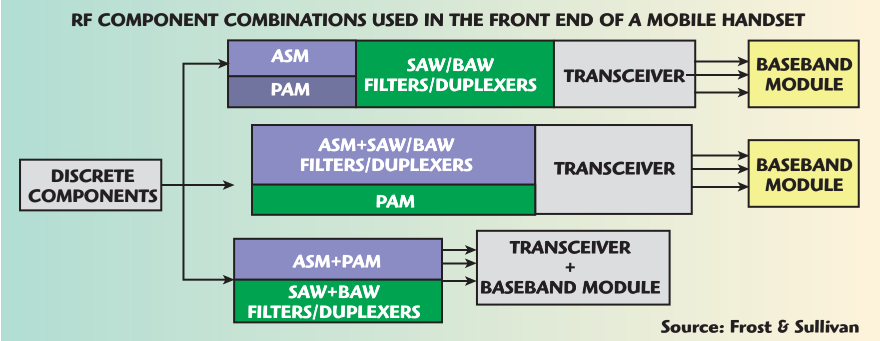
● *Required Functionality* ▲ *Optional* – *Not present*

TABLE II
RF MODULE MANUFACTURERS

Manufacturers \ RF Modules	ASM	SFM	TXM	DUP+PA	Switch Duplexer	Filter Bank	Transceiver Module
ANADIGICS			●	●			
Avago				●	●		
FMD*				●		●	
Freescale			●				
HITACHI MEDIA		●			●	●	
HITACHI METALS	●	●			●		
IM Tech	●						
KYOCERA	●	●					
MURATA	●	●	●	●	●	●	●
NXP**			●				
Pilkor CND	●						
Qualcomm							●
Renesas			●				
RFMD	●	●	●	●	●		
Skyworks	●	●	●	●	●		
SONY	●						
STM**							●
TDK-EPC	●	●			●	●	
TriQuint	●	●	●	●	●		
RDA Microelectronics			●				

**FMD-Fujitsu Media Devices; **Merged wih ST-Ericsson(Q1-2009)*
Courtesy of Navian Inc.

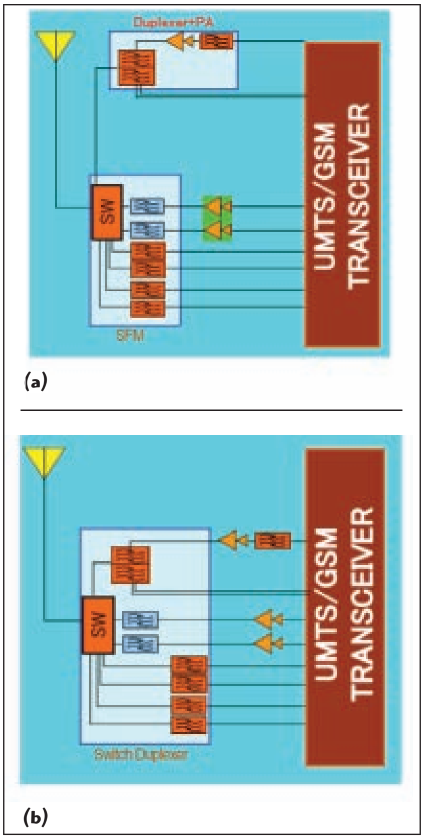
The multi-duplexer module is an attractive front-end configuration for multi-band UMTS/GSM terminals due to the adoption of multi-band, multi-mode PAs among the top tier handset OEMs. ***Figure 9a*** shows the high and low band PAs (two pairs supporting UMTS and GSM) as separate modules from the narrow band filter/duplexer switch module, which toggles between bands (UMTS) and modes (UMTS/GSM). The tri-band UMTS configuration shown could be expanded through module development to support more bands (via additional duplexers and higher throw switching). However, given the addional distribution switch required to route the duplexers, the PAE will degrade, requiring additional current. If required, 4G phone support is achieved with an additional, dedicated LTE PA-Duplexer Module and separate antenna.



▲ *Fig. 7 Different ways in which integration has been adopted in the front end (does not necessarily represent the signal flow).*

An alternative configuration is based on PAs that are integrated with band specific duplexers for UMTS and a transmit module/filter bank combination (see ***Figure 9b***) or a switch filter module (see ***Figure 9c***) for GSM support. Using a GSM Tx Module with Rx filter bank and individual PA-Duplexer modules is an approach found in some Nokia phones and Samsung platforms (note: the Rx SAW filter and LNA are integrated into the UMTS/GSM transceiver), while the GSM Switch filter module, individual PA-Duplexer module and Rx filter bank is found in the iPhone 3G/3GS and certain phones from Samsung, LG and Huawei. As band support increases, stacking PA-duplexer modules becomes increasingly inefficient.

At issue will be the need to improve individual component performance within the multi-mode module solution while making the changes to the fundamental multi-band, multi-mode architecture so that it (the combination of PAs, filters, switches and signal paths) is more efficient and reduces redundancy. This is critical in order to cut size and cost, but can challenge performance if not approached systematically.

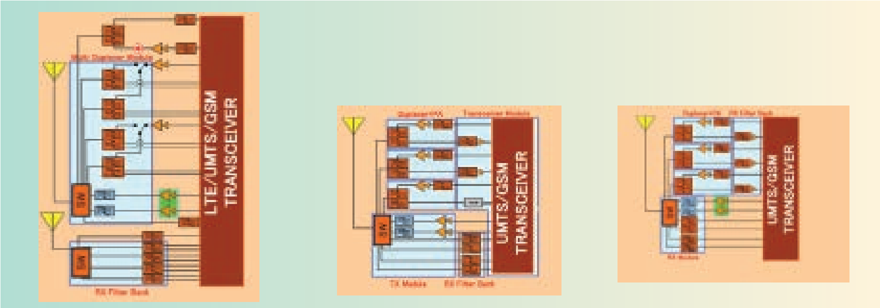


▲ *Fig. 8 Single band UMTS/GSM (backward compatible 3G entry phone) based on a Switch filter and PA-Duplexer module (a) and integrated RX/ Switch Duplexer module (b).*

THE PA MODULE

Leading GaAs PA manufacturers include RFMD, Skyworks, TriQuint, AVAGO, ANADIGICS and Renesas. Analysts report that Skyworks has a slight market share lead over RFMD with each company supplying more than a third of the world's handset PAs, followed by TriQuint supplying around 15 percent. Handset OEMs often use multiple suppliers. For example, Samsung uses W-CDMA PAs from TriQuint, RFMD and AVAGO, GSM/GPRS/EDGE PAs from RFMD, Skyworks and TriQuint, and AVAGO and ANADIGICS in its CDMA products. Likewise, LG uses PAs from Skyworks and TriQuint in its W-CDMA phones and Skyworks and RFMD in its GSM phones.

> "While handset OEMs today seldom rely on sole source suppliers, Waters (Skyworks) predicts that in the next decade, sole sourcing will become much more frequent as complex solutions and scale of R&D lead to high barriers of entry."



▲ *Fig. 9 Three different FEM configurations for multi-band UMTS/GSM support (courtesy of Navian Inc.).*

"Our (Skyworks) handset customers place a high value on architectures that help them to reduce size and help them resolve noise problems in many applications. In many cases, they are looking to reduce the bill of material complexity and otherwise, enable their competitive differentiation. We have been capitalizing on the increase in handset front-end module content, leveraging our in-house building blocks to produce cost-effective solutions that help decrease the handset manufacturers overall bill of material costs. Because of the complexity, the competitive landscape is narrowing with fewer and fewer suppliers able to support both the technical requirements and the manufacturing scale required by the leading handset OEMs." At this point, Skyworks reports that the company is supporting all five top tier handset OEMs as well as all key Smartphone suppliers and was first (early 2009) to introduce a family of power amplifiers and front-end modules (FEM) for 4G, long-term evolution (LTE) applications, supporting 13 bands.

"With front-ends supporting an increasing number of bands and modes, there is a trend toward using converged multi-mode, multi-band PA modules, rather than having redundant PAs for each band specific signal path (due to the BPF) in the Tx module. Companies with multi-mode, multi-band PA module portfolios and meaningful market positions in GPRS, EDGE and W-CDMA should do well as this market trends plays out," stated RFMD.

Creviston explained the dynamics impacting the entire industry. "There exists a highly integrated 2G backbone with quad-band EDGE plus the TR switch in one box that has been driven up the maturity curve pretty high because of all the volume on the 2G side. But then with 3G, handset manufacturers stacked discrete power amplifiers and duplexers for each band, which made perfect sense when there was only one band of UMTS and was still manageable as dual-band. But inside today's Smartphones, with support for 4 or 5 UMTS bands stacked up next to 2G, the solution is no longer a bolt-on, it's becoming a majority of the content. It calls for a different way of thinking about it and so leaders in this industry began to look at breaking that switch out because it's band-specific, routing

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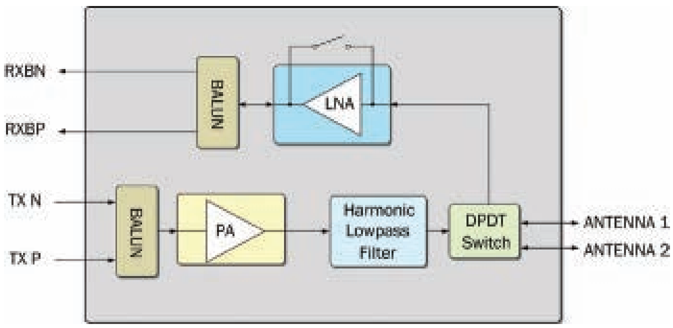
SPECIFICATIONS

Freq Range (Min) (MHz)	*Freq Range (Max) (MHz)*	*PA Gain (dB)*	*P_{OUT} (dBm)*	*OP1dB (dBm)*	*V_{CC} (V)*	*PA I_{CC} (mA)*	*LNA Gain (dB)*	*NF (dB)*	*LNA I_{CC} (mA)*	*Switch*	*Package (mm)*	*Part Number*
2400	2500	28.0	22.0	22.0	3.6	200	11.5	2.5	8	DPDT	QFN 3.5 x 3.5	RF6525

RF6525 block diagram



FEATURES

- Transmit output power: 22 dBm
- Transmit gain: 28 dB
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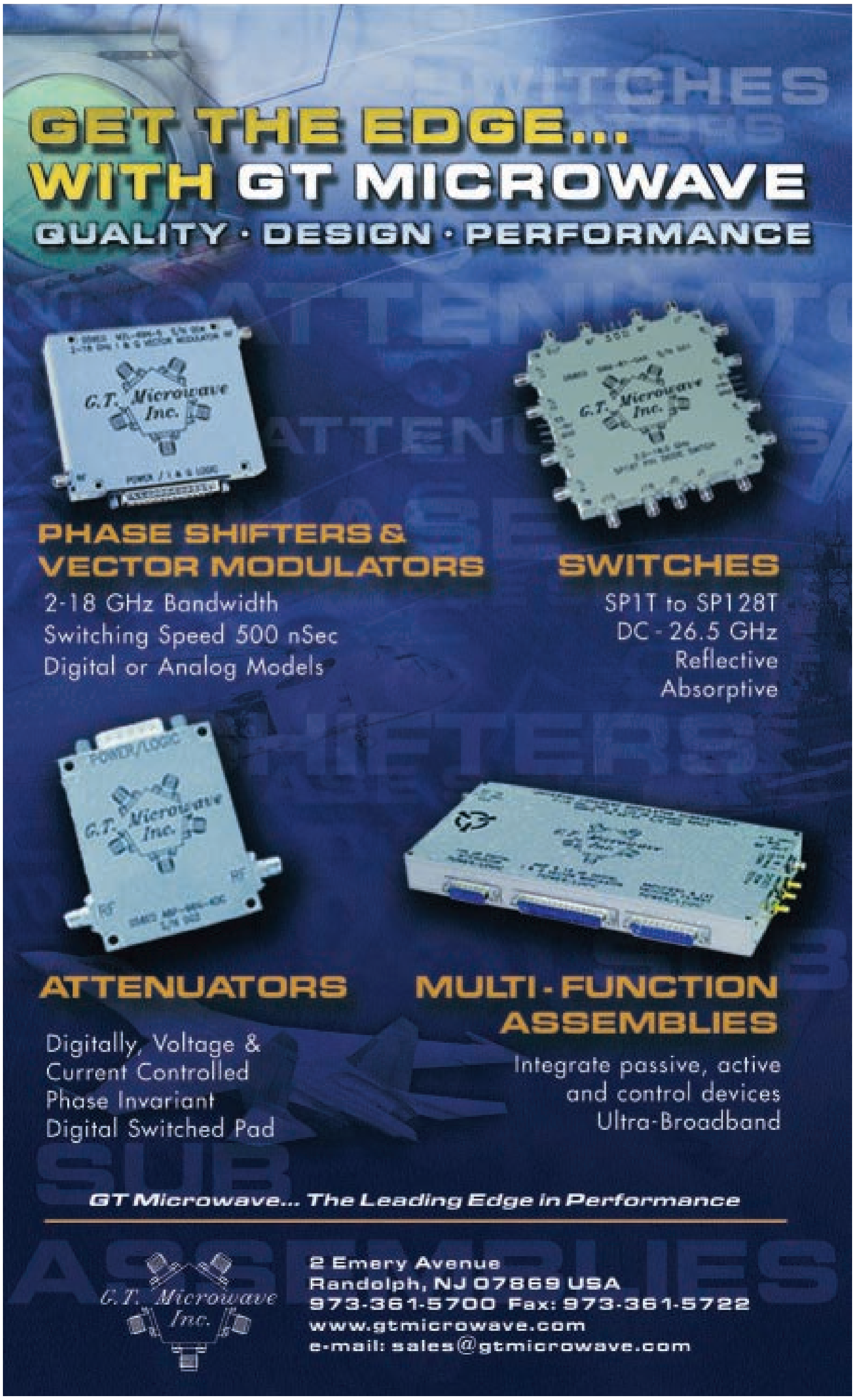
that signal through a specific duplexer and filter network. What's not band-specific are the power amplifiers because they can be made broadband, and the power management associated with the front-end is also band independent. This is where the need for the multi-band, multi-mode power amplifier comes from. For example, handset OEMs require effective power management to optimize handset energy consumption while maintaining signal quality. Traditionally, PAs have been two-state GaAs devices, switching the current between high and low power levels. RFMD has implemented patent-pending DC-DC conversion technology to dynamically control PA operating conditions, maximizing efficiency across power levels, across data rates and during non-ideal load conditions, quickly responding to load and line transients."

RFMD is addressing the multi-mode, multi-band trend with its Power-Smart™ power platform. This reflects the company's drive to integrate all RF functionality into two module placements for multi-mode, multi-band 3G/4G segments and a single module placement for all entry level phones. The two module placements are partitioned along the RF configurable power core, which includes PA, PA power management and RF mode switching and Antenna Switch, Switch Filter and Switch Duplexer Modules, which integrate all switching and filtering into a single placement.



Skyworks has also developed multi-mode PA modules for next-generation Smartphones with the release of its SKY776XX product family. Waters discussed how these new multi-mode and multi-band PA modules meet the need for increased frequency bands while reducing board space by integrating the functionality of multiple discrete PAs into a single package. These devices have been designed to operate efficiently in quad band GPRS and EDGE, and support bands 1, 2, 5 and 8 for W-CDMA and HSUPA modulation. These PA modules have been designed for improved performance under mismatch conditions and have reduced current consumption over the entire power range of the handset. The company's custom BiCMOS controller and interface IC provides the integrated (accurate and fast closed loop circuitry) power amplifier control function, called iPAC™, using a low power control slope. Other innovative technology cited by Waters includes their developments in merged HBT-FET (BiFET) devices, copper backside process, and stacked die and flipped chip technologies.

Likewise TriQuint is developing a scalable 3G/4G converged RF architecture for multi-mode, multi-band mobile devices by converging functionality into one PA module, a move that should offer up to a 50 percent size reduction over today's discrete approach. The TriQuint Unified Mobile Front-end (TRIUMF) is architected to support numerous frequency bands and air interfaces used in 3G mobile devices supporting modes like GSM/GPRS/EDGE for voice and lower-data-rate applications and W-CDMA/HSPA/LTE for high-speed data. On the multi-band side, it will handle traditional quad bands (GSM850/900/DCS1800/PCS1900)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unified with options for 3GPP-designated bands 1 through 17. In doing so, it will enable worldwide W-CDMA/HSPA/LTE coverage. In addition, TriQuint's power amplifier modules utilize the combination of a BiHEMT process for higher integration, and performance and proven flip-chip technology that enhances their devices' thermal characteristics.

TriQuint reports that they have been able to simplify the RF front-end while reducing size through a multi-mode module solution using a converged PAM for the traditional bands and PA-Duplexers Modules for LTE. Quinsey commented that their proprietary design techniques have an advantage in that they do not compromise current consumption when compared to today's discrete architectures.

AVAGO improves power efficiency in the low output power range with an active bypass PA technology called CoolPAM, while ANADIGICS' High-Efficiency-at-Low-Power (HELP) technology uses an integrated pHEMT switch based on its BiFET InGaP processes to allow different amplifier chains to be chosen in the PA, depending on the output power required. AVAGO has plans to develop multi-mode, multi-band PA structures and is working toward that approach.

THE SWITCH

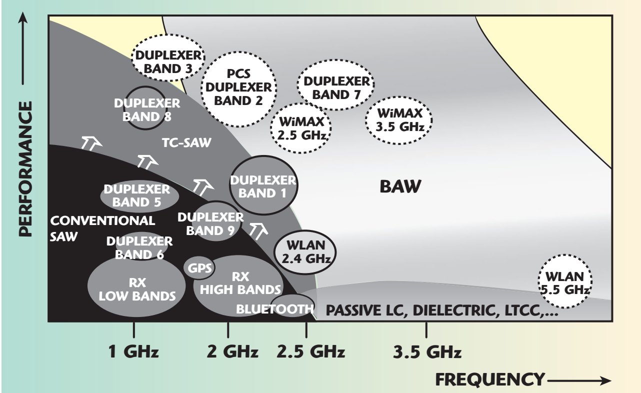
In multi-band, multi-mode handsets where different RF paths are required for the appropriate filtering and amplification of the signal, the RF switch is required to provide access to the shared antenna. The RF switch must be capable of switching up to 15 paths of high-power RF signals between different duplexers (and GSM filter-paths). Performance-wise, the switch must have low insertion loss (so as not to degrade the effective PAE of the PA), high isolation (to prevent leakage across channels) and exceptional linearity (it is generally agreed that the switch needs an IP3 of better than +65 dBm).

While a PIN diode switch has very low insertion loss and harmonic distortion, a multi-throw PIN diode switch requires quarter-wave transmission lines that make them unacceptably large for today's applications. GaAs PHEMT switches dominate today's market share, but have low ESD tolerance and need additional decoding and DC-blocking circuitry.

TriQuint leverages its unique E/D pHEMT process to address the demanding performance requirements of 3G switches where insertion loss, linearity and harmonics must be optimized.

RF CMOS is making inroads into front-end modules, either as bulk CMOS and silicon-on-insulator (SOI) or silicon-on-sapphire (SOS). RFMD's RF CMOS switches use high-resistivity silicon substrates from a leading foundry to meet or exceed the stringent linearity and isolation requirements for 3G and 4G Smartphones, while providing excellent ESD performance (HBM data rated at 2000 V). By integrating the controller and RF switch, the company has been able to improve performance while reducing size and cost.

Skyworks also employs multiple generations of HEMT material as well as 0.25 μm SOS and 01.3/0.18 μm RF CMOS on SOI for its switches. The company offers a family of GaAs and SOI antenna switch modules for 2/3/4G handsets, including a



▲ *Fig. 10 Application space for RF filters[6] (courtesy of Artech House).*

single pole ten throw CMOS switch that supports five 3/4G transmit-receive ports, three receive ports and two GSM transmit paths with LPF.

FILTER/DUPLEXER TECHNOLOGY

RFMD and Skyworks both obtain filter/duplexer technology from multiple leading sources (Murato and TDK Epcos, Panasonic, Taiyo Yuden and AVAGO), allowing them to optimize performance for a given application. RFMD does not participate in the discrete market since duplexers are mostly becoming integrated into switch duplexer and PA-duplexer modules. Both companies state that this approach (buying filter/Duplexers) allows them to select the best filter technology available and integrate it into their products.

Taking a different position, TriQuint believes it can best achieve the same objective with its own in-house development of filter technology. Quinsey sees TriQuint's filter technology as a significant differentiator for his company. "As you transition from 2G to 3G, from voice to data, duplexers become very important because it becomes a frequency domain duplex market as opposed to time domain based on switches. The market for 3G and 4G duplexers is going to be billions of dollars in the future. Other front-end suppliers buy duplexers and integrate them into modules, whereas we custom design our building block for each integrated module using in-house technology such as SAW, TC-SAW (temperature compensated) and BAW duplexers, switching and power technology. This enables us to create highly integrated modules and long-term roadmaps, focused on integration and performance, size and cost."

Receive filters are typically based on surface acoustic wave (SAW) technology and implemented in single-end to balanced topology for better receiver sensitivity and dynamic range. They are designed with three basic topologies: the ladder filter for low pass-band insertion loss, the coupled resonator filter (CRF) for high out-of-band rejection, and hybrid forms combining ladder and CRF elements.

SAW technology dominates the cellular-band duplexer market, while bulk acoustic wave (BAW) duplexers based on film bulk acoustic resonator (FBAR) and solidly mounted resonator (SMR) technologies dominate in PCS band duplexers as well as the PCS inter-stage transmitter BPFs. A BAW resonator has a higher quality factor (Q) than a SAW resonator near and above 2 GHz, which

results in lower insertion loss and a steeper filter skirt. BAW resonators also exhibit better thermal stability, superior ESD robustness and better power handling capability compared to a typical SAW resonator; however, at lower frequencies, SAW filter performance is more than sufficient for handset applications, where its maturity and commodity pricing give it the advantage (see ***Figure 10***).

RF SAW filter packages and assembly processes have evolved through three major generations in recent years: chip & wire, flip-chip and chip-scale package (CSP). The CSP generation is considerably more complicated, which has led to diverse manufacturing solutions. The only common threads among major SAW suppliers remain footprints, pin-outs and the hermeticity requirement. Currently, all major SAW suppliers are developing "packageless SAW" through wafer-level packaging (WLP), including Murata, AVAGO, TriQuint, etc. Multi-band and multi-mode support will require larger quantities of both to be integrated into filter or duplexer banks if not directly into front-end modules using flip-chip technology and WLP.

CONCLUSION

Driven by global demand for 2G/3G entry phones, a strong smart phone market and M2M communications, the economic outlook for suppliers of RF FEMs for mobile devices is very promising. Supporting multiple bands and standards have allowed suppliers to increase the RF dollar content of their solutions provided they have the R&D scale to meet the engineering challenges. Each major player is developing technologies ranging from flip-chip, copper metallization, devices (HBT, PHEMT, RF CMOS, BiFET, BiHEMT, etc.), packaging and architecture that will help them achieve better performance at reduced size and cost. The good news for RF engineers is that all three executives recognized the absolute necessity of having talented technologists on staff and were very vocal about their efforts to recruit and retain them. For more comments from RFMD, Skyworks and TriQuint on how these companies are approaching the engineering challenges for tomorrow's mobile device front-ends, go to www.mwjournal.com/mobile_FEM_2010. ■

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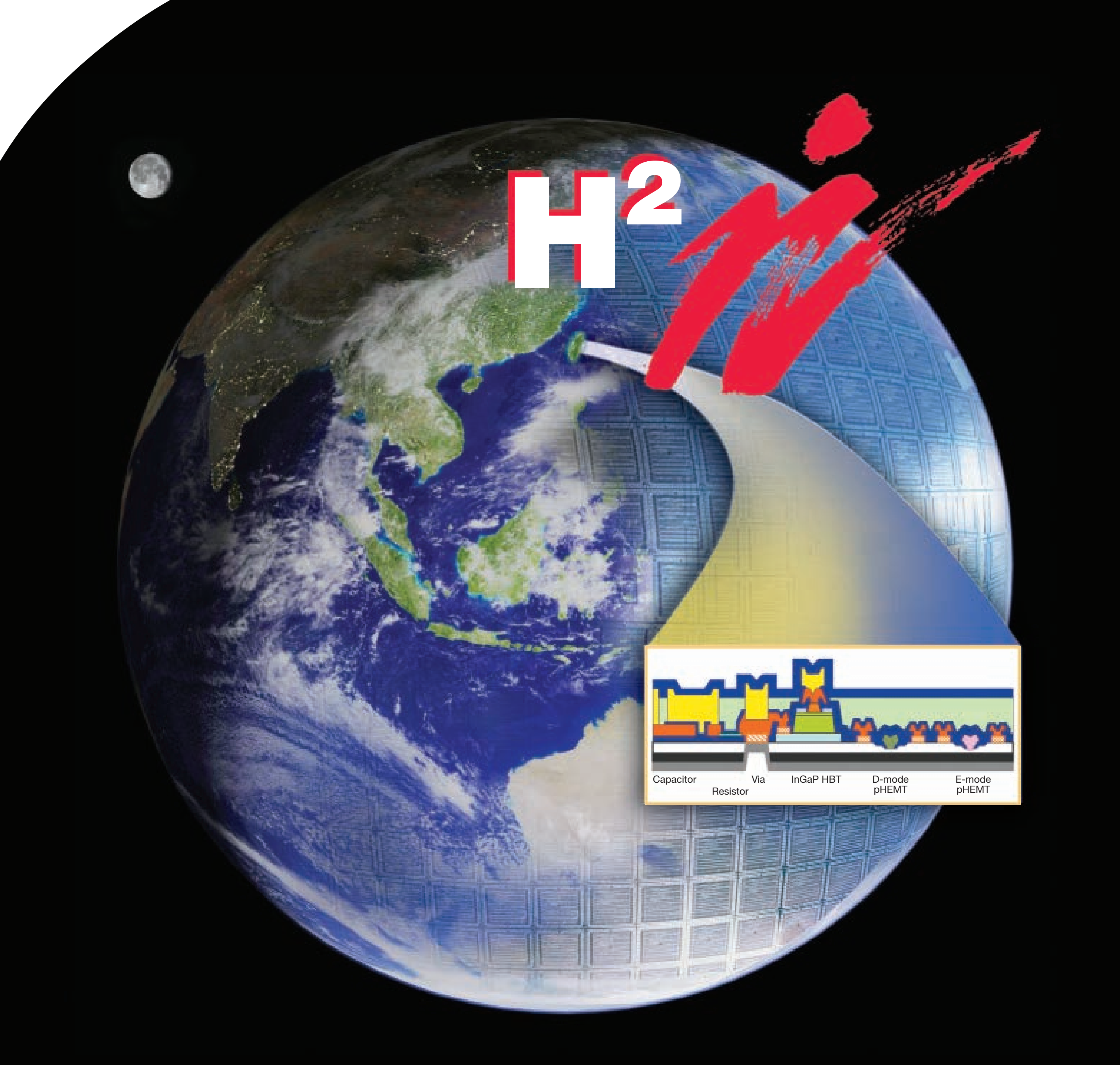
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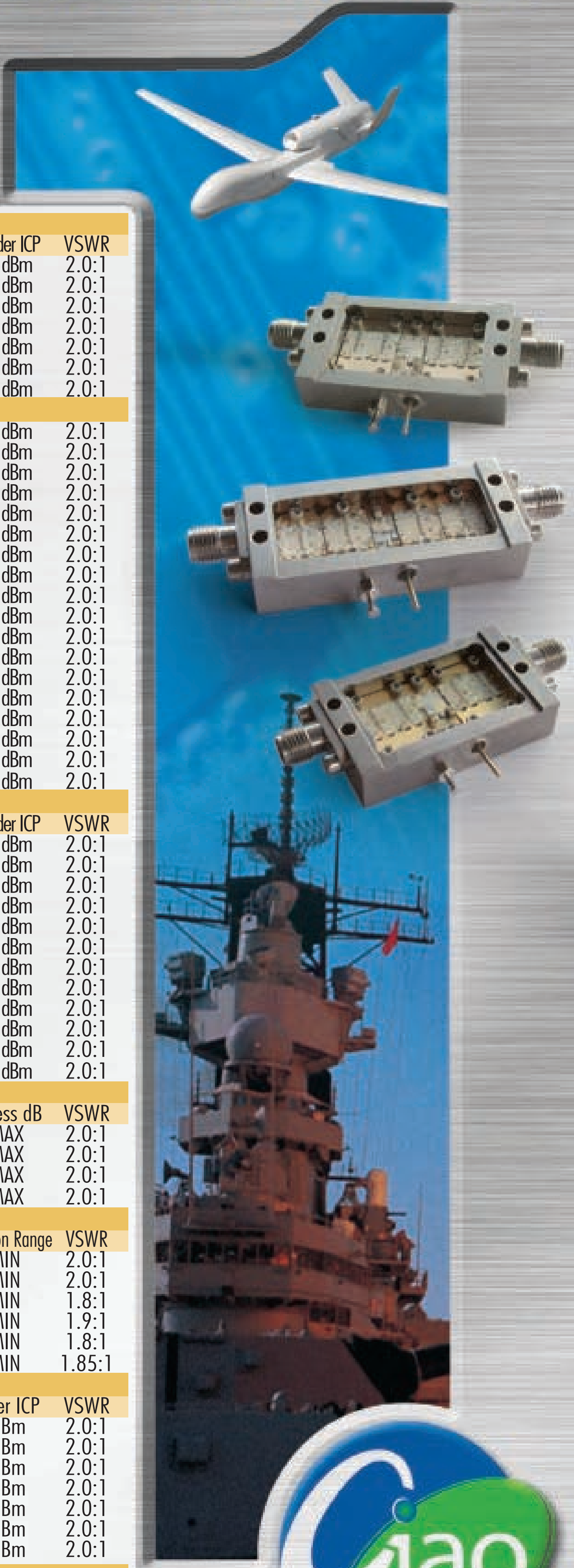

OCTAVE BAND LOW NOISE AMPLIFIERS

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB)	Power-out @ P1-dB	3rd Order ICP	VSWR
CA01-2110	0.5-1.0	28	1.0 MAX, 0.7 TYP	+10 MIN	+20 dBm	2.0:1
CA12-2110	1.0-2.0	30	1.0 MAX, 0.7 TYP	+10 MIN	+20 dBm	2.0:1
CA24-2111	2.0-4.0	29	1.1 MAX, 0.95 TYP	+10 MIN	+20 dBm	2.0:1
CA48-2111	4.0-8.0	29	1.3 MAX, 1.0 TYP	+10 MIN	+20 dBm	2.0:1
CA812-3111	8.0-12.0	27	1.6 MAX, 1.4 TYP	+10 MIN	+20 dBm	2.0:1
CA1218-4111	12.0-18.0	25	1.9 MAX, 1.7 TYP	+10 MIN	+20 dBm	2.0:1
CA1826-2110	18.0-26.5	32	3.0 MAX, 2.5 TYP	+10 MIN	+20 dBm	2.0:1

NARROW BAND LOW NOISE AND MEDIUM POWER AMPLIFIERS

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB)	Power-out @ P1-dB	3rd Order ICP	VSWR
CA01-2111	0.4 - 0.5	28	0.6 MAX, 0.4 TYP	+10 MIN	+20 dBm	2.0:1
CA01-2113	0.8 - 1.0	28	0.6 MAX, 0.4 TYP	+10 MIN	+20 dBm	2.0:1
CA12-3117	1.2 - 1.6	25	0.6 MAX, 0.4 TYP	+10 MIN	+20 dBm	2.0:1
CA23-3111	2.2 - 2.4	30	0.6 MAX, 0.45 TYP	+10 MIN	+20 dBm	2.0:1
CA23-3116	2.7 - 2.9	29	0.7 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA34-2110	3.7 - 4.2	28	1.0 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA56-3110	5.4 - 5.9	40	1.0 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA78-4110	7.25 - 7.75	32	1.2 MAX, 1.0 TYP	+10 MIN	+20 dBm	2.0:1
CA910-3110	9.0 - 10.6	25	1.4 MAX, 1.2 TYP	+10 MIN	+20 dBm	2.0:1
CA1315-3110	13.75 - 15.4	25	1.6 MAX, 1.4 TYP	+10 MIN	+20 dBm	2.0:1
CA12-3114	1.35 - 1.85	30	4.0 MAX, 3.0 TYP	+33 MIN	+41 dBm	2.0:1
CA34-6116	3.1 - 3.5	40	4.5 MAX, 3.5 TYP	+35 MIN	+43 dBm	2.0:1
CA56-5114	5.9 - 6.4	30	5.0 MAX, 4.0 TYP	+30 MIN	+40 dBm	2.0:1
CA812-6115	8.0 - 12.0	30	4.5 MAX, 3.5 TYP	+30 MIN	+40 dBm	2.0:1
CA812-6116	8.0 - 12.0	30	5.0 MAX, 4.0 TYP	+33 MIN	+41 dBm	2.0:1
CA1213-7110	12.2 - 13.25	28	6.0 MAX, 5.5 TYP	+33 MIN	+42 dBm	2.0:1
CA1415-7110	14.0 - 15.0	30	5.0 MAX, 4.0 TYP	+30 MIN	+40 dBm	2.0:1
CA1722-4110	17.0 - 22.0	25	3.5 MAX, 2.8 TYP	+21 MIN	+31 dBm	2.0:1

ULTRA-BROADBAND & MULTI-OCTAVE BAND AMPLIFIERS

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

LIMITING AMPLIFIERS

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

AMPLIFIERS WITH INTEGRATED GAIN ATTENUATION

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

LOW FREQUENCY AMPLIFIERS

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

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MarketWatch

While work is ongoing on GaN and SiC technologies, Strategy Analytics predicts that GaAs will continue to represent the primary compound semiconductor technology for defense markets through 2014. The focus for GaAs MMIC utilization in the military market is on communications, RADAR and smart munitions; Strategy Analytics expects the market for GaAs devices to see continued growth at a CAAGR of 6 percent through to 2014.

The next generation of military tactical radios will serve as nodes and hubs in mobile, ad hoc networks, which will connect ground-based, sea and airborne assets. Achieving this requires changes in radio architecture that will profoundly impact future electronic component demand from this defense sector. Strategy Analytics hosted a 40-minute complementary webinar on September 1 (see www.strategyanalytics.com for further details) to present an overview of the trends in this market.

As well as tactical radios, a desire for higher bandwidth and networking capabilities in Military Satellite Communications (MilSatCom) is creating new opportunities for advanced electronic components. Strategy Analytics, in conjunction with *Microwave Journal*, will be holding a webinar on October 26. See www.mwjournal.com/milsatcom_webinar for further details. Strategy Analytics will also be at this year's MILCOM 2010 in San Jose, CA. Contact Asif Anwar at aanwar@strategyanalytics.com if interested in arranging a meeting at MILCOM 2010.

Strong Growth Ahead for Military Airborne Radio Semiconductor Market

Representing a growing market for communications electronics, unmanned aerial vehicles (UAV) will be the fastest growing category of airborne platforms. The Strategy Analytics Advanced Defense Services (ADS) forecast model, "Airborne Communications Platforms - Advanced Electronics Component Forecast," concludes that with the number of airborne platforms growing and increasingly sophisticated communication requirements, there will be steady growth in the market for military airborne communications systems through 2020.

...there will be steady growth in the market for military airborne communications systems through 2020.

The fighter plane category will continue to represent the largest category of airborne platforms driving demand for communications systems and the subsequent electronics components. The overall military airborne communications market is projected to grow at a 4 percent CAAGR over the next decade to reach nearly $1 B. Driven by multi-band and higher frequency radio requirements, the electronics content of the radio is forecast to grow at a slightly higher CAAGR of 5 percent to reach $167 M in 2020.

This forecast data model details dynamics for airborne communications systems related to military airborne platforms. The total communications systems market is sized and segmented by geography, airborne platform and system function. Further quantitative analysis details the electronics, functional components and primary semiconductor technologies that will underpin future communications systems used on military airborne platforms through 2020.

TASC Implements 3-D RFID Asset Management System for US Navy

A new inventory management system developed by TASC Inc. for the US Navy will allow Naval warehousing facilities to automatically count and locate RFID-tagged inventory in real time. The software platform integrates a radio frequency identification (RFID) system with an inventory management system. "Good asset management is essential to the military supply chain, and this system is essentially 'spell-check' for inventory control," said Pat Talty, Mission Engineering Vice President at TASC. "The system will identify the shipment of the wrong items, or, if an item is misplaced, show you exactly where in the warehouse you can find it."

"Good asset management is essential to the military supply chain..."

Using a passive Radio Frequency (pRFID) Real Time Location System (RTLS), the solution automatically inventories stock count and locations for reconciliation. From automatic stock count and location queries, users receive real-time inventory reports and a three-dimensional graphical presentation of items' location in the warehouse. With the TASC system, users can resolve any discrepancies caused by human error and maintain a higher level of accuracy for both physical stock and database records.

Lockheed Martin and Raytheon Partner for GMD Development and Sustainment Contract

Lockheed Martin and Raytheon Co. announced that they are partnering to pursue the US Missile Defense Agency's Ground-based Midcourse Defense (GMD) Development and Sustainment Contract. Together, Lock-

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"Lockheed Martin and Raytheon systems combined have achieved more than 50 intercepts in combat and testing..."

heed Martin and Raytheon develop, produce and sustain interceptor weapon systems for missile defense. As strategic partners for GMD Development and Sustainment, the companies will apply their proven experience to ensure the reliability and readiness of the GMD element of the Ballistic Missile Defense System, which defends our nation, deployed military forces, and friends and allies against a limited attack by intermediate- and long-range ballistic missiles.

"Lockheed Martin and Raytheon are continuing a successful track record of delivering on key missile defense programs," said Mathew J. Joyce, GMD Vice President and Program Manager, Lockheed Martin Space Systems Co. "Lockheed Martin and Raytheon systems combined have achieved more than 50 intercepts in combat and testing —more than any other team." These systems include Terminal High Altitude Area Defense, Aegis Ballistic Missile Defense including Standard Missile-3, Patriot and Patriot Advanced Capability-3, and GMD Exoatmospheric Kill Vehicle.

Harris Awarded Antenna Contract

Harris Corp. has been selected to provide the ground antenna system for a National Oceanic and Atmospheric Administration (NOAA) program that will enable receipt and processing of weather data 40 times faster than today, as well as delivery of weather images directly to end users.

Under the 10-year, $130 M contract, Harris and its teammates—General Dynamics SATCOM Technologies and ARES—will supply antennas and control systems for NOAA's Geostationary Operational Environmental Satellite Series-R (GOES-R) program. The antennas will provide communications links for command, telemetry and sensor data, as well as the communications link to direct data users. The contract includes design, fabrication and testing of six new 16.4-meter antennas and upgrading four 9.1-meter antennas. The 16.4-meter antennas will be installed at the NOAA Wallops Command and Data Acquisition Station in Wallops, VA, and a remote backup site in Fairmont, WV. The new antennas will be built to withstand sustained winds of 110 mph and gusts of up to 140 mph. Upgrade of the 9.1-meter antennas will take place at the NOAA Satellite Operations Facility in Suitland, MD. The new antennas will operate with next-generation GOES-R satellites and will be compatible with existing GOES-N through GOES-P satellites. The antennas are designed to operate continuously for the life of the GOES-R program.


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Study Addresses European Military Aerospace Development

A Future Air System for Europe (FAS4Europe) study titled, "The Future of the European Military Aerospace Defence Technological Industrial Base (DTIB)—MilAerospace 2035+," will consider the industrial and technological base of future European military aerospace. Led by Saab, the one-year study will identify and propose the collaborative actions governments need to take to safeguard Europe's ability to independently provide competitive aerospace solutions to meet the Common Security and Defence Policy (CSDP) capability requirements in the 2035 timeframe.

> *. . . collaborative actions governments need to take to safeguard Europe's ability to independently provide competitive aerospace solutions . . .*

The study is part of EDA European Defence Technological and Industrial Base Strategy and its main aims are to prepare an initial roadmap identifying the key industrial capabilities in the EDTIB and then formulate an implementation plan for the next ten years with prioritized actions.

The study result will support the EDA participating Member States decision making on the future capability development for military aerospace systems and will underpin the necessary common European approach to the aerospace DTIB.

Lennart Sindahl, Senior Vice President Saab AB and head of business area Aeronautics, commented, "Saab is very honoured to be the company to lead this study, representing a major part of the European Aeronautic Industry. It is very encouraging that EDA has launched this important strategic study regarding our challenging joint future regarding European FAS capabilities. We appreciate the engagement the stakeholder community has shown in supporting our proposal. The study will be very broad and include several workshops involving relevant stakeholders to ensure to get the appropriate input for the analysis and final report."

UK Government to Revolutionise Digital Infrastructure

The UK is set to benefit from a new generation of wireless services and improved mobile broadband coverage under new government plans to revolutionise the country's digital infrastructure. The programme of measures for radio spectrum modernisation will allow mobile operators to deliver the latest technologies to consumers and extend the reach of mobile broadband across the country.

> *". . . our mobile industry will have access to the 21st Century infrastructure it needs. . ."*

The spectrum modernisation programme will be implemented under a Direction to regulator OFCOM. The new Direction requires OFCOM to co-ordinate a combined auction of 2.6 GHz and 800 MHz spectrum as soon as possible in order that operators can deliver widespread high speed mobile broadband. It also tasks OFCOM with carrying out a competitive assessment of future 3G and 4G markets, including the potential for new entrants. Their assessment will inform the design of the auction, aimed at enabling delivery of new competitive mobile broadband services for UK consumer and business benefit.

Announcing the initiative the UK Minister for Communications, Ed Vaizey, commented, "The past 20 years has seen a revolution in mobile technologies and devices that have transformed the way we communicate, learn and do business. We want the UK market to remain at the fore of delivering devices like the iPad and smart phones but they need the networks to continue to improve and increase services."

He continued, "Under our plans, our mobile industry will have access to the 21st Century infrastructure it needs to give UK consumers the latest technologies and even better coverage for broadband on their mobile phones."

European Project on Integrated Electronic System-in-Package Solutions

The largest research project in Europe to research and develop highly integrated electronic system-in-package solutions has been launched. Working together on the Efficient Silicon Multi-Chip System-in-Package Integration (ESiP) project are 40 microelectronics companies and research institutions from a total of nine European countries, with the aim of making miniaturized complex microelectronics systems more reliable and testable.

> *. . . ESiP project should put Europe in a leading position in the development and manufacture of miniaturized microelectronics systems. . .*

Under the leadership of Infineon Technologies the research project will run until April 2013. The company's contribution to the ESiP project is to further develop system integration solutions comprising several microchips and improve them in terms of failure analysis, reliability and testability.

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The results of the ESiP project should put Europe in a leading position in the development and manufacture of miniaturized microelectronics systems. In the future, several chips with different production techniques and structure widths will be integrated in a standard chip package for more and more applications.

With a total budget of €35 M, the aim of ESiP is to investigate the reliability of new production processes and materials required to build a System-in-Package (SiP). The project will also involve developing new methods for error analysis and testing. The results of the ESiP project will in the future be used in communication technology devices, medical equipment and electric vehicles.

NGMN Alliance and TM Forum Sign Next Generation Network Agreement

The Next Generation Mobile Networks (NGMN) Alliance and the TM Forum have signed a co-operation agreement to work together on optimized management systems and operations of the next generation of mobile networks. The co-operation between the two organizations will facilitate the delivery of solutions that directly address the operator needs in managing these networks.

The two organisations have agreed to work together on Operational Efficiency enhancements for next generation multi-technology networks in this joint project. Its key aims are to: define deliverables and timelines within the TM Forum to support the NGMN Operations Requirements for next generation mobile networks; address the wireless-wireline convergence aspects of the operational requirements; and under the umbrella of NGMN, achieve collaboration with other standards forums, e.g. 3GPP, in the area of NGMN Operations Requirements for next generation multi-technology networks.

"…scalability and customer satisfaction will be the keys to monetization of the network."

"Self-optimising capabilities and standardized O&M systems are essential for the successful operations of next generation mobile networks," said Peter Meissner, Operating Officer of the NGMN Alliance. "We will work together with the TM Forum to ensure broad, industry-wide support and adoption of NGMN's requirements and use-cases in those areas for the benefit of the whole industry."

"With widespread broadband service all the way to the handset as next generation mobile networks will provide, scalability and customer satisfaction will be the keys to monetization of the network," said Keith Willetts, Chairman of the TM Forum. "Working with the NGMN Alliance will provide us with an invaluable set of requirements firsthand so that the standards that will enable cost effective and flexible operating environment are ready for the market, when the market needs them."

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Dan Massé, Associate Technical Editor

Wireless Sensor Networks and RFID in Asia

Governments in Asia have been strongly advocating RFID in all its forms—from passive RFID tags to tags with a battery or energy harvester that can be used to create Wireless Sensor Networks (WSN), including mesh networks.

China will eventually become the biggest market for RFID. Indicators of this are as follows: In the last two years most new RFID manufacture capacity has been installed in China; the Chinese Government is a strong advocate for RFID, and has the power to mandate companies to use it. China has already executed the largest RFID order by value (over one billion national identification cards for adults—six billion US dollars including systems) and has a policy of making its own requirements throughout the RFID value chain. Most products will be source tagged, and because China is one of the largest exporters the tags will be supplied there. Many companies in the West are manufacturing passive tags in Asia today. In addition, Chinese companies such as Invengo are now successful global providers of RFID hardware.

China will eventually become the biggest market for RFID.

Tags with batteries—known as Active RFID—are used for longer read range applications and where more functionality is required, such as multiple sensor inputs. The fastest areas of growth are Real Time Locating Systems (RTLS) and Wireless Sensor Networks (WSN). The US is most active, followed by Korea. Only Korea has a nationally coordinated program directed at the future of WSN. East Asia will become a more important territory for WSN in the years to come, with Japan and Hong Kong using wireless sensors today to monitor pollution from traffic.

For mesh (self-organizing, self-healing) networks alone, applications have started with killer applications such as meter reading in buildings, growing to include automatically anticipating and monitoring forest fires, avalanches, hurricanes, failure of country wide utility equipment, traffic, hospitals and much more over wide areas. The market for this alone will grow rapidly from $0.48 B in 2010 to $2.75 B in 2020. Companies such as EnOcean and Dust Networks will present case studies and the huge savings that have been made by deploying wireless sensors.

Skyworks Maintains PA Share Lead

Exploring changes in the handset and cellular device power amplifier (PA) market brought about by the economic slowdown and contraction in cellphone shipments, Strategy Analytics released, "Skyworks Maintains Power Amp Share Lead," from the Strategy Analytics RF & Wireless Component market research service. This report analyzes the effect these changes will have on PA suppliers in 2010 and beyond. The rapid resurgence in handset production pushed the PA market to over $2.4 B in 2009, driving the two largest suppliers, Skyworks and RF Micro Devices. Skyworks held its number one position, led by success in GSM/GPRS/EDGE, while RFMD remained the leading supplier of W-CDMA PAs.

The rapid resurgence in handset production pushed the PA market to over $2.4 B in 2009...

"It is gratifying to see last year's prediction play out as the acquisition of CMOS PA supplier Axiom Micro Devices helped Skyworks maintain share in the recession-resistant low-cost segment of the market," commented Christopher Taylor, Director of the RF and Wireless Components service. "At the same time, demand for ultra low-cost and grey market GPRS handsets expanded rapidly, helping all vendors, but particularly boosting RDA Micro out of obscurity."

"Compound semiconductor-based PAs will continue as the enabling technology for the high-growth 3G and emerging 4G markets," observed Asif Anwar, Director of the Strategy Analytics GaAs and High Speed Semiconductor service.

Low Bands to Dominate in LTE Mobile Devices Through 2014

The Strategy Analytics RF & Wireless Components service report, "LTE Device & Band Scenarios," predicts that mobile devices with low-band (700 to 850 MHz) LTE capabilities will make up the largest segment of the LTE device market through 2014. This research, based on regional spectrum allocations and the plans of leading wireless operators, provides a baseline forecast through 2014 of LTE device shipments for the 12 most important E-UTRA LTE bands. The report is intended to provide product development guidance to suppliers of radio components (transceivers, PAs, filters, antennas) and other interested parties.

"Verizon and AT&T Mobility will be among the first to use the 700 MHz bands for LTE."

According to Christopher Taylor, Director of the RF & Wireless Components market research service and author of the report, "Verizon and AT&T Mobility will be among the first to use the 700 MHz bands for LTE. Most mobile operators prefer the lower bands for LTE (700 to 850 MHz) as these bands provide better range and indoor reception than higher frequency bands. Once operators es-

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tablish LTE coverage, they will add FD and TD capacity at the higher frequencies, in particular 2.3 and 2.6 GHz." Stephen Entwistle, VP of the Strategy Analytics Strategic Technologies Practice, added, "In many regions, regulatory authorities have not yet approved or auctioned bands suitable for LTE, but are expected to do so soon, which is considered in this forecast, which also covers LTE in bands refarmed from legacy GSM."

Handset Semiconductor Revenue to Increase

After four quarters of decline, the global mobile handset market began showing signs of life starting in 4Q 2009. ABI Research expects the trend to continue through the next five years.

According to Industry Analyst Celia Bo, "Due to the resurgence of the mobile handset market, the total revenue for handset semiconductors is forecast to increase about 4 percent this year. Major semiconductor components such as baseband processors and application processors, accounting for more than 60 percent of the revenue in this segment, are expected to show revenue increases of 3 and 8 percent respectively in 2010."

As well as the baseband processor, the application processor is another important component enabling mobile devices to deliver better performance, more reliable connectivity and longer battery life; today's chipsets are becoming ever more compact and competitive.

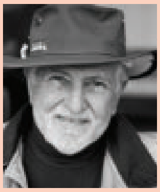
Qualcomm announced the dual core Snapdragon processor in June this year; it signaled a new era for technology architecture development, and the market is set to see some significant improvements in application processor performance and power consumption. In 2010, application processor shipments are forecast to increase significantly while ASPs drop.

In 2010, application processor shipments are forecast to increase significantly while ASPs drop.

"Connectivity chips will be key drivers of handset semiconductor market growth in the next five years," Bo notes. "Bluetooth has the highest attach rate: the average penetration rate is expected to be 57 percent in 2010. The penetration rate of GPS is expected to double between 2010 and 2015. Wi-Fi chips will deliver the highest revenue of the three connectivity chips over the next five years."

Jennifer DiMarco, Staff Editor

INDUSTRY NEWS



Harry Sidney Rutstein passed away on July 24, 2010. He lived in several cities, on both coasts, and explored hundreds of countries over his 80 years. Rutstein served in the army during the Korean War where he worked in Intelligence. Rutstein was a modern day Marco Polo and is the first person in history to have followed the route of Marco Polo over land and sea from Venice, Italy to Peking, China. He wrote books, articles and produced a film on his travels. Harry was the President of Dorado International Corp. of Seattle, a manufacturer of microwave components with factories in China and Russia. He was a former Vice President and founder of Nurad Inc., a microwave antenna company in Baltimore. Harry started his career as a research associate at the Radiation Laboratory of the Johns Hopkins University developing RF and microwave equipment. An author, a brother, a husband, a father, a grandfather, an entrepreneur, an explorer, a philosopher, and an inspiration to many, Harry leaves behind his wife Nancy Rutstein of 30 years, his five children and his two, soon-to-be-three grandsons.

Teledyne Technologies Inc., a leader in the design and manufacture of custom electronic components and systems, announced that it has acquired **Labtech Microwave**, a leader in custom microwave packaging solutions and microwave components, as part of the acquisition of **Intelek plc.** Labtech Microwave Packaging Group, founded in 1984, and located in Presteigne, UK, specializes in the design and manufacture of innovative low cost custom packaging solutions utilizing low cost organic materials for monolithic microwave integrated circuits (MMIC), multichip module (MCM) and higher level printed circuit board (PCB) applications.

Bird Technologies Group (BTG), a supplier of radio frequency measurement and management technology, has acquired **X-COM Systems** of Reston, VA. X-COM, founded in 1994, manufactures RF test equipment, deployable RF signal sources, and military digital communications equipment, primarily sold to the US Department of Defense and other government agencies.

Hittite Microwave Corp. announced it has acquired a license from **IBM** to manufacture and market silicon IC millimeter-wave transceivers developed by IBM. Also covered by the license are certain 57 to 64 GHz IC, package and antenna technology, as well as 71 to 76 GHz and 81 to 86 GHz IC intellectual property. Hittite will apply this advanced high frequency technology to markets that require highly integrated solutions. The company also entered into a Joint Development Agreement with IBM related to millimeter-wave technology. Financial terms of the transaction were not disclosed.

ON Semiconductor Corp. and **SANYO Electric Co. Ltd.** announced the signing of a definitive purchase agreement providing for the acquisition of SANYO Semiconductor Co. Ltd., a subsidiary of SANYO Electric, and other assets related to SANYO Electric's semiconductor business, by ON Semiconductor in a cash and stock transaction with a purchase price of approximately $366 M (¥33.0 B), subject to adjustment pursuant to the terms of the transaction. Based on the most recently completed quarter, SANYO Semiconductor's annualized revenue was approximately $1.2 B and the annualized revenue of the combined entity would be approximately $3.5 B. The acquisition is expected to be completed before the end of 2010.

Cornell Dubilier has acquired the **Panasonic** electrolytic foil formation facility in Knoxville, TN. Last year this facility produced 10 percent of the world's electrolytic foil with the industry's most modern and efficient equipment.

WiSpry Inc. announced that it is working with **IBM** to develop MEMS process technology and manufacture its tunable RF product roadmap. This development includes WiSpry's current generation of tunable impedance matching products, slated for production with a major tier-one OEM this fall, as well as future generations of highly integrated products for the entire mobile terminal front-end.

Empower hosted its worldwide rep network at a reception, dinner and "mini-tradeshow" event as part of its commitment to provide timely updates and access to key management in support of business growth objectives. Key leaders from across the company, including executive management, engineering, operations and business development were in attendance at the event and spent the evening discussing opportunities, highlighting key features of products/capabilities on display and answering questions. The event was aimed at educating both established Empower sales reps and those completely new to the company through various presentations and Q&A sessions.

Renaissance Electronics Corp./HXI announced that HXI's E-band Gigalink system has received Independent Communications Authority of South Africa (ICASA) operational approval certification to deploy in South Africa. This E-band Radio system is used in wireless backhaul applications.

Diablo Industries Thin Film (DITF) was awarded the Three Star Supplier Excellence Award by Raytheon Space and Airborne Systems for the second straight year. DITF, an ISO9001:2008 certified company, manufactures custom thin film interconnects for the aerospace, defense, communication and medical markets.

Richardson Electronics Ltd. announced it has received the "Top Distributor of the Year" award for 2010 from **TriQuint Semiconductor Inc.,** an RF front-end product manufac-

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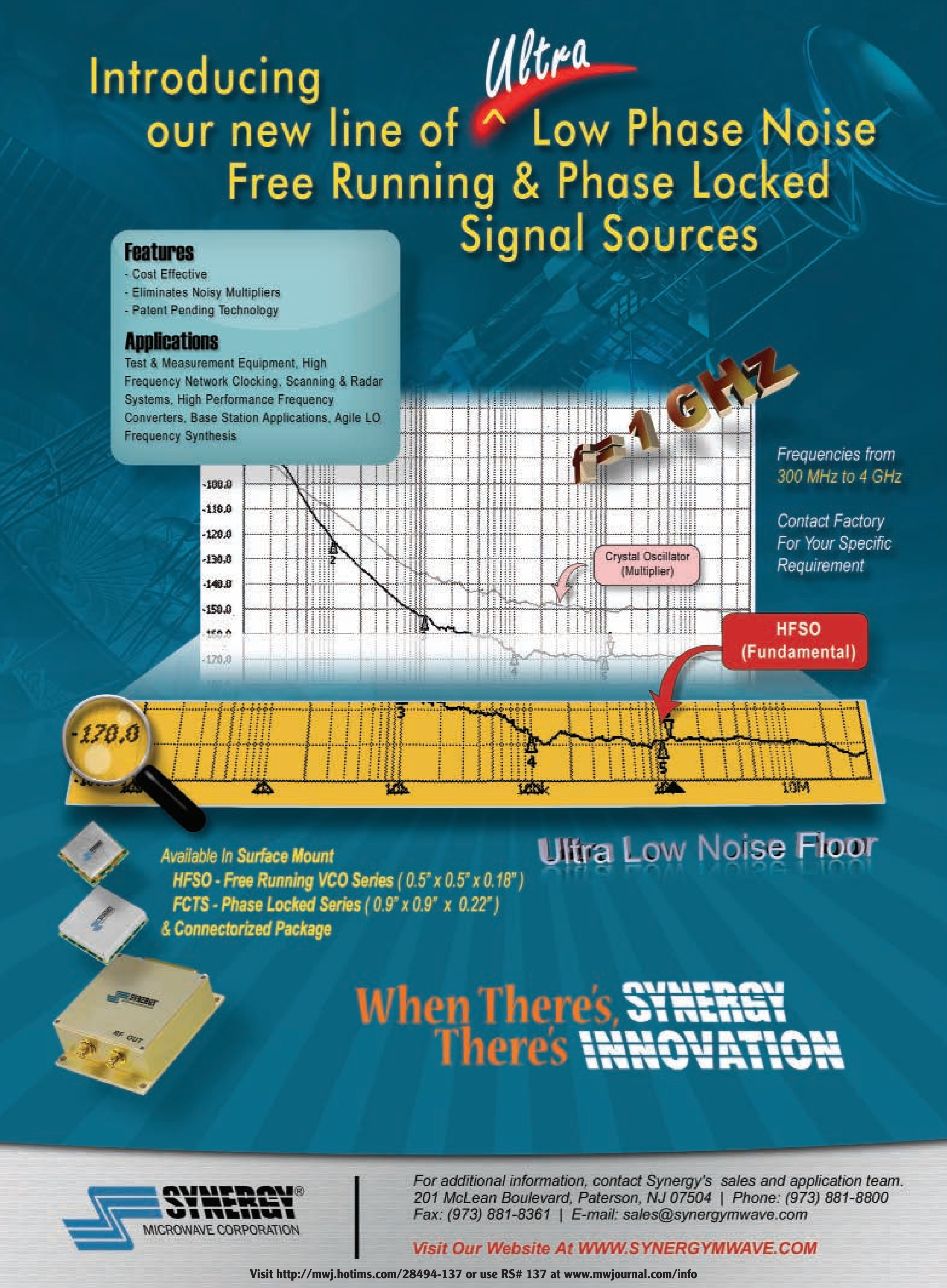
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- Eliminates Noisy Multipliers
- Patent Pending Technology
Applications
Test & Measurement Equipment, High Frequency Network Clocking, Scanning & Radar Systems, High Performance Frequency Converters, Base Station Applications, Agile LO Frequency Synthesis
f=1 GHz
Frequencies from 300 MHz to 4 GHz
Contact Factory For Your Specific Requirement
Crystal Oscillator (Multiplier)
HFSO (Fundamental)
-170.0
Ultra Low Noise Floor
Available In Surface Mount
HFSO - Free Running VCO Series (0.5" x 0.5" x 0.18")
FCTS - Phase Locked Series (0.9" x 0.9" x 0.22")
& Connectorized Package
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turer and foundry services provider. The award recognizes Richardson Electronics' superior overall performance, including support, service, design wins and responsiveness to global customers. Award winners were chosen based on nominations by members of TriQuint's executive sales team and announced at TriQuint's annual sales conference.

TriQuint Semiconductor Inc. announced it has received **Samsung**'s Quarterly Quality Award. TriQuint supplies a variety of innovative radio frequency solutions to Samsung, such as power amplifiers and multi-function integrated modules, for use in Samsung's wireless communication devices for GSM/GPRS, EDGE, WCDMA and HSPA+.

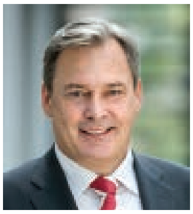
CONTRACTS

Giga-tronics Inc. announced that more than 100 of the company's 8000 series RF Switch Interface Units (RFIU) are being supplied to contract manufacturers in Asia to increase throughput and improve test asset utilization in mobile phone and other wireless device production. This is part of the growing market for high-end mobile phones and other wireless products. The Giga-tronics 8000 series RF Switch Interface Unit was chosen for its reliability and performance. The 8000 series RFIU is produced by Giga-tronics under the ASCOR brand.

Auriga Microwave announced that it has received the contract for Small Business Innovative Research (SBIR) award N093-221: Highly Efficient Transmitter for High Peak to Average Power Ratio (PAPR) Waveforms. Under a contract from the Space and Naval Warfare Systems Command (SPAWAR), Auriga will design a compact, highly efficient transmitter for complex waveforms and other waveforms with a high PAPR targeted for Joint Tactical Radio System (JTRS).

A new inventory management system developed by **TASC Inc.** for the US Navy will allow Naval warehousing facilities to automatically count and locate RFID-tagged inventory in real time. The software platform integrates a radio frequency identification (RFID) system with an inventory management system.

PERSONNEL



▲ *Manfred Fleischmann*

After a 35 year-long career with Rohde & Schwarz, including seven years on the Executive Board and five years as its Chairman, **Michael Vohrer** (62) has announced his retirement. An electrical engineer by profession, Vohrer played a key role in the company's success throughout the years. One of his major contributions was achieving market leadership in the field of mobile radio test and measurement when he headed that division. The company's recent entry into the oscilloscope market marks the end of his long and productive career. A proven test and measurement expert, Vohrer mapped out important new paths for

Rohde & Schwarz: He launched the R&S CMU200 universal radio communication tester, one of the company's all-time best selling products. He is leaving the company for personal reasons. **Manfred Fleischmann** recently assumed the role of President and CEO. He joined the company 25 years ago, and has been a member of the Executive Board since 2005. In this capacity he was responsible primarily for production, logistics and materials management. Before that, Fleischmann, who is an engineer by profession, held various management positions in quality assurance.

Agilent Technologies Inc. announced that **David E. Root**, an Agilent Electronic Measurement Group scientist, has been promoted to the position of Agilent Research Fellow. Most recently, Root was a driving force behind the development of X-parameters and nonlinear vector network analyzer technology. Few members of Agilent's technical staff achieve the level of Agilent Research Fellow. Considerations for selection include: a recognized and sought-after international expert; leadership in next-generation technology that significantly impacts Agilent and its customers; an exemplary record of enduring industry achievement; and a role model, consultant and mentor. The promotion required multiple levels of management review; internal and external letters of recommendation; and final approval by Agilent's Electronic Measurement Group President Ron Nersesian and Agilent's Chief Technology Officer Darlene Solomon.

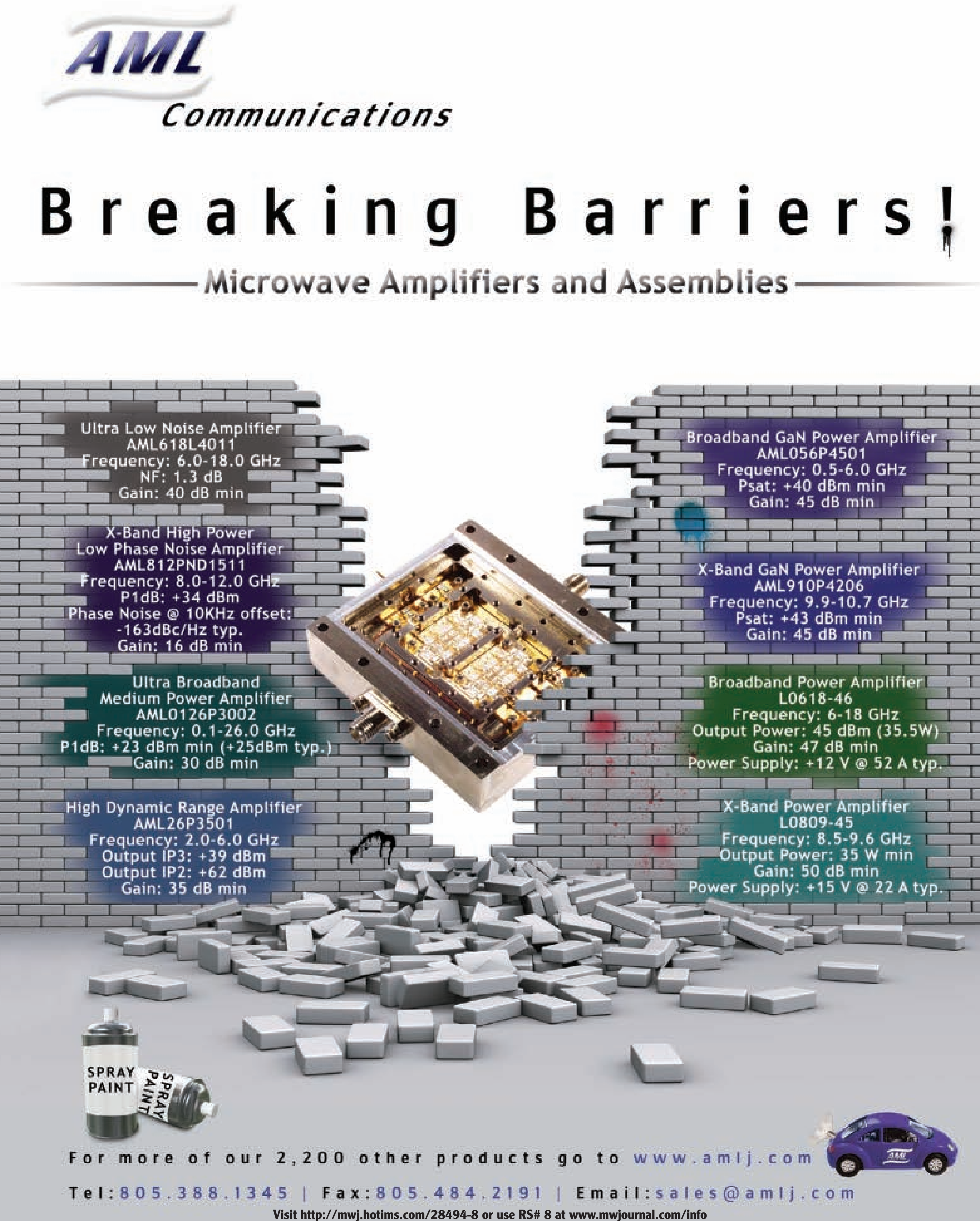

▲ *John Booher*

TotalTemp Technologies Inc. announced the appointment of **John Booher** as the CTO of its Thermal Platform manufacturing business in San Diego, CA. Booher will be leading development projects and manufacturing quality for TotalTemp. He brings a great deal of experience and specialized skill to the position as he recently worked as Senior Electrical Engineer at Sigma Systems working with their similar product lines for over 20 years. Booher previously worked in systems test at General Dynamics and Convair.

MI Technologies announced the appointment of **Fred Purvis** to the role of Director of the Customer Support Business Unit. In this role, Purvis will provide leadership in serving MI Technologies' customers with an array of capabilities and products. Purvis's management career includes various assignments in program management and other customer-facing roles in the high-tech industry. He worked at EMS Technologies for nearly 20 years in progressively advanced roles in program management.


▲ *Ronald Desilets*

Delta Microwave, a supplier of microwave filters and integrated assemblies, announced the appointment of **Ronald Desilets** as Sales and Marketing Manager. In his new position, Desilets will be responsible for expanding business in the defense, space, and high reliability commercial markets that Delta Microwave serves. Desilets' initial focus


AML
Communications
Breaking Barriers!
Microwave Amplifiers and Assemblies
Ultra Low Noise Amplifier
AML618L4011
Frequency: 6.0-18.0 GHz
NF: 1.3 dB
Gain: 40 dB min
X-Band High Power
Low Phase Noise Amplifier
AML812PND1511
Frequency: 8.0-12.0 GHz
P1dB: +34 dBm
Phase Noise @ 10KHz offset:
-163dBc/Hz typ.
Gain: 16 dB min
Ultra Broadband
Medium Power Amplifier
AML0126P3002
Frequency: 0.1-26.0 GHz
P1dB: +23 dBm min (+25dBm typ.)
Gain: 30 dB min
High Dynamic Range Amplifier
AML26P3501
Frequency: 2.0-6.0 GHz
Output IP3: +39 dBm
Output IP2: +62 dBm
Gain: 35 dB min
Broadband GaN Power Amplifier
AML056P4501
Frequency: 0.5-6.0 GHz
Psat: +40 dBm min
Gain: 45 dB min
X-Band GaN Power Amplifier
AML910P4206
Frequency: 9.9-10.7 GHz
Psat: +43 dBm min
Gain: 45 dB min
Broadband Power Amplifier
L0618-46
Frequency: 6-18 GHz
Output Power: 45 dBm (35.5W)
Gain: 47 dB min
Power Supply: +12 V @ 52 A typ.
X-Band Power Amplifier
L0809-45
Frequency: 8.5-9.6 GHz
Output Power: 35 W min
Gain: 50 dB min
Power Supply: +15 V @ 22 A typ.
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will be on expanding Delta Microwave's representatives in the US. Desilets has 30 years experience in the microwave industry. He comes to Delta Microwave from Tecom Industries where he was Sr. Manager of Marketing and Sales.

REP APPOINTMENTS

MITEQ Inc. announced the appointment of **Telepro Inc.** as the company's exclusive sales representative in Canada (excluding British Columbia). Telepro Inc. will represent MITEQ's component division of products that includes amplifiers, mixers, frequency multipliers, passive power components, switches, attenuators, limiters, phase shifters, IF signal processing components, oscillators, synthesizers, integrated multifunction assemblies and fiber optic products. Telepro Inc. can be contacted at (514) 667-7061.

Vaunix Technology Corp., a manufacturer of USB controlled and powered test equipment, has announced that ***Semi Test Solutions*** (STS) will be representing the company in the territory of northern California. Semi Test Solutions provides sales representation for companies that manufacture test and measurement equipment, RF and microwave active and passive components, and OEM products for the semiconductor, telecommunications, commercial, industrial, medical, and military electronics markets. Representative Mahesh Hingorani can be contacted via e-mail, Mahesh@semitestsolutions.com, or phone (510) 468-9769. For more information, visit the Semi Test Solutions website at www.semitestsolutions.com.

International Manufacturing Services Inc. (IMS), a manufacturer and supplier of high quality thick film resistors, terminations, attenuators, resistive splitters and couplers, thermal management devices and other RF devices to the electronics industry, announced the appointment of **R.D. Associates** as its representative for all Canadian provinces excluding British Columbia. R.D. Associates headquarters are located in Toronto, ON, with a smaller satellite office in Montreal, QC. More information is available at www.rdassociates.ca.

BC Systems Inc. announced the appointment of two manufacturer's representatives each responsible for sales of the company's RF and microwave power amplifiers and power supply products in different areas of the US. **Aurora-Franklin Marketing LLC** is now representing BC Systems in upstate New York (Orange and Putnam counties and those further north). Aurora-Franklin Marketing of Pittsford, NY, was founded in 1987 and serves a wide variety of high-tech manufacturers throughout the East Coast. The company can be reached at (585) 249-1020 or by sending an e-mail to Jim Cowey, Vice President, upstate NY Field Sales, at jcowey@auroragroup.net. **Shaw-Newman**, Ft. Wayne, IN, is now representing BC Systems Inc. in Kentucky, Indiana, Ohio, Michigan, West Virginia and western Pennsylvania. The company can be reached at (260) 637-8128 or by sending an e-mail to Mike Shaw at mike@shaw-newman.com.

Linx Technologies Inc. announced the appointment of **Apex Electronics Ltd.** as a stocking distributor.

Welcome to European Microwave Week 2010

For complete coverage of the EuMW conference, event news, exhibitor product information and special reports from the editors of *Microwave Journal*, visit our online show daily at www.mwjournal.com/eumw2010 starting September 20th.

There is probably no European city as 'well connected' as Paris, both culturally with regards to its sophistication, fashion, gourmet lifestyle, history, architecture, etc., and geographically in terms of its location and its pan-European and global transportation links. It is therefore no surprise that the theme of the 13th European Microwave Week that takes place at the city's CNIT Centre from 26 September to 1 October is *Connecting the World*. The theme not only relates to the connection that visitors from across Europe, Asia and North America have with Europe's premier RF and microwave event, but also to the literal connections that the microwave industry facilitates in the telecommunications, satellite, aerospace, military and industrial sectors. Not forgetting the development and nurturing of the human and personal connections that are vital for the industry to evolve, flourish and progress.

When organising the four conferences—the 40th European Microwave Conference (EuMC), the 5th European Microwave Integrated Circuits Conference (EuMIC), the 3rd European Wireless Technology Conference (EuWiT) and the 7th European Radar Conference (EuRAD)—particular emphasis was placed on the coordination of areas of common interest between the different conferences, workshops and short courses. The result of the call for papers was an exceptional number of submitted papers (close to 1,300) from more than 60 countries.

Illustrating the emphasis on *Connecting the World* initiative are two special sessions. The EU-North America Experts Microwave Session has gathered together a group of experts that have been recognised as 'Distinguished Microwave Lecturers' (sponsored by MTT-S) and 'European Microwave Lecturers' (jointly sponsored by MTT-S and Eu*M*A) who will address the latest developments in active and passive microwave components. The Asia-Pacific Microwave Conference Session is the result of a speaker exchange between the European Microwave Conference and the Asia-Pacific Microwave Conference (APMC). It will feature speakers from Singapore, Japan and Australia.

The international flavour is continued for the three-day European Microwave Exhibition, which not only attracts leading companies from

Gilles Dambrine
General Chair, EuMW 2010
Ivar Bazzy
President, Horizon House Publications


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Western Europe but also from farther afield, including Eastern Europe, North America, the Middle East and Asia, with a significant number of Chinese companies and a marked increase in the Korean representation. Regardless of their origin, the exhibitors recognise the importance of participating in the largest trade show dedicated to RF and microwaves in Europe.

The show floor offers a stage where companies can showcase their wares to a focused audience and put their latest and most innovative products under the spotlight. It has become an exhibition that manufacturers target to launch new and significant products and a conduit for them to 'connect' with their existing and potential customers in order to discuss specific requirements, sound out possible future developments and get informed feedback. Conference Poster Sessions will add interest to the exhibition halls on all three days, and a wide range of workshops, seminars and short courses offer numerous opportunities for attendees to gain hands on experience.

A significant addition to the programme is the Defence/Security Executive Forum, which will provide a platform for key representatives from European defence agencies, market analysts and industry leaders to discuss current initiatives, market trends and strategies impacting the European Defence/Security sector.

In recent years EuMW has increasingly recognised the importance for the RF and microwave industry to connect with its future—young engineers and designers. An event aimed at doing just that is the third EuMW Student Challenge, sponsored by Thales Nederland, which gathers students with different skills from all over the world and promotes active participation and teamwork. New to EuMW 2010 is a special session on *Young and Engineering: Education, Industrial/Academic Opportunities*, which looks at the educational, industrial and academic opportunities offered to young engineers and scientists, as well as the career opportunities open to them.

Whether young or more mature, it is important to socialise and the EuMW Welcome Reception epitomises the organiser's ongoing efforts to encourage the interaction between industry and academia, resulting in a social event that is both convivial and conducive to networking. Indeed, mixing business and pleasure can be enjoyed throughout the week through the strong calendar of social events and the Partner Programme.

A great deal of effort has been made by a large number of people to ensure a first class event. On behalf of the Local Organising Committee we would like to express our gratitude to the four international Technical Programme Committees and the hundreds of reviewers who worked hard to shape the record number of individual contributions to the final programme. Thanks also goes to those who organised the special sessions, the focused sessions, the workshops and short courses, and the special events, which we believe are essential to fulfilling the needs of delegates.

We would like to acknowledge the EuMA Board for its continued advice and guidance and thank the Horizon House personnel assigned to EuMW for their hard work, which has again proved invaluable in guiding the chair and his team through all the steps of organising a challenging event. Special thanks go to the National Center of Research (CNRS) Department INSIS, the French Research Ministry and the Nord-Pas de Calais Region-FEDER for their constant support. Last but not least, we acknowledge the financial and in-kind sponsorship of many industrial enterprises and other organisations.

Our ambition has been to create the best conditions possible to welcome the microwave community to Paris, to connect with our audience and for them to connect with each other. We are convinced that you will find European Microwave Week 2010 unforgettable. See you there.

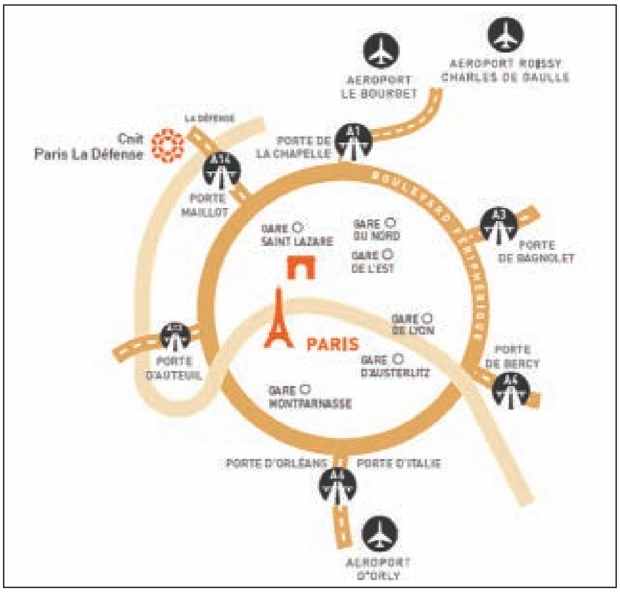

Gilles Dambrine


Ivar Bazzy

Welcome from Gilles Dambrine, General Chairman, EuMW 2010, and Ivar Bazzy, President, Horizon House Publications. ■

ATTENDING EUROPEAN MICROWAVE WEEK 2010

The Eiffel Tower is known the world over as a 'must see' landmark when visiting Paris. For the industry, another attraction that must not be missed this year is the 13th European Microwave Week, which will be held at the CNIT la Défense, in the French capital from 26 September to 1 October 2010. Just as the famous tower is unmistakable on the city's skyline, EuMW stands out as the premier RF and microwave event in Europe. It too has become a landmark, an event that attracts international visitors, with more than 4,000 attendees—comprising delegates, exhibitors and visitors—expected to descend on the conference and exhibition centre for the Week.



▲ *Transportation options to CNIT la Défense.*

The event attracts representatives from across the globe, with recent years seeing increased numbers from North America and Asia in particular. To recognise and celebrate the fact, *Connecting the World* is the theme of EuMW 2010, and the event aims to promote networking, interaction and co-operation throughout the four conferences, the European Microwave Exhibition and the myriad of workshops, forums, seminars and short courses that are being staged.

The event focuses on the needs of engineers and researchers, and provides an invaluable opportunity for both academia and commerce to consider the latest trends and developments that are widening the field of application of microwaves.

Furthermore, in order to tap into the increased interest and activity in defence and homeland security, a significant addition to the EuMW 2010 programme is the Defence/Secu-

RICHARD MUMFORD
Microwave Journal *International Editor*

rity Executive Forum, which will take place in Room Darwin 4, Level D, between 17.00 and 19.00 on Wednesday 29 September. The Forum will provide a platform for key representatives from European defence agencies, market analysts and industry leaders to discuss current initiatives, market trends and strategies impacting the European defence/security sector.

For the third year, EuMW will endeavour to engage young engineers and designers via the EuMW Student Challenge, which is sponsored by Thales Nederland and gathers students with different skills from all over the world to work together. For the fourth year running, the popular Agilent Tutorial Seminars for Young Engineers will set out to stimulate and encourage the next generation. By focussing on the application of test and measurement, the seminars aim to help young engineers along their chosen career paths.

The technical programme will begin with the European Microwave Week opening session at 10.50 on Tuesday 28 September. In addition to two distinguished key note speakers, the session includes the Award Ceremony, where both the Eu*MA* Distinguished Service Award and the Eu*MA* Outstanding Career Award will be presented.

Later that day, academia and industry get the opportunity to socialise and network at the EuMW Welcome Reception (see Social Events & Sightseeing).

To make sure that you plan these events into what is likely to be a busy schedule and to highlight just what EuMW has to offer, the following quick reference guide is designed to complement the EuMW Conference Programme and Exhibition Show Guide, which offer more in-depth information.

THE CONFERENCES

Each with their own dedicated time slots throughout the Week are the four focused conferences:

- The 5th European Microwave Integrated Circuits Conference (EuMIC) takes place on Monday 27 and Tuesday 28 September
- The 3rd European Wireless Technology Conference (EuWiT) runs from Monday 27 to Tuesday 28 September
- The 40th European Microwave Conference (EuMC) extends from Tuesday 28 to Thursday 30 September
- The 7th European Radar Conference (EuRAD) ends the Week and spans Thursday 30 September and Friday 1 October

The registration area, sponsored by NXP, is located in Salle Brillat Savarin 1 on Level B, where delegate bag collection will also be available. On-site registration begins on Saturday 25 September, when it runs from 16.00 to 19.00 and will then commence at 7:30 each morning from Sunday 26 September to Friday 1 October. Delegates can register for one, two, three or all four of the conferences. Registration at one conference does not facilitate access to other conference sessions, but those wishing to register for two or more conferences will receive a discount on these registrations.

EUROPEAN MICROWAVE INTEGRATED CIRCUITS CONFERENCE

Since 2007, EuMIC has been organised under the umbrella of both the European Microwave Association and GAAS® Association. This year there are more than 100 technical papers distributed across 17 EuMIC plenary sessions, five poster sessions, four EuMC/EuMIC joint sessions and one EuMC/EuMIC/EuWiT joint session, which highlights the strong interaction between these conferences. There will also be seven workshops and one short course. Aimed at both industry and academia, the programme features sessions ranging from basic process and device physics to integrated circuit theory based on different compounds in a number of different application domains.

Distinguished speakers at the plenary sessions include Prof. Federico Capasso, from Harvard University, who will review the recent advancements on plasmonics for beam engineering and on QCL for THz applications; Dr. Vivek Subramanian, from UCB, who will give an overview of printed electronics from materials and devices to applications, such as flexible displays, RFID tags and sensors; Dr. J.S. Moon, from HRL Laboratories LLC, will discuss the development of wafer-scale graphene RF electronics; and Dr. H. Alfred Hung, from ARL, will survey the progress in millimetre-wave and sub-millimetre-

wave devices and circuits from SiGe to III-V compounds.

Prizes and Awards

To acknowledge the high quality of papers presented, the EuMIC technical programme committee and the Eu*MA* general assembly will award a Best Paper Prize and a Best Student Paper Prize, with the winners receiving a plaque commemorating their achievements. In addition, the GAAS Association will provide three Student Fellowships to recognize the valuable work of students and to support them in the first steps of their technical and scientific careers.

EUROPEAN WIRELESS TECHNOLOGY CONFERENCE

EuWiT 2010 is a unique interdisciplinary conference aimed at enabling researchers and product developers worldwide to update and share their knowledge. It features 16 podium sessions, including six joint sessions with either EuMC or EuMiC and one poster session. It is preceded, on Sunday 26 September, by one day dedicated to workshops and short courses that includes a workshop on *Cooperative communications and networking* and a short course on *Nomadic RF transmitter architectures*.

The opening and closing sessions will take place on Monday and Tuesday afternoons, respectively, with three invited talks: *Cognitive radio for green communications* by Prof. Honggang Zhang from Zhejiang University, *Energy benefits of cooperative docitive over cognitive networks* by Dr. Misha Dohler from Centre Technologic de Telecomunicacions de Catalunya, and *Detection and location of people in emergency situations* by Dr. Philippe Morgand from Thalès Communications.

Prizes and Awards

To acknowledge the high quality of papers presented the Best Paper Prize of €3,000 and a Young Engineer Prize of €2,000 will be awarded.

EUROPEAN MICROWAVE CONFERENCE

To celebrate its ruby anniversary, the conference comprises 63 oral sessions, three poster half days and two focused sessions, together with workshops and special sessions. Additionally, an exchange of speakers between Eu*MA* and the Asian Pacific Microwave Conference (ARWC) sees authors from Singapore, Japan and Australia giving presentations on the state-of-the-art of numerical methods for solving integral equations, recent advances in millimetre-wave technologies, and ultra-wideband and microwave imaging systems.

Keeping up the international theme, there are also invited European and North American keynote speakers, and this year, for the first time, there is also a special session titled, *Young people and engineering: education, industrial/academic, opportunities and careers*, with a panel of participants from various countries.

Prizes and Awards

On Thursday afternoon the closing session will feature an award ceremony for the EuMC Best Paper Prize, and two EuMC Young Engineers Prizes for the best papers written and presented by young engineers.

EUROPEAN RADAR CONFERENCE

The number of paper submissions has continuously increased during the last seven years and EuRAD and is now more than 15 percent of the whole EuMW, which has created the necessity to increase the duration to two full days. The papers are organised in 17 oral sessions plus three focused sessions, adding up to 92 podium presentations and a poster session resulting in 30 additional papers.

The programme covers a very wide and interesting range of radar topics such as antenna scattering and measurements, radar signal processing and simulations systems, radar architecture and systems, and all radar applications covering civilian applications such as air traffic control, meteorological, wake vortex detection coastal radars and also military applications such as airborne, weapon systems, air defence and passive radars.

Three focused sessions will cover: *Sea clutter and environmental effects; Airborne radar and scanning electronic antenna*; and *Millimetre and sub-millimetre-wave radar imaging*.

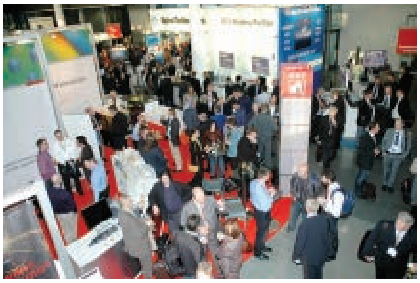
In the opening session Prof. H. Griffiths will elaborate on *Multistatic, MIMO and networked radar: The future of radar sensors*. Dr. F. Barbaresco from Thales will then consider *Wake vortex radar monitoring: state-of-the-art and challenges*, while Prof. W. Menzel concludes with *Millimetre-wave radar for civil applications*. During the closing session Dr. E. Marquis will give a presentation on *Coastal radar development*. The conference programme is completed by four workshops, two of which are joint with EuMC.

Prizes and Awards

This year there is one Radar Conference Prize and two Young Engineer Prizes. The Radar Prize of €3,000 is sponsored by Raytheon and is awarded to the paper that best advances the state-of-the-art in radar. Raytheon also sponsors one Young Engineer Prize to the value of €2,000, while the second Young Engineer Prize of €2,400 is sponsored by EADS. Both are awarded to young engineers or researchers who have presented an outstanding paper at the conference.

EXHIBITION

In easy reach of the registration area and the conference floor, the European Microwave Exhibition will be located in Salle Pierre et Marie Curie on Level C of the CNIT. With 262 exhibiting companies, taking up 7,000 square metres (gross), the show floor is a prime example of *Connecting the World* as the exhibition has attracted key companies from across the globe. Exhibitors not only emanate from Western Europe but also from farther afield, including Eastern Europe, North America, the Middle East



▲ *Exhibition floor at EuMW 2009 (photo courtesy of Shmuel Auster).*

and Asia, with a significant number of Chinese companies and a marked increase in the Korean representation. Closer to home, the French Pavilion, which began when EuMW last visited Paris in 2005, and has travelled with the show to every venue since, attracts local interest with smaller companies and distributors banding together to have a collective presence.

Regardless of their origin, the exhibitors recognise the importance of participating in the largest trade show dedicated to RF and microwaves in Europe. The show floor offers a stage where companies can showcase their wares to a focused audience and put their latest and most innovative products under the spotlight. It has become an exhibition that manufacturers target to launch new and significant products and a conduit for them to 'connect' with their existing and potential customers in order to discuss specific requirements, sound out possible future developments and get informed feedback.

For the first time at a European RF and microwave event, the set up of Interactive Poster Sessions in specially constructed modules, within the exhibition hall, with seating, will enable authors to present their results interactively, discuss their findings face to face and obtain immediate feedback. The hall will also be the venue for the conference session coffee breaks, a Publishers' Corner and two CST sponsored Cyber Cafés, providing Internet access direct from the show floor.

European Microwave Week has, particularly in recent years, aimed to provide useful, practical workshops, but in 2010 the number has increased dramatically with companies including Agilent Technologies, Rohde & Schwarz, NXP and National Instruments all offering attendees the opportunity to gain hands-on experience and guidance.

Exhibition Opening Hours

Tuesday 28 September: 9.30 to 17.30 (followed by the Welcome Reception); Wednesday 29 September: 9.30 to 17.30; Thursday 30 September: 9.30 to 16.30

GETTING TO CNIT LA DÉFENSE

Whether travelling by public transport on the Metro, train or bus, the conference and exhibition centre is easily accessible. On the RER take Line A and disembark at La Défense Station; on the Metro (Subway) it is at the end of Line 1, La Grand Arche de la Défense station. Please keep your ticket as you will need it to pass through the barriers when you exit. At the main La Défense Grande Arche station, take Exit E - Le Parvis.

By Tram

Take line T2 to the La Défense stop.

By SNCF Trains

Take the Paris Saint-Lazare/Saint-Nom la Bretèche line or the Versailles-RD/Saint-Quentin en Yvelines/La Verrière line to the La Défense stop.

By Bus

Take line 73, 141, 144, 159, 258, 262, 272, 275, 278, 360, 378, 161, 174 or 178 to the La Défense stop.

HOTEL RESERVATIONS

D.G.M.P. Travel is the officially

appointed travel agency for EuMW 2010. The company has carefully selected hotels near CNIT La Défense and in the city centre's most popular locations at the 'Best Available Rate' during the event period. Only bookings made through D.G.M.P. Travel will benefit from these rates. To find out more, visit www.dgmp.eu/eumw2010. For delegates (young people), the St. Christopher's Paris Hostel is available at a 10 percent discount on presentation of their badge. For information and reservations, visit www.st-christophers.co.uk.

SOCIAL EVENTS & SIGHTSEEING

The main event of the Week is the EuMW Welcome Reception on Tuesday 28 September, sponsored by Agilent Technologies, Horizon House Publications and Eu*M*A, which epitomises the organiser's ongoing efforts to encourage the interaction between industry and academia. The evening will begin with a Cocktail Reception in Brillat Savarin Banquet Hall on Level B of CNIT at 18.30. Guests will then be addressed by the 2010 EuMW Chairman, who will hand over to the 2011 EuMW Chairman, followed by the Platinum Sponsor, Agilent Technologies, after which a French/Italian seated buffet will be served.

From museums to restaurants, Paris has so much to offer visitors. Some of the most famous Parisian landmarks include Notre Dame de Paris, the Arc de Triomphe as well as the Eiffel Tower. Other sites include the Tuileries Gardens, the Champs-Élysées, the Invalides museum, the Panthéon church, the Palais Garnier, the Sainte-Chapelle palace chapel and the Église de la Madeleine.

As well as the Louvre, the capital city offers 180 museums and monuments that include the Musée Picasso, Musée Rodin, Musée du Montparnasse, Musée National d'Art Moderne, Musée Cluny, Musée d'Orsay and the Musée du quai Branly. As a hub of arts and culture, Paris has many theatres, including Bobino, Théâtre Mogador and the Théâtre de la Gaîté-Montparnasse and opera houses, two of the largest being the Opéra Garnier and the Opéra Bastille. For shopping, few places in the world can beat the size and range of shops along the boulevard Haussmann. Other shopping areas of note are the Rue de Rivoli, on the Left Bank and the Madeleine.

Cityrama offers a wide range of tours and excursions before, during and after European Microwave Week. To book a tour or excursion, visit www.pariscityrama.com. Those booking online will benefit from a special five percent discount by entering the promotion code "EMW2010". This offer is valid for all the tours available from 20 September 5 October. Information regarding Cityrama and last minute bookings will be available at the Tourist Information Desk in the EuMW registration area.

GENERAL INFORMATION

In advance, take time to familiarise yourself with the event and plan your visit by logging onto the show website at www.eumweek.com. ■

2010 EuMW Exhibitor List

The following list is complete as of August 4, 2010.
Exhibitors in bold have an ad in this issue.

- AA Group ... 52
- AA MCS ... 52
- Adrio Communications Ltd. ... PUB
- Advanced Control Components ... 56
- **Aeroflex ... 143**
- AFT Microwave GmbH ... 154
- **Agilent Technologies France SAS ... 62**
- Albatron Science ... 109
- Allstron Corp. ... 102
- AMCAD Engineering ... 20
- AMD ... 148
- AML Microtechnique Lorraine ... 20
- **Analog Devices Ltd. ... 111**
- Anritsu EMEA Ltd. ... 85
- **Ansoft ... 24**
- **Applied Wave Research Ltd. (AWR) ... 84**
- **AR Europe ... 23**
- Arkivator AB ... 150
- Arlon-Materials for Electronics Div. ... 4
- **Artech House ... 124**
- ARVA-RF ... 32
- AT Wall Co. ... 11
- ATEM SA ... 159
- Audace Media SARL ... PUB
- Aurora Software & Testing SL ... 113
- Axon' Cable SAS ... 146
- BAE Systems, Integrated System Technologies ... 17
- Beam-Verlag ... PUB
- BEREX ... 160
- Bilz Vibration Technology AG ... 109
- BL Microwave Ltd. ... 36
- **Boonton Electronics Corp ... 114**
- Brush Ceramic Products Inc. ... 2
- Brush Wellman Inc. ... 2
- BSC Filters Ltd. ... 82
- Cambridge University Press ... 77
- Cascade Microtech Inc. ... 6/62
- CCPIT Commercial Sub-council ... 166
- CCPIT Commercial Sub-council ... 5
- CEA-LETI ... 88
- Chalmers Microtechnology & Nanoscience ... 150
- **Channel Microwave Inc. ... 81**
- Chengdu Seekon Microwave Communications Co. Ltd. ... 93
- Cicor Microelectronics ... 96
- CISTEME ... 20
- **Cobham plc ... 193**
- **Coilcraft Europe Ltd. ... 137**
- Competitiveness Cluster Elopsys ... 20
- COTELEC ... 147
- **CPE Italia SpA ... 105**
- Creowave Oy ... 39
- **CST AG ... 66**
- **dBm ... 109**
- DelfMEMS ... 165
- DICONEX ... 107
- **Dielectric Laboratories Inc. ... 42**
- Dow-Key Microwave Corp. ... 42
- Dyne-Tech Co. Ltd. ... 103
- e2v Technologies ... 156
- EADS Defense & Securite ... 162
- Efield AB ... 150
- Electroniques ... 141
- Elexience ... 197
- ELEXO ... 120
- **Elisra Electronic Systems Ltd. ... 78**
- ELLIPTIKA ... 71
- EM Software & Systems GmbH ... 25
- EMC Partner France ... 20
- EMC Technology ... 155
- EMCoS Consultations & Software ... 18
- Emerson & Cuming Microwave Products NV ... 41
- Equipements Scientifiques ... 133
- **EuMW 2011 ... 202**
- Europa Electronics ... 146
- European Radio & Microwave Interest Group ... 150
- EuropTest ... 168
- Farran Technology Ltd. ... 62
- FI Science France ... 109
- Florida RF Labs ... 155
- Focus Microwaves Inc. ... 89
- Fraunhofer FHR ... 44
- Fraunhofer-IAF ... 44
- General Microwave ... 196
- GERAC ... 20
- Giga-Concept ... 148
- GigaHertz Center ... 150
- **GigaLane Co. Ltd. ... 132**
- Giza Technologies SA ... 160
- GNI Microwave Co. Ltd. ... 55
- Guangdong Shenglu Telecommunication Co. Ltd. ... 198
- HCM/Systrel ... 135
- Hemera RF/Prana R&D/Siepel ... 20
- *High Frequency Electronics ... PUB*
- **Hirai SK Corp. ... 129**
- Hitachi Chemical Europe GmbH ... 192
- **Hittite Microwave Deutschland GmbH .. 57**
- **Holzworth Instrumentation ... 52**
- Huang Liang Precision Enterprises Co. Ltd. ... 142
- **Huber & Suhner AG ... 72**
- *IEEE Communications Magazine ... PUB*
- *IEEE Microwave Magazine ... PUB*
- IEMN Institut Electronique Microelectronique Nanotechnologie ... 40
- IHP GmbH ... 136
- IMC Microwave Industries Ltd. ... 160
- IMS 2011 ... 19A
- **IMST GMBH ... 12**
- Ingun Pruefmittelbau GmbH ... 72/147
- Innertron Inc. ... 126
- Innovationszentrum fur Telekommunikation-stechnik GmbH IZT ... 195
- INOVEOS ... 20
- Institut Carnot MIB ... 94
- Institut Carnot Telecom-Eurecom ... 94
- Integrations Electronique Hyperfrequencies Telecommunications ... 30
- John Wiley & Sons Ltd. ... 38
- Keenlion Microwave Technology Co. Ltd. ... 166
- Kyocera Fineceramics SAS ... 49
- LEMS-Linwave Electronic Manufacturing Services ... 191
- Les Instituts Carnot ... 94
- Link Microtek Ltd. ... 120
- Linkra Srl ... 121
- **Linwave Technology Ltd. ... 191**
- LPKF Laser & Electronics AG ... 128
- M/A-COM Tech Asia ... 91
- **M/A-COM Technology Solutions ... 90**
- Marki Microwave ... 81
- MATECH Electronique ... 52
- **Maury Microwave Corp. ... 62**
- MB Electronique ... 62
- Mesures ... PUB
- Mesuro Ltd. ... 19
- MEUSONIC SAS ... 161
- **MiCIAN GmbH ... 98**
- Micro Systems Engineering GmbH ... 131
- Microlab ... 114
- *Microwave Engineering Europe ... PUB*
- ***Microwave Journal ... 125***
- Microwave Road ... 150
- Microwave Vision ... 62
- Microwavefilters SrL ... 11
- MiG Microwave Innovation Group ... 27
- Mimix Broadband Inc. ... 90
- **MITEQ Inc. ... 52**
- Mitsubishi Electric Europe BV ... 123
- MM Microwave ... 160
- MT SRL ... 148
- National Instruments ... 31
- NEL Frequency Controls Inc. ... 10
- Noise eXtended Technologies ... 168
- Noise XT ... 168
- Noisecom ... 114
- **Norden Millimeter Inc. ... 81**
- NTT Advanced Technology Corp. ... 33
- NXP Semiconductors Netherlands BV ... 194
- **OML Inc. ... 81**
- **OMMIC ... 100**
- ON Semiconductor ... 140
- Park Electrochemical Corp. ... 199
- **Pascall Electronics Limited ... 58**
- Plextek Ltd. ... 152
- Pluton Joint Stock Co. ... 127
- Precision Devices UK Ltd. ... 139
- Presto Engineering ... 9
- Quantum Focus Instruments Corp. (QFI) ... 109
- Radar Systems Technology ... 81
- RENATECH network/CNRS ... 163
- RF Microtech srl ... 28
- RF Morecom Corea ... 122
- **RFHIC Corp. ... 34**
- RJR Polymers Inc. ... 200
- **Rogers BVBA ... 106**
- **Rohde & Schwarz GmbH & Co. KG ... 70**
- **Rosenberger Hochfrequenztechnik GmbH & Co KG ... 144**
- RTx Technology Co. Ltd. ... 110
- Sage Laboratories Inc. ... 65
- SARAS Technology Ltd. ... 104
- Schott Electronic Packaging ... 3
- Scintera Inc. ... 164
- SELEX Galileo ... 8
- Selmic Oy ... 196
- SEMA Industries ... 167
- SETTECH ... 7
- Shanghai Huaxiang Computer Communication Engineering Co. Ltd. ... 5
- **Sonnet Software Inc. ... 35**
- **Southwest Microwave Inc. ... 108**
- SPEAG (Schmid & Partner Engineering AG) ... 86
- Spinner France ... 29
- Spinner GmbH ... 29
- **Sumitomo Electric Europe Ltd. ... 83**
- SV Microwave ... 117
- SynQor Inc. ... 1
- Taconic Advanced Dielectric Division ... 63
- Tegam Inc. ... 118
- Tektronix ... 19
- **Teledyne Coax Switches ... 153**
- Teledyne Electronics and Communications ... 153
- Teledyne Labtech Ltd. ... 80
- Teledyne Relays ... 153
- Teledyne-MEC ... 153
- Telemobile Electronics ... 62
- Temex Ceramics ... 149
- Thales Microelectronics ... 16
- TowerJazz ... 64
- Transcom Inc. ... 26
- **TriQuint Semiconductor ... 60**
- TRU Corp. ... 81
- UMS SAS ... 101
- Universite Paul Cezanne d'Aix Marseille III ... 94
- Vectron International ... 42
- Verspecht-Teyssier-DeGroote ... 20
- Via Electronic GmbH ... 3
- Virginia Diodes Inc. ... 62
- WAVENICS ... 160
- Wave-Tech Inc. ... 95
- **WIN Semiconductors Corp. ... 97**
- WIPL-D d.o.o. ... 130
- **Wireless Telecom Group ... 114**
- **Z-Communications Inc. ... 201**

Microwaves in Europe: On the Road to Recovery?

As the first decade of the 21st century comes to an end, how healthy is the European RF and microwave industry? What collective remedial action has the European Union taken to inoculate industry and academia from the affects of the economic downturn? What role is technology playing in the recovery and is the prognosis for the future encouraging?

Individual companies, from SMEs to large organisations, research bodies and academic institutes in Europe, have had to face up to the realities brought about by the economic downturn and adapt their operation and practices to the prevailing market conditions. For some, survival has not been easy, with a number requiring intensive care, a transfusion of investment or professional counselling. For others, the prescribed remedy has been harsher, such as the transplantation into a larger, healthier organisation in order for the company to be properly supported and function better.

Of course, not all companies, academic institutions, agencies, etc., have found themselves in need of treatment. Most will have undergone a thorough examination of their working practices, financial stability, market potential, etc., however, and, to a certain extent, those that have survived this far have proved their well being and should be looking to the future.

Almost all will have learned lessons, either personally or through the experience and the fate of similar organisations such as partners, competitors, etc. Initially, the gut reaction for many was to err on the side of caution, be wary of risk taking and not raise their heads above the parapet. However, with the dust having settled, companies are realising that regardless of whether the market is smaller, larger or just the same, they have to compete and play to their strengths, whether that is price, service or innovation.

The RF and microwave industry is generally one of innovation and, as the 2010 European Microwave Week demonstrates, Europe has the expertise and ability to play a significant role in developing the technologies that are shaping the modern world, helping it to communicate and protect its national and international borders. The event is the obvious barometer for gauging the state of the industry, with the chairs of the four individual conferences best placed to identify key areas of activity and evaluate future trends. Therefore, in this report they offer an overview of their specific market sectors—RF & Microwaves, ICs & Semiconductors, Wireless Technologies and Radar.

First, in order to provide a context for their opinions, let us consider the political, commercial, technological and market conditions in which the European microwave industry is currently operating.

European Perspective

In 2009/2010 Europe has been grabbing the headlines in the wake of the economic

Richard Mumford
Microwave Journal, *International Editor*

downturn. The monetary bail-out that Greece received from the EU and the difficulties being experienced by Spain and Portugal have been the lead stories, but the economies of the majority, if not all, European countries have been seriously impacted. Many individual governments originally put stimulus packages in place to shore up industry, encourage training and support employment. Having steadied the ship to some degree, the reality is that austerity measures are being put in place to address financial deficits and stabilise national economies. Governments may be trying to sweeten the pill by maintaining that savings can be made through greater efficiency, less bureaucracy and improved productivity, but the reality is that there is less money in the coffers.

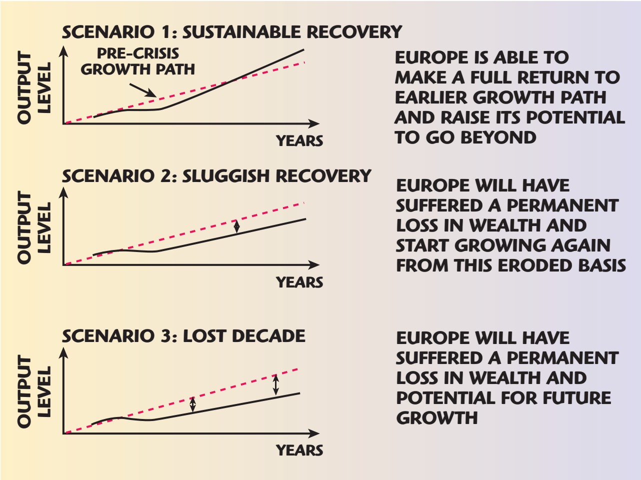
Any decrease in public spending will affect the RF and microwave industry, with the defence, security and aerospace sectors the obvious target areas for cutbacks, but any long-term project, be it the expansion of communication networks, investment in updating the technology that emergency services employ, etc., will come under close scrutiny. There is no doubt that companies will have to compete hard for contracts and any funding on offer.

Over recent years there has been general polarisation of the industry geographical, with Western Europe focused on high value products and the exploitation of a rich vein of research and development, while the emphasis in Eastern Europe has been on manufacturing, often aided by grants and tax incentives. However, due to the expansion of the European Union to 27 countries, with many of the newer participants being from Eastern Europe, such boundaries are becoming blurred as the EU's vision of a united Europe comes more sharply into focus.

A cornerstone of that vision is the Treaty of Lisbon, which came into force on 1 December 2009. It aims to provide the EU with modern institutions and optimised working methods to address issues prevalent in modern society, including globalisation, climatic and demographic changes, security and energy. The EU approach stresses the need for common strategies that promote European principles and long-term goals, and in the current economic climate structured frameworks for development are more vital than ever.

A case in point is Europe 2020, which was launched in March 2010 and offers a vision of how the EU can become a smart, sustainable and inclusive economy delivering high levels of employment, productivity and social cohesion (see ***Figure 1***). It puts forward three mutually reinforcing priorities: Smart Growth—developing an economy based on knowledge and innovation; Sustainable Growth—promoting a more resource efficient, greener and more competitive economy; and Inclusive Growth—fostering a high-employment economy delivering social and territorial cohesion.

Although it has a broad remit, Europe 2020 focuses significantly on the development of industry and academia, emphasising the importance of investing in high-risk research, includ-



▲ *Fig. 1 Three scenarios for Europe by 2020 (courtesy of European Commission).*

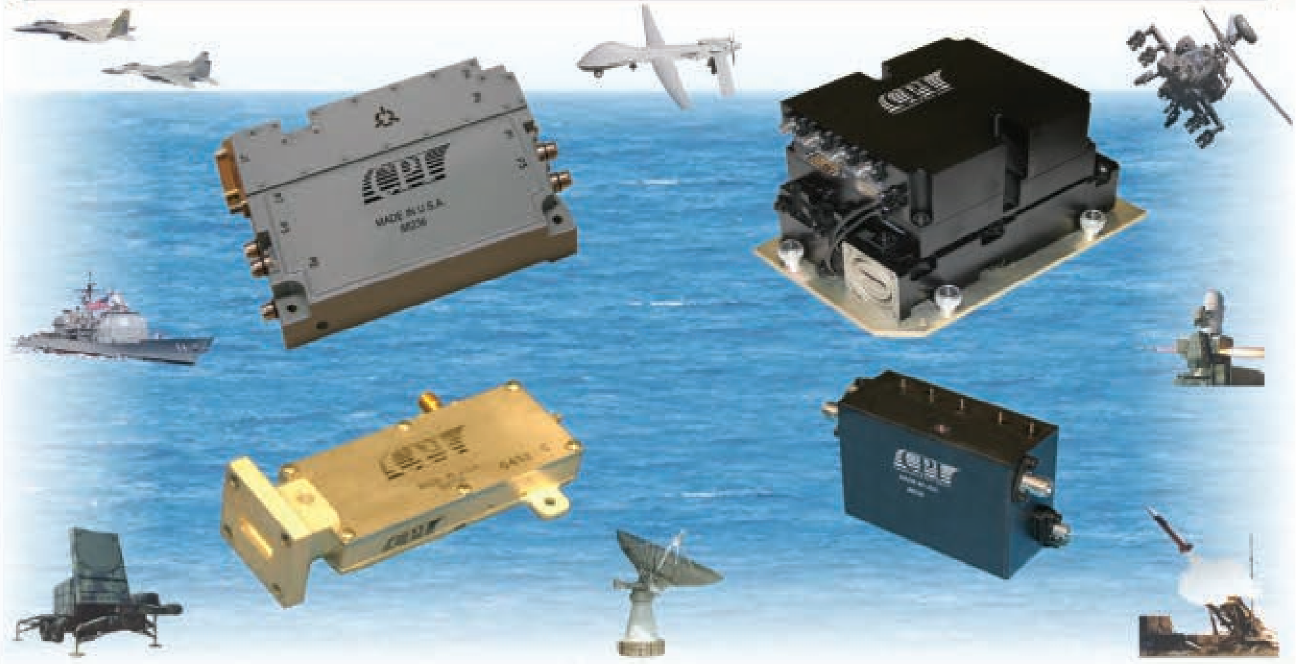
ing multi-disciplinary fundamental research, and the coordination and pooling of resources between Member States and industry. Its stated targets include: 'Innovation Union' to improve framework conditions and access to finance for research and innovation so as to ensure that innovative ideas can be turned into products and services that create growth and jobs; 'A Digital Agenda for Europe' to speed up the roll-out of high-speed Internet and reap the benefits of a digital single market for households and firms; and 'An Industrial Policy for the Globalisation Era' to improve the business environment, notably for SMEs, and to support the development of a strong and sustainable industrial base able to compete globally.

Financially, the Europe 2020 strategy reiterates the goal of raising European research and development spending to 3 percent of gross domestic product (GDP) from its current level of below 2 percent.

Also, this year the European Commission adopted two major initiatives to initiate changes to the financial regulations and simplify the procedures with regard to the EU's research Framework Programmes. As well as making it easier for researchers to gain access to EU funds, the new rules are aimed at facilitating more public and private funding and enable new EU programmes to get up and running.

In particular, these initiatives will help to further strengthen the Seventh Framework Programme (FP7), which since its inception in 2007 has been a key driver in commercialising the results of research and identifying the potential of new technology. The RF and microwave industry has been a significant beneficiary of its efforts and continues to be so, with current initiatives including:

- GIGARADIO – Radio technologies for short-range gigabit wireless
- SATURNE – Microsystems based on wide band gap materials for future space transmitting ultra-wideband receiving systems
- MITEPHO – MIcrowave and TErahertz PHOtonics



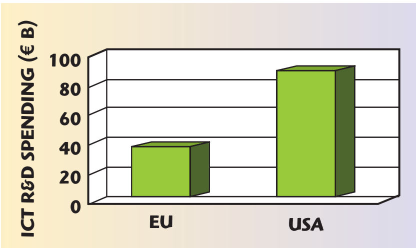
- WIMAGIC – Worldwide interoperability microwave broadband access system for next generation wireless communications
- FLEXWIN – Flexible microsystem technology for micro and millimetre-wave antenna arrays with intelligent pixels
- GRAPHENERF – Graphene-based radio frequency electronics
- NEMSMART – Development of high-performance and high-reliability NEMS switches for smart antenna structures
- PAR4CR – Partnership for the development of cognitive radio
- DARWIN – Deep mm-wave RF-CMOS integrated circuits.

FP7 is key to the European Research Area (ERA), is a conduit for all research-related EU initiatives and plays a vital role in reaching the goals of growth, competitiveness and employment; along with the Competitiveness and Innovation Framework Programme (CIP) that began in 2007 and extends to 2013, Education and Training programmes, and Structural and Cohesion Funds for regional convergence and competitiveness.

As was referred to previously, a new initiative is the 'Digital Agenda for Europe', which the European Commission launched in May and is one of the seven flagship initiatives under the Europe 2020 strategy. Importantly, the agenda focuses on achieving greater investment in research and development and the use of information and communication technology (ICT) to address challenges facing society. Under the Seventh Framework Programme, a total of €9.1 B has been earmarked for funding ICT research (relative to total ICT R&D spending; see ***Figure 2***).

The EU also supports the international Cooperation in Science and Technology (COST) programme, which was set up to expand and coordinate nationally funded research on a European level. It is a collaboration of a total of 36 countries, including EU Member States, eight Associated Countries (Bosnia and Herzegovina, Croatia, the Former Yugoslav Republic of Macedonia, Iceland, Norway, Switzerland, Serbia and Turkey) and one cooperating state (Israel). Currently, close to 300 projects in nine key domains including materials, physical and nanosciences; Earth system science and environmental management; and information and communication technologies are being carried out with support from COST.

Looking forward, the European Union's Research and Innovation Strategy, which, at the time of going to press, is scheduled to be published by September 2010, will focus on the major societal challenges, have a broad definition of 'innovation' and seek to remove bottlenecks to the flow of knowledge.



▲ *Fig. 2 Total ICT R&D spending in billion € (2007) (courtesy of European Commission).*

However, the future of the European RF and microwave industry is not just dependant on technological and economic development, but also lies in its ability to engage, encourage, stimulate and support potential young designers and engineers that are vital for the industry to evolve technologies that will be the commercial future.

The RF and microwave industry is highly knowledge intensive, which has grown and profited through nurturing and investing in an educated and skilled workforce over the years. It is multidisciplinary, requiring understanding on a number of levels and demands a strong commitment to learning. The challenges the industry faces is to persuade the young, who are faced with a multitude of options, that RF and microwave design and engineering can be a rewarding and an exciting career choice. Such rhetoric has to be backed up by a structured path to learning at least up to PhD level that is recognised across Europe, which continues via formal routes for developing and maintaining research and production activity between universities and research centres and industry.

The Lisbon Strategy states that the 'knowledge triangle'—research, education and innovation—is a core factor in European efforts to meet its goals and lies at the EU's aim to become the "most dynamic competitive knowledge-based economy in the world".

SECTOR OVERVIEWS

Against this background, how is the European microwave industry faring? Which fields are seeing particular activity and growth? The most likely place to find answers to these questions is the 2010 European Microwave Week in Paris, so this report has enlisted the chairs of the four EuMW conferences to offer overviews of their sector of the market.

RF & MICROWAVES

Sector overview by Danielle Vanhoenacker-Janvier, EuMC 2010 Conference Chair

Radio and microwave technologies are widely used in mass market applications such as wireless and optical networks, radio and television broadcasting, mobile communications and global positioning systems (GPS). Additionally, these technologies are employed for a wide range of applications, including RF identification and sensors, ultra-wideband communication systems, healthcare systems, intelligent transport and car safety systems, earth observation, security and defence. European industries are particularly strong in mobile and satellite communications and radar.

Wireless portable devices are driven by cost down road-mapping with a high level of integration using standard foundry technologies, while microwave professional and niche markets are driven by performance with specific technology features. The size of the global microwave semiconductor market is close to $4 B and is growing by seven percent a year. High volume production is moving away from Europe, but European companies have a long tradition for developing new added-value systems and

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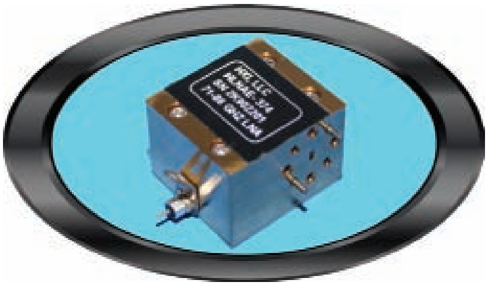

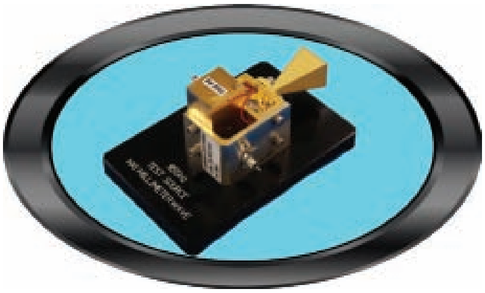

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applications, in collaboration with research centres and academia. Future trends will be in integration of wireless devices and systems (System-On-Chip) and performance breakthroughs in professional markets, which will result in technology and product architecture innovations. This is particularly true for the base station sector where energy management and power consumption reduction is a strong driver.

Upscale cars already incorporate technology driven safety features, but soon all cars will be equipped with basic safety equipment such as radar. The market volume is still low, but will increase rapidly, assuming the challenge of European standards (for road radar and vehicle-to-roadside communication) is solved. Microwave electronic tolling systems are already in use, which speeds up goods transportation; these new applications will continue to have an impact on the automotive industry.

Also, robust and secure communication systems are necessary for the deployment of rescue forces to tackle natural or man-made disasters. Radio and microwaves are essential for these purposes because they can provide communications, direction finding and sensing. In the field of transport security, the recent development of THz imaging systems increases the capacity of concealed weapon detection and security scanning systems.

Significantly, it is not just the development of technology that we should be concerned about, but also the progression of the engineers and designers who will develop it. As a university lecturer, I am eager to attract young people to pursue careers in the field of microwave engineering. In recent years there has been a marked lack of interest in microwave electronic studies in various European countries, even though industries are opening up positions in the field. There is no doubt that if the foreseen shortfall in microwave engineers in the near future becomes a reality, it will impair the further development of the European microwave industry.

On the other hand, Europe is aware of the importance of being ahead of the developments in microwave and millimetre-wave technologies. Interest groups like EuRaMIG and associations like Eu*M*A are bringing together people from industry, research centres and academia for further development, and close contact is being maintained with the US and Asian countries in order to develop new collaborations.

ICS & SEMICONDUCTORS

Sector overview by Frédéric Aniel, EuMIC 2010 Chairman

[In collaboration with M. Laboureau (President of UMS SAS France), M. Leclerc (UMS SAS) and H. Maher (OMMIC)]

Telecommunication, defence, automotive, space and imaging systems require RF and microwave ICs using different processes, with semiconductor devices and ICs forming the core of today's microwave and mm-wave sys-

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					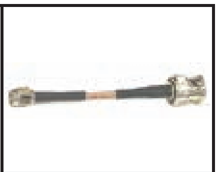
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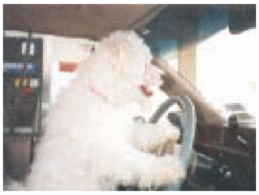
FAIRVIEW MICROWAVE



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tems. European microwave companies and research centres produce, develop and are involved in research that covers a broad range of technologies, which play an increasingly significant role in everyday life and open up new opportunities for economic development. Nowadays, applications have spread to a multitude of technological fields: mobile communications, new digital televisions, next generation radar systems, radiolocation devices and extremely high frequency systems that extend to the THz region.

With regards to the marketplace itself, the III-V semiconductor industry is still suffering from the 2008/2009 financial crisis, although the consequences were not as catastrophic as those of the telecom crisis of 2000/2001. This is due, to some extent, to the technological evolution and innovation the III-V European industries are undertaking (e.g., Fablight) and also because the defence market was partially spared.

Against this background, in this brief overview of the IC/Semiconductors sector, I would like to identify, from the European point of view, the present and future trends, stressing how the technology is evolving and where the greatest impact is likely to be.

Silicon technologies are steadily improving their operating frequency and their level of integration, as is illustrated by RF automotive electronics where Si-based technologies are without rival, except for anti-collision equipment. Also, Si-based processes combine low cost and ease of on-chip integration of RF or AMS circuits and digital functions.

Gallium Arsenide technology continues to be the driving force in many of the RF/HF industries, ranging from telecommunications to defence. GaAs can still compete with other technologies and remains the benchmark in terms of performance.

Gallium Nitride technologies are able to provide very high RF power density over a wide frequency range at excellent power added efficiency (PAE) and also exhibit high values of breakdown voltage under high temperatures. For example, GaN HEMT could surpass LDMOS technology with regards to base station power amplifiers. There is currently dynamic academic research and industrial development in the GaN devices sector. For instance, in the second half of 2010, UMS SAS will be introducing lumped 0.5 µm GaN technology.

Other issues include the advancement of plasmonics for QCL in the THz range. HF semiconductor device technologies could play a major role in the near future in the development of the THz sector, providing tuneable sources and detectors under moderate bias conditions at low cost, thus narrowing the gap between the microwave and optics domains.

The microwave photonics interdisciplinary area continues to be a dynamic topic giving rise to increasing research efforts, as does the development of wafer-scale graphene RF electronics, with graphene and CNT seeing a significant amount of research activity. The development of millimetre-wave and submillimetre-

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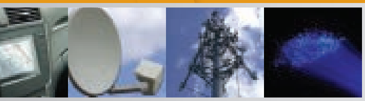

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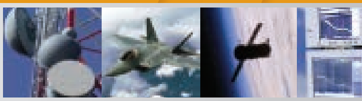

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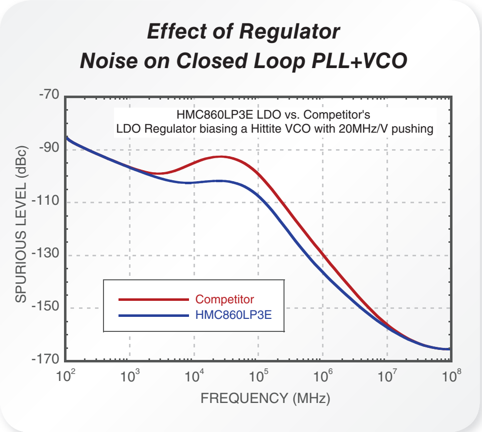

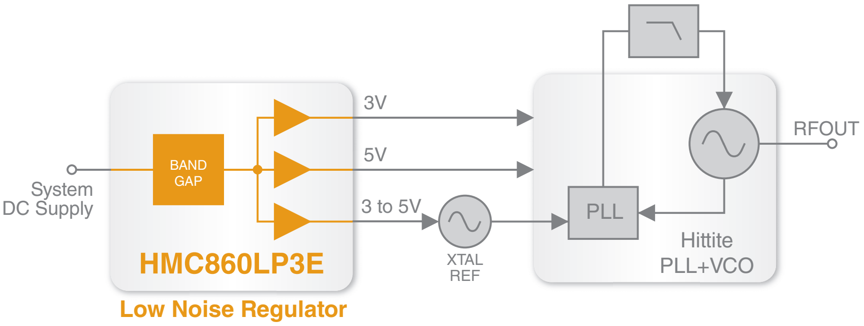

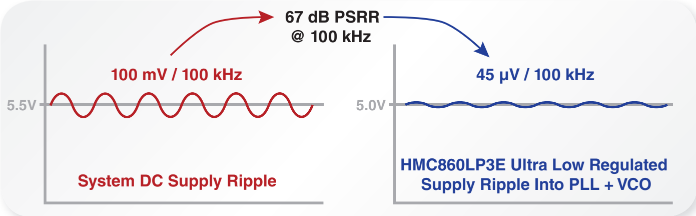

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	0.78 - 0.87	-120 dBc/Hz	-147 dBc/Hz	+12	190	0.05	**HMC824LP6CE**
NEW!	0.795 - 3.78	-108 dBc/Hz	-143 dBc/Hz	+7.5	120	0.07	**HMC838LP6CE**
	0.99 - 1.105	-118 dBc/Hz	-145 dBc/Hz	+10	190	0.07	**HMC826LP6CE**
NEW!	1.05 - 4.82	-110 dBc/Hz	-140 dBc/Hz	+7	120	0.09	**HMC839LP6CE**
	1.285 - 1.415	-116 dBc/Hz	-142 dBc/Hz	+10	190	0.10	**HMC828LP6CE**
	1.33 - 1.56	-115 dBc/Hz	-142 dBc/Hz	+10	190	0.10	**HMC822LP6CE**
	1.72 - 2.08	-113 dBc/Hz	-140 dBc/Hz	+10	190	0.12	**HMC821LP6CE**
	1.815 - 2.01	-112 dBc/Hz	-141 dBc/Hz	+9	190	0.13	**HMC831LP6CE**
	2.19 - 2.55	-110 dBc/Hz	-139 dBc/Hz	+10	190	0.17	**HMC820LP6CE**
	3.365 - 3.705	-107 dBc/Hz	-135 dBc/Hz	0	190	0.25	**HMC836LP6CE**
	7.3 - 8.2	-102 dBc/Hz	-140 dBc/Hz	+15	196	0.55	**HMC764LP6CE**
	7.8 - 8.5	-102 dBc/Hz	-139 dBc/Hz	+13	193	0.58	**HMC765LP6CE**
	11.5 -12.5	-100 dBc/Hz	-134 dBc/Hz	+11	181	0.78	**HMC783LP6CE**
	12.4 - 13.4	-98 dBc/Hz	-134 dBc/Hz	+8	175	0.81	**HMC807LP6CE**

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wave devices and circuits from SiGe to III-V compounds is continuing to progress. Furthermore, III-V integration on Si and III-V isolated gate FETs are among the leading themes driving research in Europe.

Also, the need to reduce the cost of module manufacture, which is extremely high, is provoking continued demand on the packaging of MMICs using SMD technology for frequencies up to 40 GHz and beyond. In the 30 to 60 GHz frequency range, the enhanced plastic QFN has proved to be very useful and efficient, while beyond 60 GHz, EM coupled plastic packages and wafer level packaging techniques are helping to reduce costs.

Finally, I would like to stress that advanced simulation and modelling is a key factor in achieving RF and HF circuits and systems. Thermal modelling appears to be a key issue for high power devices such as GaN HEMT and especially for ultra short gatelength transistors. New models have to be developed to simulate accurately the thermal behaviour of such devices.

WIRELESS TECHNOLOGIES

Sector overview by Geneviève Baudoin, EuWiT 2010 Conference Chair

Since the success of GSM, wireless communication has been one of Europe's most active technological sectors. Over the last 10 years, the worldwide growth of the mobile industry has exceeded all the predictions with more than 4.6 billion mobile phone subscribers in the world today.

We have moved from cellular phones dedicated to talk to 'smart' phones or communicating devices integrating different types of short-range wireless connectivity (Bluetooth, WiFi, NFC), mobile TV and radio receivers, GPS receiver, multimedia sensors, various other sensors such as accelerometers, with sufficient computing power to support all the features of a personal digital assistant and technologies such as speech recognition, and 3G broadband wireless connection allowing for mobile internet and, of course, telephony.

In the past two or three years, we have seen the actual penetration of mobile broadband (3G and soon 4G) connections enabling mobile Internet access and generating new mobile services and applications such as social networks or augmented reality. These applications necessitate outdoor on the move broadband links and indoor ultra-broadband connections to support future 3D television programmes, for example.

Wireless technology is also diffusing into new areas such as transport, environmental monitoring, healthcare, e-inclusion, machine-to-machine communication (M2M) with the 'Internet of things' and the management of emergency situations. Most of the new applications rely on wireless communications associated with location technology and information providers. In the field of transport, the ongoing normalization work on transport information—e.g., Service Interface for Real time Information (SIRI)—facilitates the development of multimodal information servers

and traveller information applications on mobile devices.

Such evolution creates new challenges for research and innovation that cover the four main fields of the EuWiT conference: applications and standards, systems and signal processing, antennas and propagation, and key architectures and sub-systems for base stations and terminals.

For applications and standards, we can cite millimetre-wave mobile communications with low power consumption, autonomous communicating sensor networks and Body Area Networks. With regards to systems and signal processing the main trends are flexible and spectrum-aware radio access, cognitive radio and cooperative systems, and green energy aware wireless systems.

In the field of antennas and propagation, hot topics include the design of small antennas for personal communications devices in which many services in different frequency bands have to coexist, compact MIMO arrays, antenna and sheet-like waveguide for wearable and body-centric applications, electromagnetic modelling of complex environments such as the human body and modelling of non-stationary channels for vehicular communications.

MIMO and OFDM techniques have emerged as enabling technologies for 4G communication systems. They have also generated new challenges in terms of transmitter architectures with good efficiency and linearity, and in terms of integration of MIMO transceivers in mobile terminals. For base stations, a good compromise has been reached with Doherty power amplifiers using digital predistortion and GaN technology.

For mobile terminals, the evolution of wireless systems involves the introduction of more intelligence and dynamic reconfigurability in the transceiver in order to obtain more efficient spectral resource management and better transmission quality with low energy consumption. To take advantage of digital CMOS technology, RF analogue blocks are migrating to the digital domain (frequency synthesis, digital mixing and amplification, for example) and digital signal processing is used for RF Impairment Correction and Built In Self Test (BIST).

Finally, the European Commission is playing a major role in the definition of the strategic research agenda, and supported in the Sixth Framework Programme (FP6) work on 'systems beyond 3G', which led to the design of LTE technology. The first commercial products and services using LTE technology have just begun in Europe. Within the FP7 future networks research programme, the EC has already funded many projects organized into three clusters: Converged and Optical Networks, Radio Access and Spectrum, and Future Internet Technologies. The European Network of Excellence in Wireless Communications (NEWCOM++) gathers researchers from 17 major European institutions working on the Network of the Future, mainly on 'Ubiquitous network infrastructure and architectures.'

One of the biggest projects launched by the ICT Call 4 is ARTIST 4G, which intends to offer ubiquitous user experience in cellular mobile systems through innovations related to interference management and new relay concepts.

RADAR

Overview of European radar activities by Philippe Eudeline, EuRAD 2010, Conference Chairman

The 7th European Radar Conference (EuRAD 2010) reflects the continued activity and attraction of the radar sector in Europe and worldwide. With regards to specific needs, the European radar industry is developing new equipment and systems that are capable of addressing new threats, either for military applications such as Tactical Ballistic Missiles (TBM), piracy and illegal fishing or civil applications like the detection of birds, the wind farm environment and wake vortex detection.

In particular, these new requirements have a huge impact on the development of: radar architecture to accommodate new functionalities and improved performance; active array antennas with very high power T/R modules to withstand range requirements; and dedicated algorithms to detect very small targets (birds) or avoid clutter on wind farms.

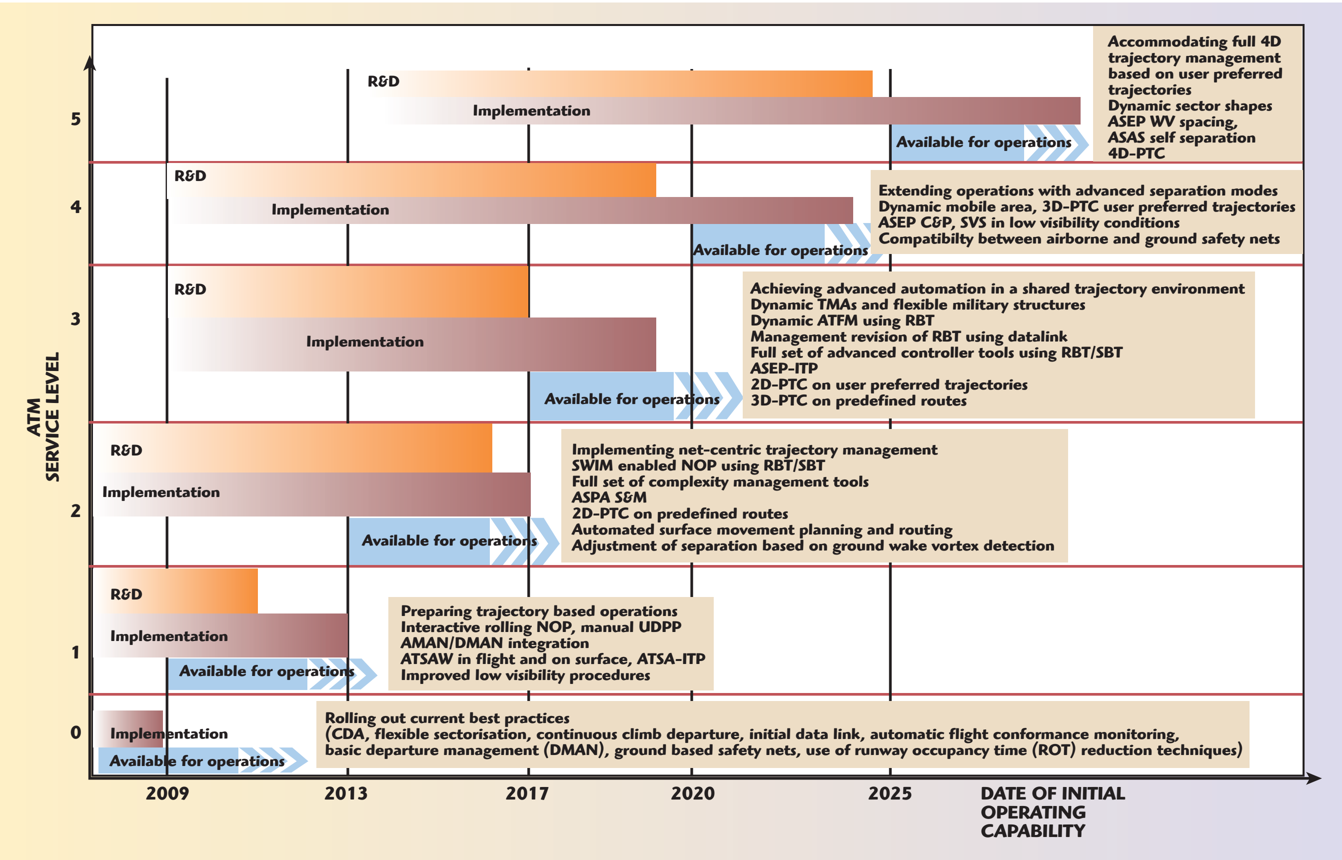
All these developments have to be carried out in the face of intense competition from US radar companies. To enhance their position, connections between the European radar industry and European universities are being forged to enable them to work closely together to jointly develop future advanced radar capabilities and also increase the involvement of European SMEs, with the aim of achieving cost targets.

Antenna scattering and measurements, radar signal processing and system simulation, radar architecture and systems are all key considerations. They are being developed for civil applications such as air traffic control (see ***Figure 3***), meteorological, wake vortex detection and coastal radar as well as military applications such as airborne, weapon systems, air defence, passive radars, environmental remote sensing applications, space-time adaptive processing, through-the-wall radar imaging, ultra-wideband radar, multilateration, new radar waveforms, including those with communication capabilities, sky-wave and ground-wave Over-the-Horizon (OTH) radar, Active Electronically Scanned Arrays (AESA) and Multifunction Phased Array Radar (MPAR).

Although the interest in coastal radar has been prompted, in some countries, by increased incidents of piracy, there are also issues such as sea clutter and environmental issues that are being addressed concurrently. Other innovations to be aware of are in the fields of MIMO and networked radar, automotive radar sensors in the millimetre frequency range, CAD tools and advanced techniques for radar and telecom systems design, waveform-agile radars, etc.

CONCLUSION

The sector overviews demonstrate the depth and scope of the current technological activity in the European RF and microwave industry. The industry has a vital role to play in helping to shape modern life, be it the ever expanding world of communications,



▲ *Fig. 3 Air traffic management plan for Europe (courtesy SESAR Consortium).*

the maintenance of a greener more efficient environment or the defence and security of individuals and nations.

This European perspective outlined the collective measures that the European Union and European Commission have put in place to ensure that these activities are encouraged, supported and sustained by providing the political, financial and technological framework necessary for SMEs, large companies, academia and research institutes to each fulfil their critical roles in the value chain.

Indeed, new programmes such as the Europe 2020 strategy, the EU's Research and Innovation Strategy, and the Digital Agenda for Europe have been initiated to provide the structure, funding and incentives that will enable companies and institutions to forge the necessary partnerships and alliances that will stimulate the development of technology. It is encouraging that these initiatives, along with the necessary funding, both public and private, are being put in place at a time when they are needed most. The Seventh Framework Programme, in particular, has laid the foundations for commercialising the results of research and realising the potential of new technology, with significant and ground-breaking projects in the RF and microwave sector initiated.

The focus of this report has been on the European RF and microwave industry—political and financial influences, the infrastructure that supports it, and the main fields of activity and development. Of course, most European companies, research institutes, etc., operate on the global stage, with many being part of, or partnered with, international organisations. The global market offers significant challenges as some traditional markets have been squeezed, while the competition to gain commercial advantage in emerging 'new technology' markets is fierce, with Asian companies in particular making their presence felt.

It is imperative that Europe maintains a strong industrial base in order to compete globally. In the current environment, that means taking advantage of the collective strengths of the European Union and the routes to development that have been put in place and for companies/organisations to play to their individual strengths such as R&D, service or innovation.

One weakness is the number of young microwave engineers being recruited. If the shortfall that has been predicted materialises, it will have a significantly detrimental effect on the further development of the European microwave industry. Academia and industry have both made efforts to accommodate student/trainees, but perhaps it is not enough simply to make academic places and work positions available. Young people need to be attracted to our industry and maybe more needs to be made of the fact that our field of expertise facilitates access to social networks, games, movies, helping the planet and maintaining Homeland Security.

The title of this report asked if the European microwave industry was on the road to recovery? No one would claim that there has been anywhere near a full recovery from the ills that have been suffered over the past few years. However, the technological activity highlighted in this report demonstrates that the lifeblood of our industry—invention and innovation—is still flowing strongly. ■

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SPST								
0.2 – 2	SW1-002020RN1NF	1.7	70	1.6:1	10/10	20	35	35/70
2 – 8	SW1-020080RN1NF	2	80	1.7:1	10/10	20	35	35/70
4 – 12	SW1-040120RN1NF	2.2	80	1.7:1	10/10	20	35	35/70
2 – 18	SW1-020180RN1NF	3	80	2:1	10/10	20	35	35/70
1 – 18	SW1-010180RN1NF	3	70	2:1	10/10	20	35	35/70
SP2T								
0.2 – 2	SW2-002020RN1NF	1.5	70	1.6:1	10/10	20	35	60/60
2 – 8	SW2-020080RN1NF	1.8	80	1.7:1	10/10	20	35	60/60
4 – 12	SW2-040120RN1NF	2.2	80	1.7:1	10/10	20	35	60/60
2 – 18	SW2-020180RN1NF	2.8	80	2:1	10/10	20	35	60/60
1 – 18	SW2-010180RN1NF	3	70	2:1	10/10	20	35	60/60
SP3T								
0.2 – 2	SW3-002020RN1NF	1.6	70	1.6:1	20/20	150	180	85/85
2 – 8	SW3-020080RN1NF	1.9	80	1.7:1	20/20	150	180	85/85
4 – 12	SW3-040120RN1NF	2.4	90	1.7:1	20/20	150	180	85/85
2 – 18	SW3-020180RN1NF	3	80	2:1	20/20	150	180	85/85
1 – 18	SW3-010180RN1NF	3.1	70	2:1	20/20	150	180	85/85

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MIXED-SIGNAL ACTIVE LOAD PULL: THE FAST TRACK TO 3G AND 4G AMPLIFIERS

The current trend towards increased data rates in mobile services has direct implications for the power amplifiers operating in these systems, which now need to be not only efficient but also wideband and, above all, linear. To operate efficiently, an amplifying device needs to see its optimum terminations at the input and output. Although basic amplifier theory suggests that an almost infinite number of harmonics need to be controlled to establish a particular device class of operation (such as (inv.) Class B, E, F),[1] in practice, control of the fundamental, second and third harmonic is most of the time sufficient to achieve high performance. Furthermore, in order to operate linearly, the active device requires—in addition to a proper control at its fundamental and harmonic impedances—the correct baseband or envelope impedance, which, in the circuit implementation, is mostly determined by the biasing networks at the device input and output.

Since active devices operate in a large-signal/nonlinear mode when reaching high efficiency operation, the properties of the device under test (DUT) cannot simply be extrapolated from small-signal measurements. Consequently, active devices intended for large-signal operation need to be characterized under the exact same conditions as in their final application. To address this need, harmonic load-pull measurement systems have become a widely established tool. In these systems, the (harmonic) reflection coefficients offered to the device under test are "physically" varied to find the optimum (harmonic) loading conditions at the device input and output. With this optimum set of loading conditions the final matching circuit for the active device can be designed. Load-pull systems can be divided into two main categories: passive and active.

PASSIVE TUNER-BASED SYSTEMS[2,3]

A typical passive load-pull configuration, shown in ***Figure 1a***, makes use of sliding mechanical probes to tune the reflection coefficient. The bias tee placed after the tuner reduces the impact of its losses, but yields larger memory effects due to the baseband inductance. These kinds of systems are currently still the preferred industry large-signal test bench choice, due to their simplicity and high power handling capabilities. Unfortunately, passive load-pull setups are constrained by losses in the tuners, connecting cables and wafer probes, which limit the magnitude of the reflection coefficients that these systems can provide to the DUT.

MAURO MARCHETTI
Anteverta Microwave B.V.
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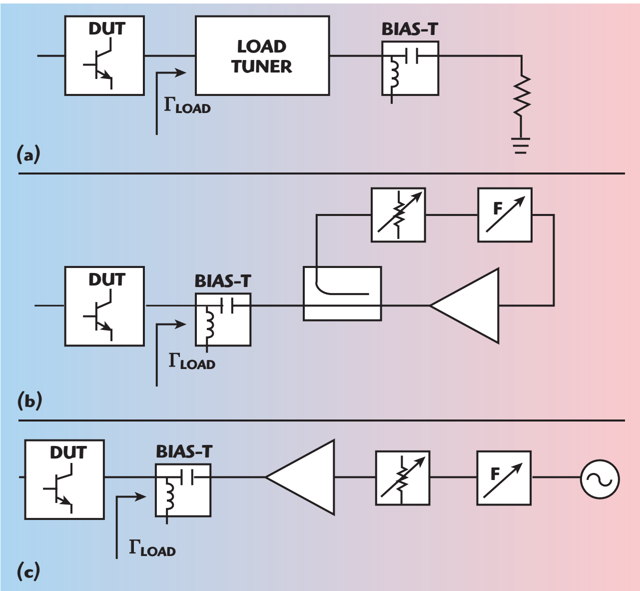
ACTIVE LOAD-PULL SYSTEMS

Active systems can, thanks to the use of amplifiers, overcome the reflection magnitude restrictions due to losses. Two main types of active systems can be identified, namely:

- Closed-loop active systems[4] achieve their desired reflection coefficient by coupling out of the main path (using directional couplers) a portion of the wave generated by the DUT, adjusting it in amplitude and phase and then injecting it back as an incident wave to the active device (see ***Figure 1b***). Here, the bias tee is placed as close as possible to the DUT to reduce unwanted memory effects. Since the injected signal is a direct function of the coupled wave, the loop gain and phase shift determine the reflection coefficient independently of power and spectral content of the signal. This makes the closed-loop concept suitable for fast device characterization, but also prone to oscillations since the loop gain cannot be very selectively controlled over frequency. To avoid the risk of oscillation, most closed-loop systems include sophisticated filtering.
- Open-loop active systems[5] instead do not reuse the waves generated by the DUT, but directly inject a signal into the DUT, which is phase coherent with the input signal to the device, to compose a desired reflection coefficient (see ***Figure 1c***). The desired reflection coefficient is created by adjusting the amplitude and phase of the injected wave. Here also, the bias tee is placed as close as possible to the DUT, to reduce the memory effects caused by bias path inductance. Since the injected signals are no longer a modified version of the waves generated by the DUT, the realized reflection coefficients are power and signal dependent. Therefore, iterations are needed during the measurements to find the optimal injection signals to offer the desired reflection coefficients to the DUT.



▲ *Fig. 1 Typical load-pull configurations.*

ELECTRICAL DELAY IN LOAD-PULL SYSTEMS

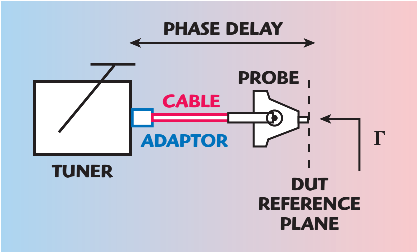
When working with modulated signals, for a well controlled linearity behavior of the DUT, the reflection coefficients offered to the DUT should ideally be constant (not vary versus frequency) within the modulation bandwidth at the fundamental, as well as in all related frequency bands at baseband and harmonic frequencies. This situation is approximated in real circuit implementations, where the matching networks are placed directly at the reference planes of the active device.

In conventional load-pull setups, however, the actual physical impedance is always located at some distance from the DUT (see ***Figure 2***), which is much larger than for any practical matching network. This distance, as well as any physical length within the tuning element itself (such as the length of the active feedback loop, or the position of the probe in mechanical tuners), yields very large electrical delays causing rapid phase changes of the reflection coefficients versus frequency. Typical values for these phase fluctuations can vary from approximately 3°/MHz for a passive mechanical tuner to 30°/MHz in a conventional active closed-loop system (see ***Figure 3***). Note that based on these values for a W-CDMA signal with adjacent and alternate channels (total bandwidth of 25 MHz), the reflection coefficient offered by a passive tuner would vary 75° in phase over this bandwidth, while in a conventional active closed-loop the phase change of the offered reflection coefficient would amount to 750°.

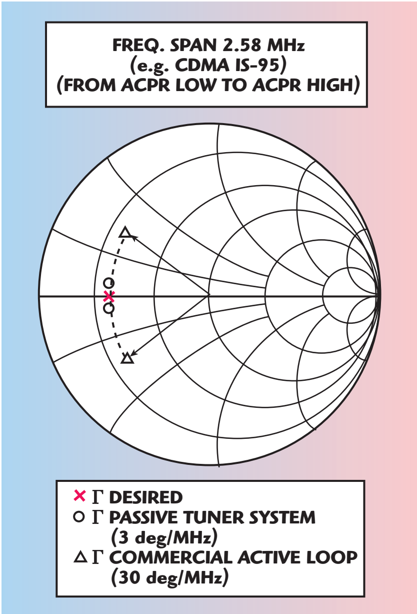
It is clear that these large phase deviations represent nonrealistic circuit conditions and will cause measurement errors such as IM3 asymmetry, spectral re-growth and EVM degradation. In general, maintaining the reflection coefficients constant over frequency is getting more and more difficult with the increase in modulation bandwidth of communication signals, not only in practical circuits, but definitely in load-pull measurement setups.

MIXED-SIGNAL LOAD PULL FOR WIDEBAND IMPEDANCE CONTROL

To overcome the aforementioned problems of losses and electrical delay



▲ *Fig. 2 Phase delay caused by electrical lengths of cables/adaptors/probe.*



▲ *Fig. 3 Reflection phase rotation at the DUT reference plane.*

in conventional load-pull characterization systems, while being able to work with realistic wideband communication signals, some major measurement system innovations are required. The principle of the proposed wideband open-loop active load-pull approach is shown in ***Figure 4***. When the nonlinear DUT is excited with a user-defined modulated signal a_s, it generates signals in the baseband, fundamental and higher harmonic frequency bands. By measuring the device reflection coefficient at every frequency, the waves to be injected are estimated at every iteration. When the required reflection coefficient versus frequency (at every controlled band) is achieved, the iteration has converged and the large-signal parameters (that is power added efficiency, output power, intermodulation distortion, etc.) are measured. To address these needs a novel open-loop system was developed[6] employing wideband signal generation and signal acquisition. A simplified block diagram of such a system is given in ***Figure 5***.

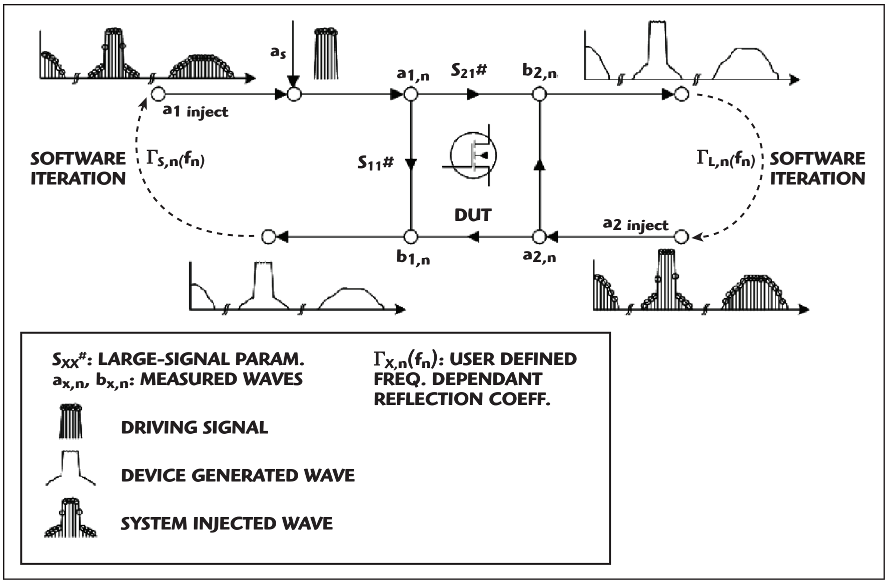


Fig. 4 Principle of the proposed wideband open-loop active load-pull approach.

SIGNAL GENERATION

When working with complex modulated signals, a good place to start is the modulation test standard.[7,8] According to the test standard, a test signal is created, which consists of a finite sequence of IQ data samples specified in the time domain. In conventional lab instrumentation such as vector-signal generators, this sequence for a given standard (such as W-CDMA) is typically embedded in the instrument. In testing operation, these signals are uploaded in internal arbitrary waveform generators (AWG) and upconverted with IQ mixers yielding the modulated RF signal. In practice, these test records are sequentially repeated, yielding in the frequency domain a large but finite number of discrete spectral components. More precisely, the number of samples, in combination with the sampling speed

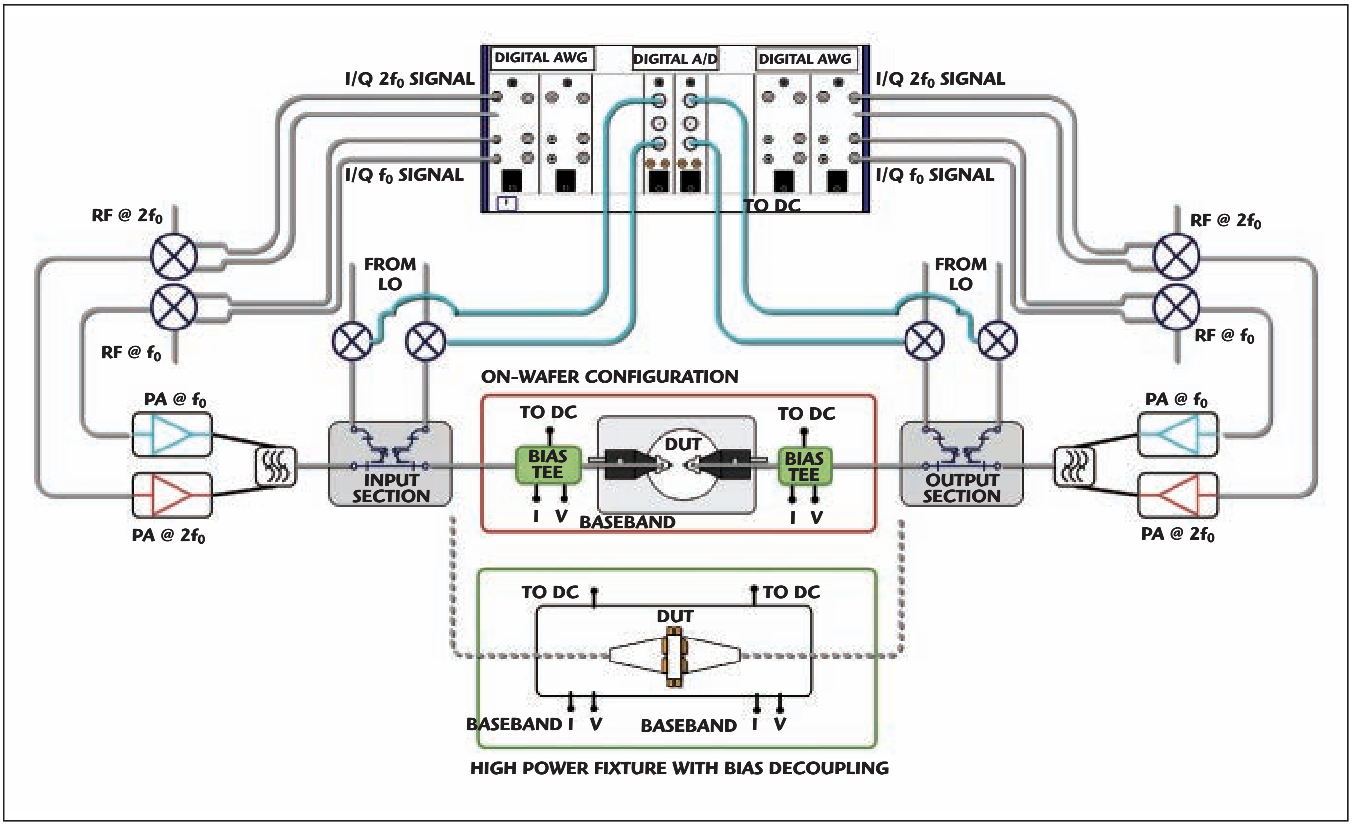


Fig. 5 Simplified schematic of the mixed-signal active open-loop load-pull system.

at which the signal is generated, results in an effective frequency bin size (Δf_{AWG}), or frequency resolution of the generated signal

$$\Delta f_{AWG} = \frac{fs_{AWG}}{N_{AWG}} = \frac{1}{T_{MOD}} \qquad (1)$$

where Δf_{AWG} represents the frequency bin size of the generated signals, fs_{AWG} and N_{AWG} are respectively the sampling frequency and the number of samples used by the arbitrary waveform generators, and T_{MOD} is the time period of the source signal that is needed to meet the requirements of the modulation standard according to the given test model.

To provide the reader with an example, a W-CDMA signal has a channel bandwidth of 5 MHz, a chip rate of 3.84 Mcps, 2560 chips/slot and 15 slots/frame. When considering one frame, the complex waveform is 10 ms long or, in other words, it will have a frequency resolution of 100 Hz. If then a single slot is considered, the frequency resolution becomes 1.5 kHz. This frequency representation allows one to analyze modulated communication signals like "classical" multi-tone signals, but now with a very large number of frequency tones.

SIGNAL ACQUISITION

A fraction of the waves incident and reflected by the DUT is taken by the directional couplers and fed to high linearity mixers that down-convert the signals for digitization after which an FFT is applied to obtain their spectral content. Also here the sampling speed of the A/D converter and the time span used for the data-acquisition set an effective frequency bin size, which must be compatible with the original applied test signal, as described by the following expression

$$\Delta f_{A/D} = \frac{fs_{A/D}}{N_{A/D}} = \frac{\Delta f_{AWG}}{k} = \frac{1}{kT_{MOD}} \qquad (2)$$

where $\Delta f_{A/D}$ is the resulting frequency bin size of the acquired signals, $fs_{A/D}$ and $N_{A/D}$ are respectively the sampling frequency and the number of samples used by the A/D converters, and k is an integer.

CONTROLLING THE REFLECTION COEFFICIENTS

When testing a nonlinear device with modulated signals, the measured waveforms will include not only the fundamental frequency band, but also the baseband, higher-order harmonics and intermodulation distortion products (see Figure 4). Since the reflection coefficient is defined as the ratio of two travelling waves, the effective control of the impedances over the whole modulation bandwidth offered to the DUT can be enforced by establishing the desired linear ratios of the incident and device generated waves on the DUT versus frequency. Or, in other words, a signal must be injected, at all the frequency components of interest, according to the linear relation,

$$a_{x,n}(f_n) = b_{x,n}(f_n) \cdot \Gamma_{x,n}(f_n) \qquad (3)$$

in which $a_{x,n}$ and $b_{x,n}$ are the incident and reflected waves at port x and harmonic index n, while $\Gamma_{x,n}$ represents the user defined reflection coefficient versus frequency for port x and harmonic index n. As in the classical open-loop approach, the new b-wave, containing all the frequency components of the signal of interest (that is more than 23000 frequency tones for a W-CDMA signal in a 35 MHz band), can be created from scratch, and any desired reflection coefficient behavior versus frequency can be created by adjusting the amplitude and phase of the injected waveform independently at each frequency component of interest.

Although conceptually simple, this method requires very fast highly linear data acquisition with high dynamic range to measure the reflection coefficients at every spectral component of the complex modulated signals with its related distortion products. Secondly, the a-waves need to be generated arbitrarily with a high dynamic range. Third, the signal injection at the various ports needs to be phase coherent at both the RF frequencies as well as at the baseband.

PRACTICAL IMPLEMENTATION

The block diagram of the system implementation is shown in Figure 5. The wideband reflection coefficients at the DUT reference planes are measured by coupling the traditional mixer-based super-heterodyne down-conversion used in conventional VNAs with wideband A/D converters (100 MHz sampling frequency). This hardware configuration enables the measurement of the device reflection coefficients over a wide bandwidth in a single data acquisition interval. Wider bandwidths, up to 120 MHz, can be measured by stepping the frequency of the local oscillator used for down-conversion.

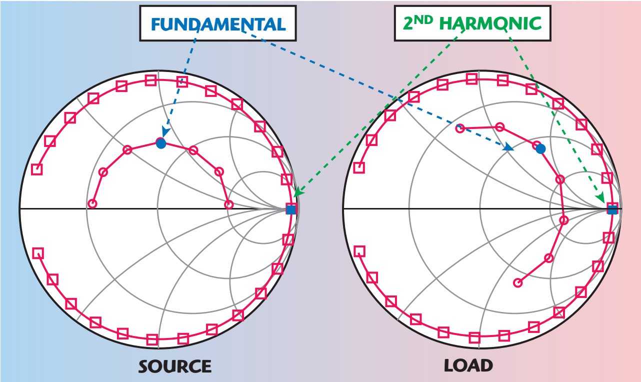
The fundamental and harmonic frequency loads are synthesized by injecting fully coherent RF signals that are generated by IQ up-converted baseband signals, which are provided by (200 MS/s) arbitrary-waveform-generators (AWG). Custom bias tees with low inductance are placed directly at the DUT reference planes in order to minimize the electrical delay of the baseband (BB) impedance, implemented here as a passive impedance switch bank.[9] On the baseband board also, the low-frequency couplers for the baseband impedance measurement are implemented. Note that in a more extended version, the baseband impedance can also be made active and controlled by an additional AWG.

WIDEBAND MEASUREMENT RESULTS AND COMPARISON

To demonstrate the unique capabilities of the setup, a NXP Gen 6 LDMOS device with a gate width of 1.8 mm was measured. In the experiments, the drain current and voltage are set to 13 mA and 28 V, respectively. In this experiment, the optimum fundamental load and source matching conditions are found to be $\Gamma_{L,f1} = |0.6|\angle 45°$ and $\Gamma_{S,f1}=|0.5|\angle 90°$, while the input and output baseband impedances are set to a short condition. In addition, the input and output 2nd harmonics are set to circuit-like open conditions ($\Gamma_{L,f2} = \Gamma_{S,f2} = |0.95|$) to optimize the efficiency.

To highlight the excellent controllable bandwidth and the electrical delay-free operation of the new measurement setup, a comparison is made with a previously developed state-of-the-art active harmonic load-pull system,[9] which was especially optimized for minimum electrical delay. For this purpose, a two-channel W-CDMA signal is used (centered at 2.135 and 2.145 GHz) and the input and output reflection coefficients in the newly developed setup are set to the following two cases:

- without electrical delay
- with an electrical delay of 4.85°/



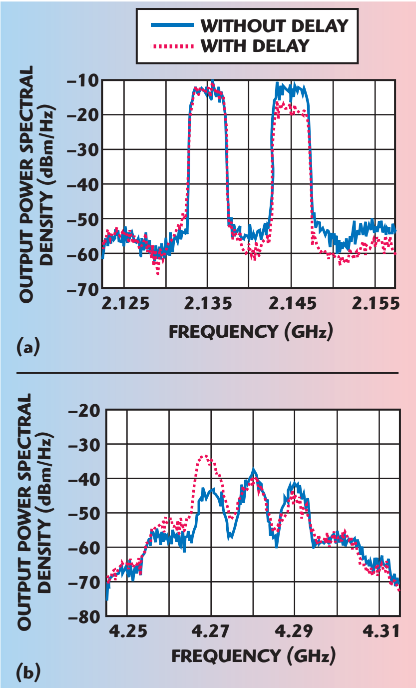
▲ *Fig. 6 Source and load reflection coefficients at the device reference plane.*

MHz for the fundamental source and load and 4.6°/MHz for the 2nd harmonic source and load

Figure 6 illustrates the source and load matching conditions in the fundamental (2.1225 to 2.1575 GHz) and harmonic (4.245 to 4.315 GHz) frequency range provided to the active device under test, with electrical delay (open symbols) and without electrical delay (filled symbols). Note that the filled markers represent the source and loading conditions for the two-carrier W-CDMA signal without any electrical delay, yielding completely overlapping points in the Smith chart. As shown in Figure 6, for the case with electrical delay, the fundament load trajectory has been shifted, such that the optimum matching condition is now centered at 2.135 GHz. This was required to avoid the unstable region of the active device.

It is important to note that this is a comparison to the "best possible case" of a classical closed-loop active load-pull system, since practical closed-loops will be subject to amplitude variations within the control frequency bands. Moreover, oscillation conditions in closed-loop systems for these very large bandwidths are difficult to avoid, due to the usage of wideband loop filters. Passive load-pull systems will have a comparable variation of the reflection coefficients versus frequency than the closed-loop system used in this comparison. The phase change can be even worse if high-Q resonators are used to control the harmonic terminations.

The measurement results are summarized in ***Table 1***. There is significant performance degradation for the measured active device when the electrical delay is present in the reflection coefficients. This is also evident from ***Figure 7***, which shows the power spectral density at the device output reference plane for the fundamental and 2nd harmonic frequency bands. Note that a 5 dB output power drop and close to 8 percent degradation of the power added efficiency (PAE) can be observed, when compared to the case with no electrical delay. It is important to stress that this performance degradation is a measurement artifact, the result of an incorrect measurement, which would mislead the user in judging the device performance.



▲ *Fig. 7 Measured output power spectral density vs. frequency of a NXP GEN6 LDMOS device: (a) at fundamental and (b) at second harmonic.*

TABLE I

MEASUREMENT RESULTS

	Without electrical delay	*With electrical delay*
PAE	24.2%	16.3%
P_{OUT} Ch. 1	20.3 dBm	20.5 dBm
P_{OUT} Ch. 2	20.6 dBm	15.4 dBm
ACLR1 Ch. 1	-43.9 dBc	-43.0 dBc
ACLR2 Ch. 1	-42.2 dBc	-41.6 dBc
ACLR1 Ch. 2	-42.1 dBc	-41.8 dBc
ACLR2 Ch. 2	-39.6 dBc	-39.2 dBc

ACTIVE LOAD INJECTION POWER AND LINEARITY

To provide the DUT with a specific Γ_L, a certain injection power is needed, which not only depends on the output power of the DUT and the desired Γ_L, but also on the output impedance of the device.[10] When considering high-power devices, with output impedances in the order of few Ohms, the required injection power to cover the desired Smith chart area can be extremely high (2 to 10 times higher than the maximum output power of the DUT). To overcome this issue, typically, a pre-matching is used, which converts the 50 Ω impedance of the system to a value that is much closer to the output impedance of the DUT, thus reducing the power requirement of the load injection amplifier.

To give an example, a DUT with an output impedance of 2 Ω and an available output power of 200 W requires, when the system impedance is pre-matched to 10 Ω, an injection power of 360 W to synthesize a load impedance of 1 Ω. Reducing the system pre-matched impedance to 5 Ω lowers the required injection power for the same load condition to 142.2 W.

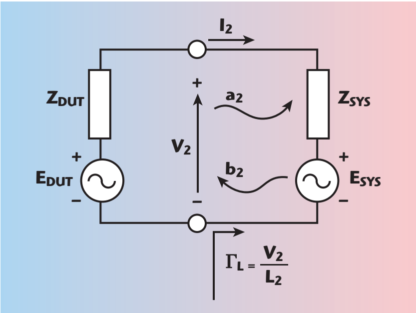
When considering multi-tone or modulated signals, the situation becomes more complicated as the linearity of the injection amplifier needs to be taken into account. To study the linearity constrains on the injection amplifier, consider a two-tone test signal, for which the power injected by the load amplifier at the IM3 frequencies of the two-tone test signal is given by

$$P_{a_2,IM_3} = 3P_{a_2,fund} - 2IP_{3,a_2} = \tag{4}$$

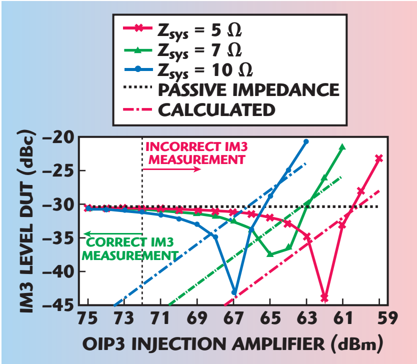
$$= 3P_{b_2,fund}\frac{(1-|\Gamma_{DUT}|^2)}{(1-|\Gamma_{SYS}|^2)}\cdot\frac{|Z_{DUT}+Z_0|^2}{|Z_{SYS}+Z_0|^2}\cdot\frac{|Z_L-Z_{SYS}|^2}{|Z_{DUT}+Z_L|^2} - 2IP_{3,a_2}$$

where Z_{DUT} and $P_{b_2,fund}$ are the output impedance and the available power coming out of the DUT (see ***Figure 8***). The load impedance offered to the DUT at the reference plane is varied by adjusting the equivalent voltage source ESYS in amplitude and phase. The related power needed to synthesize depends strongly on the equivalent system impedance Z_{SYS}, which is the passive load impedance at the DUT reference plane; $P_{a_2,fund}$ and IP_{3,a_2} are the power injected by the load amplifier and its output third-order intercept point, respectively.

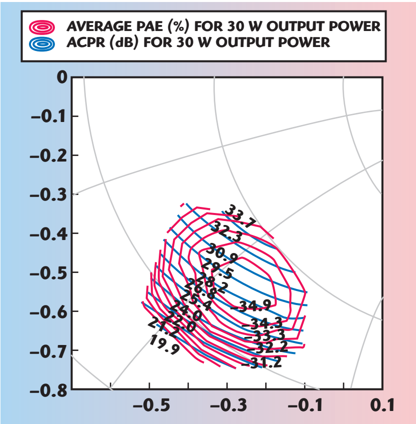
Figure 9 shows the results of a harmonic balance simulation, where the apparent IM3 of the DUT versus decreasing output IP3 of the injection amplifier is shown for different pre-matching conditions of the system impedance. The dotted line is the actual IM3 level as would be achieved with passive matching techniques. The dot-dashed line represents the IM# level due to the $P_{a_2,IM3}$ as approximated by Equation 1. A polynomial model was used for the amplifier linearity. In this experiment, the same DUT is used as for the single-tone considerations (P_{avs} = 200 W, output impedance = 2 Ω), which is set in the simulation to have an output IP3 of 63 dBm. For this device the output power is set equal to 50 W per tone, to have the same peak voltage as in the single-tone case. These conditions yield an actual IM3 of the DUT of -30.35 dBc. From Figure 9, it can be seen that this level (a correct measurement) is only achieved for sufficiently high IP3 of the injection amplifier. When the injection amplifier is less linear, it will introduce significant IM3 products, which can be approximated by Equation 4, and are also plotted in Figure 9. Note that IM3 cancellation effects can also occur. Consequently, to have reliable linearity measurements in a conventional active load-pull setup, even when pre-matching is used, the injection amplifier linearity (and thus its peak power) needs to be at least 10 times higher than that the of the DUT.



▲ *Fig. 8 Thevenin equivalent schematic of an active load-pull configuration.*



▲ *Fig. 9 Harmonic balance simulated IM3 level vs. output IP3.*



▲ *Fig. 10 Measured load-pull contours of average power added efficiency and ACPR for an averaged output power of 30 W.*

It is obvious that at high power, these amplifiers, if available, will be extremely expensive. For this reason, active load-pull systems that can offer communication standard compliant device testing, for example W-CDMA, at base station power levels (100 W and above) have not yet been demonstrated.

In a mixed-signal load-pull system, an iteration procedure is performed to obtain a user-defined reflection coefficient at each individual frequency component of a complex modulated signal, in and out of band. Due to these iterations, the injection amplifier is basically pre-distorted for its own nonlinearities, which allows the use of injection amplifiers with a much lower linearity than what is typically required in conventional active load-pull systems. As an example, consider ***Figure 10***, which shows the ACPR and average PAE for a single-channel W-CDMA signal at 2.14 GHz, with a peak to average ratio of 9.5 dB. In these experiments the injection amplifier used has a maximum saturated power rating of only 200 W with an associated 60 dBm output IP3, while the reflection coefficient is controlled over a 35 MHz frequency span.

CONCLUSION

Mixed-signal techniques have been applied to extend the capabilities of traditional active load-pull setups. The realized system provides an unprecedented measurement speed, high dynamic range and is currently the only system that can handle communication standard compliant signals that are truly wideband such as multicarrier W-CDMA. The ability to eliminate losses and electrical delay, while being completely free in defining the source and load reflection coefficients versus frequency, allows perfect mimicking of in-circuit situations, making the system a tool of fundamental importance for the RF power amplifier developer. ■

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ACTIVE MODE-COUPLINGS ENABLE HIGH FREQUENCY FUNDAMENTAL VCXOs

This article reports a novel circuit for high frequency fundamental voltage-controlled crystal oscillators (VCXO) using an active mode-coupling mechanism. The reported VCXO circuit has the characteristic features of low drive level, fast start-up and high negative resistance for the realization of HHF/VHF frequency applications. The performance of the active mode-coupled VCXO circuit is validated by an experimental evaluation of 622 MHz fundamental crystal resonators. The typical measured phase noise at 10 kHz offset for a carrier frequency of 622 MHz is –141 dBc/Hz, with an operating bias of 5 V, 10 mA, which is 10 to 15 dB superior to commercially available 622 MHz SAW VCO reference frequency standards.

The increasing demand of the wireless communication service creates a demand for broadband networks and higher operating frequencies in the market place. As the operating frequency shifts higher, the generation of low drive level, fast start-up, low phase noise and stable reference signal sources with low cost become challenging due to the frequency limitations of crystal resonator and device circuitry.[1-12]

Many research works[6-10] have exploited different circuit architectures of Colpitts-type circuits, which usually play a role in improving start-up time, drive level and negative resistance characteristics of the crystal resonator above the 500 MHz range. However, they exhibit inferior phase noise performance in comparison to commercially available surface acoustic wave (SAW) resonator-based reference frequency standards at 622 MHz and above in the gigahertz ranges.

Recent analysis indicates that, by decreasing the Miller capacitance of the transistor used for the conventional Colpitts-type crystal oscillator, a reasonably high negative resistance value can be achieved in a gigahertz frequency band.[4,5] Reducing the Miller capacitance improves the negative resistance values at UHF/VHF ranges, but at the cost of poor jitter, thermal stability and phase noise performances. To meet the above challenge, most such effort is in the direction of employing a phase locked loop (PLL) using a crystal resonator. The drawback of this approach is spurious oscillations in the fundamental mode due to the multiplying mechanism by the PLL circuit. This is causing deterioration in jitter characteristics and introducing bit error in the communication systems.[4]

Therefore, designing a low phase noise high frequency VCXO as a reference frequency standard is challenging for a given cost, size, stability, phase noise and power consumption. In this work, a high frequency VCXO topology is reported that has the characteristic features of high negative resistance and low drive level, while maintaining the thermal stability and phase noise performances. The reported

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VCXO circuit is validated by modifying a conventional Colpitts oscillator with an active mode-coupling mechanism that optimizes the performance of crystal oscillators, even those with relative low Q resonators, for low phase noise and high frequency fundamental VCXO applications.

DESIGN THEORY

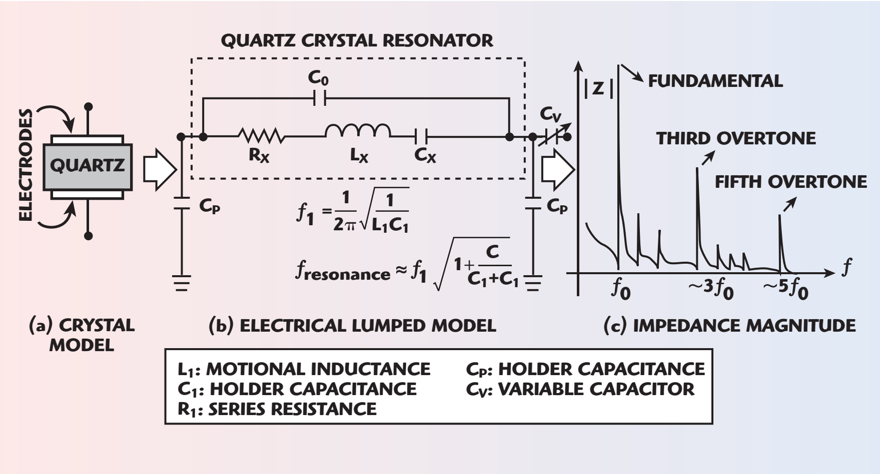
An important application of the crystal resonator is in a VCXO, where the crystal resonator is typically incorporated in series with a tuning diode to vary the oscillation frequency. But these resonators suffer from multi-mode resonances and crosstalk due to the large value of the series resistance (R_s) and parasitic holder capacitances (C_0) at UHF/VHF frequencies (see ***Figure 1***).

Crystal Resonator

Quartz crystal is a piezo-electrical material in which mechanical deformations due to vibrations (compression/torsion/shear) cause potential differences across the distinct surfaces and vice versa. With two electrodes evaporated on the quartz crystal, an electrical model is obtained that typically exhibits a multi-mode resonances pattern. The figure shows the typical impedance characteristics of an electromechanical crystal resonator, which vibrates due to the piezo-electric effect and exhibits multi-mode resonances. As depicted, to the right of the fundamental response, the next major response is the third overtone, then the fifth overtone, and so on.[11]

Since the crystal does not produce harmonics, overtone responses are not the harmonics of the fundamental. To design a high performance crystal oscillator, the oscillator circuit topology determines the crystal configuration (fundamental, overtone, parallel and series). In other words, the oscillator circuit topology forces the crystal resonator into either the fundamental (lowest major resonant response), overtone (major responses other than fundamental), parallel (one of the inductive regions of the crystal's reactance curve as shown) or series (one of the resistive points on the crystal's reactance curve) operation.

As described, the motional parameters (L_x, C_x and R_x) govern the natural series resonance, whereas C_0 is the parallel holder capacitor and C_v denotes the tuning diode capacitor required for pulling up the resonant frequency.



▲ *Fig. 1 Typical quartz crystal: (a) electrode model, (b) lumped element model and (c) impedance characteristics.*

The series (f_s) and parallel (f_p) resonances are given by[11]

$$f_s(\text{series mode}) = \frac{1}{2\pi\sqrt{L_x C_x}} \tag{1}$$

$$f_p(\text{parallel mode}) \approx f_s\left(1+\frac{C_x}{2C_0}\right)\Bigg|_{C_0>C_x} \tag{2}$$

As illustrated, the electrode holder capacitance C_0 supports the pole that implies a parallel resonance (f_p) and can be viewed as a parallel resonant circuit with capacitive transformations. From Equations 1 and 2, the mode separation (f_s - f_0) can be expressed through the figure of merit M as[11]

$$M = \frac{2Q(f_p - f_0)}{f_0} \tag{3}$$

From Equation 3, the figure of merit M describes the existence of series (f_s) and parallel (f_p) resonance modes. Therefore, due care must be taken for suppressing the unwanted resonance mode; otherwise, it leads to mode jumping. For stable oscillations, the series resonance frequency f_s (wanted oscillation mode) is to be tuned by a series tuning diode C_v; the relative frequency shift can be expressed as

$$\frac{\Delta f}{f_s} = \frac{C_x}{2(C_0 + C_v)} \tag{4}$$

From Equation 4, the frequency drift can be optimized as a correction factor, but C_v is temperature sensitive and induces relative change ∂f in $f_{resonance}$ (pulled up resonance frequency) as

$$f_{resonance} \approx f_s\sqrt{1+\frac{C_x}{C_x + C_v}}, \quad \frac{\partial f}{f_{resonance}} \approx k_{C_v}\left[\frac{dC_v}{C_v}\right] \tag{5}$$

where k_{C_v} is the temperature coefficient that causes relative frequency fluctuations with temperature as a legitimate penalty to pull up the overall frequency shifted due to holder capacitance C_0 and package parasitics, although the overall performance degrades at higher UHF/VHF ranges.

However, if the condition for resonance at UHF/VHF frequency could be established at the fundamental, the crystal resonator oscillator could be designed with excellent jitter characteristics, without being influenced by the spurious characteristics from fundamental operation.[4]

Start-up and Drive-level Characteristics

Quartz crystal oscillators seem to have reached their limit in terms of the frequency stability. However, they are still attractive as a reference frequency standard for their volume, size, cost and relative low power consumption in steady state, especially for space communications. As the size of the communications equipment and portable electronics

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become smaller, the crystal resonator size also shrinks to meet the real estate constraints. The reduction in crystal resonator size demands for larger activation current in the resonator network.

In the past, a crystal oscillator with automatic gain control (AGC) has been used as a low drive-level VCXO. A typical VCXO with AGC consists of the oscillator stage, amplifier stage and the rectifier stage. The output of the rectifier stage is fed back into the bias circuit to obtain steady-state oscillation at low drive level. Due to the large filter time constant in the rectifier stage, the start-up characteristic is very slow; therefore, an AGC approach is not suited for portable telephone sets, where frequent switch-on and switch-off of the power supply are repeated for the power saving of the batteries. In addition, it is difficult to maintain a low resonator drive-level current IR without reduction in the magnitude of the negative resistance $R_n(t)$ of the conventional Colpitts-type circuit (see ***Figure 2***).

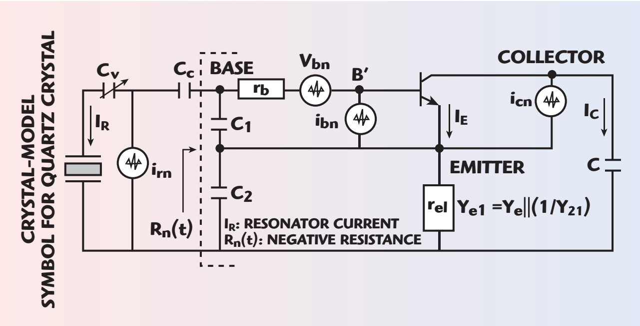
The negative resistance and resonator drive level at steady state can be described for circuits shown as[11]

$$R_n = -\left[\frac{Y_{21}}{\omega^2 C_1 C_2}\right] \tag{6}$$

$$I_R \cong \frac{2I_E}{\omega C_2 R_n} \tag{7}$$

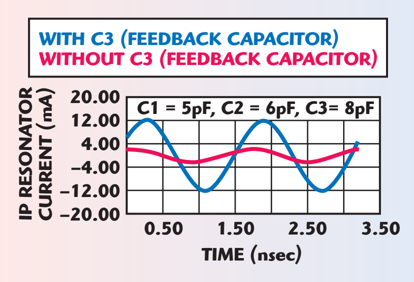
$$Y_{21}\Big| = G_m(x) = \frac{qI_{dc}}{kTx}\left[\frac{2I_1(x)}{I_0(x)}\right]_{x=\frac{g_m I_R}{\omega C_1 I_E}} \tag{8}$$

$I_1(x)$ and $I_2(x)$ are the modified Bessel functions of order 0 and 1, respectively. From Equations 6 and 7, the resonator current drive-level I_R can be lowered by increasing the value of the feedback capacitor C_2 for a given emitter current I_E,

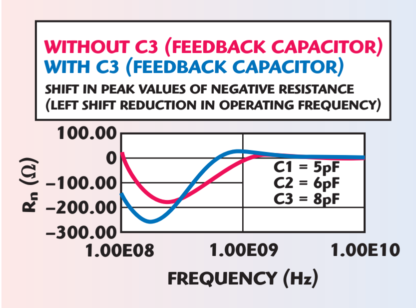


▲ *Fig. 2 Typical Colpitts oscillator circuit including noise contribution.*

but at the cost of reduction in the value of negative resistance R_n. In order to maintain the same value of negative resistance R_n as required to compensate the loss resistance of the resonator at steady-state oscillation, the value of feedback capacitor C_1 has to be reduced. However, there is a practical limitation of the minimum value of the C_1 that is decided by a specified value of the load capacitance of the crystal resonator.[9]



▲ *Fig. 4 Plot of the resonator current for the 622 MHz crystal oscillator.*



▲ *Fig. 5 Plot of the input resistance R_n of the crystal oscillator.*

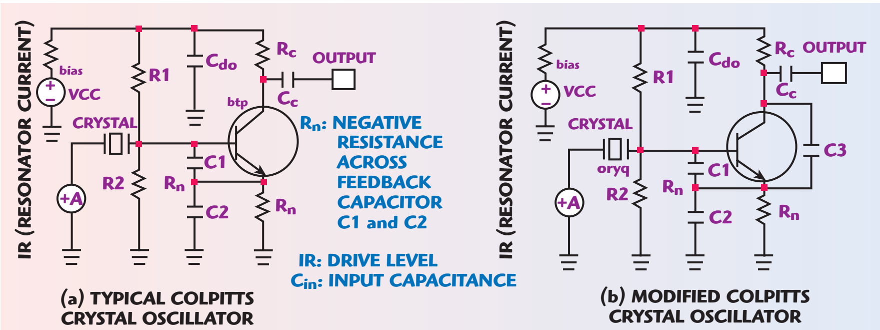
The conventional oscillator toplogy is beginning to approach theoretical limits for a given cost, size, frequency and drive level. Therefore, further reduction in the drive level will concentrate on the new proposed circuit, using a mode-coupling mechanism for improving the start-up, drive level and loss resistance characteristics at higher frequency (UHF/VHF).

UHF/VHF CRYSTAL OSCILLATOR CIRCUIT

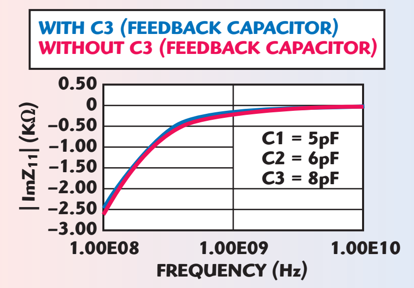
The resonance characteristic of the crystal resonator depends upon the thickness of the resonator. As the resonance frequency becomes higher, the crystal resonator becomes very thin and care must be taken to minimize the resonator drive level to avoid breakage of the resonator at high operating frequency. To avoid the breakdown phenomena of the crystal resonator at high frequency, one can opt for higher series resistance of the crystal that will restrict the level of the current accepted and returned from the crystal but at the cost of increased noise resistance associated with the series resistance R_X.

Figure 3 shows conventional and modified Colpitts oscillator configurations for comparative analysis of drive level and negative resistance characteristics.[6]

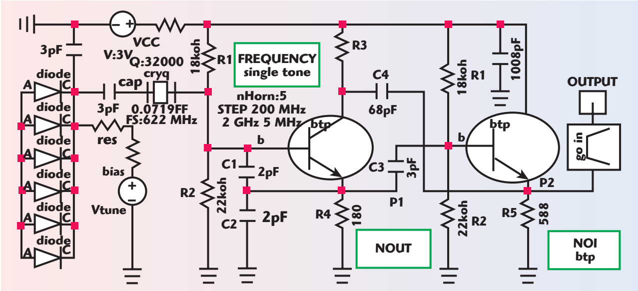
As illustrated, the feedback capacitor C_3 of the modified topology is added to reduce the emitter voltage of the transistor, resulting in lower base current and drive level. ***Figures 4*** and ***5*** show the plot of the resonator drive-level current and negative resistance of the conventional and modified Colpitts oscillators. The feedback capacitor C_3 ($C_3 > C_1$) reduces the resonator current at steady state, but at the cost of shift in the peak value of the negative resistance. Therefore, this is a frequency limited approach. ***Figure 6*** depicts the characteristics of the equivalent input capacitance of the



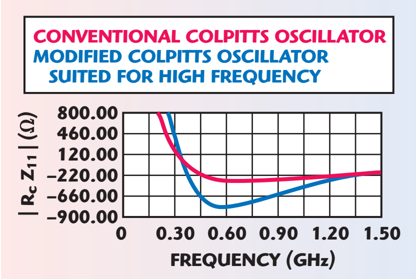
▲ *Fig. 3 Typical Colpitts oscillator: (a) conventional and (b) modified topology.*



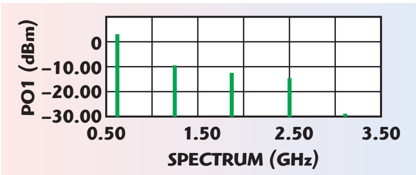
▲ *Fig. 6 Plot of the input capacitance C_{in} of the crystal oscillator.*



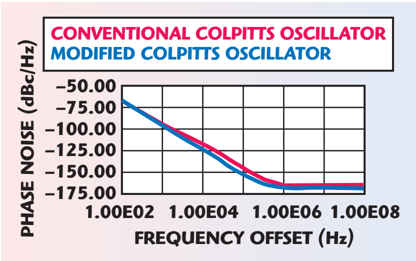
▲ *Fig. 7 Example of a typical high frequency VCXO circuit (622 MHz).*



▲ *Fig. 8 Simulated input resistance of the typical high frequency VCXO circuit.*



▲ *Fig. 9 Simulated output power of the Colpitts oscillator.*



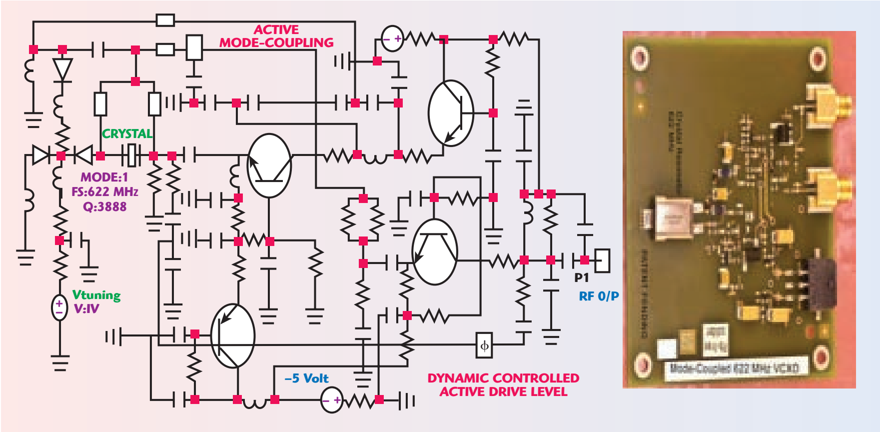
▲ *Fig. 10 Phase noise of the 622 MHz crystal oscillators.*

crystal oscillator circuit. It can be seen that the value of the input capacitance is reduced; therefore, the circuit fails to oscillate at high frequency. In addition, the holder capacitance C_0 of the crystal resonator influences the input impedance of the oscillator circuit in the UHF/VHF range, causing the C_0 to perform at very low impedance at a high oscillation frequency.

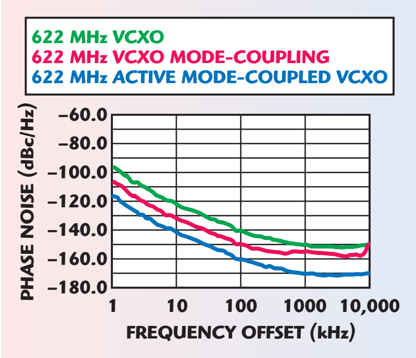
Therefore, in order to apply the conventional circuit to the high frequency operation, it is necessary to obtain reasonably high value of negative resistance, while maintaining the equivalent input capacitance of the circuit. ***Figure 7*** depicts the modified version of the Colpitts oscillator, in which the output signal from terminal P1 of the conventional Colpitts oscillator is fed through the capacitor C_3 into the common-collector amplifier and brings the output signal from terminal P2 of the amplifier back into the collector through capacitor C_4 of the conventional Colpitts oscillator.

Figure 8 shows the plot of the equivalent input resistance of the modified Colpitts crystal oscillator circuit in comparison with the conventional Colpitts toplogy. It can be seen that negative resistance of the modified Colpitts oscillator at 622 MHz is typically twice as large as that of a conventional Colpitts oscillator circuit; therefore, it is suited for high frequency reference signal source applications. The drawback of this approach is the loading due to the feedback capacitor C_4, which is compensated by connecting port P2 into the buffer amplifier for minimum load capacitance and power level variations.[4]

Figure 9 shows the spurious characteristics of the 622 MHz VCXO. It can be seen that output response is a fundamental oscillation, therefore, free from sub-harmonics problems, which can be a major factor to deteriorate the jitter characteristic and phase noise performances of the VCXO. ***Figure 10*** shows the phase noise plot of the conventional and modified Colpitts VCXO at 622 MHz. The typical phase noise plot of the modified version at a 10 kHz offset is 10 dB better than the conventional topology. However, the close-in phase noise performance (below 1 kHz offset) is the same.



▲ *Fig. 11 622 MHz active mode-coupled VCXO (patent pending).*



▲ *Fig. 12 Typical measured phase noise of 622 MHz crystal oscillators.*

ACTIVE MODE-COUPLING ENABLES 622 MHZ VCXO

Although the modified topology exhibits good phase noise performance at a far offset (> 1 kHz), it is still not superior to the commercially available 622 MHz SAW resonator-based oscillator. To overcome the phase noise problem, a novel VCXO circuit is proposed (see ***Figure 11***) using an active mode-coupling mechanism that minimizes the jitter and phase, even those with relative low Q crystal resonators, for low phase noise and high frequency fundamental VCXO applications.

Figure 12 shows that the typical measured phase noise at 10 kHz offset for a 622 MHz carrier frequency is -141 dBc/Hz, which is 10 to 15 dB superior to a commercially available 622 MHz SAW oscillator. At lower offset (1 Hz), the improvement in phase noise performance is limited due to the influence of the 1/f noise, which can be optimized by selecting a transistor that has low value of 1/f noise.

CONCLUSION

This work offers a cost-effective solution and can be applied for a crystal resonator (both high-Q and low-Q)-based VCXOs for substantial reduction in phase noise. ■

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IMPROVED LINEARITY PERFORMANCE OF A PHEMT DRIVER AMPLIFIER USING TUNABLE FIELD-PLATE VOLTAGE TECHNOLOGY

In this study, a high-linearity AlGaAs/InGaAs pseudomorphic HEMT RF driver amplifier was developed using a tunable field-plate (FP) bias voltage technology. In order to improve the circuit linearity performance, an FP device was employed at the output stage to provide an additional mechanism to suppress the power of the second- and third-order harmonics in a two-stage 5.2 GHz driver amplifier. A standard Class AB driver amplifier without using FP technology was also implemented for comparison under identical power consumption. The two-tone measurement in the output stage of the circuit with an FP device biased at V_{FP} = -4 V demonstrated that there is at least a 2 dB improvement of input power at the third-order intercept point (IIP3) over the standard one within the useful power range.

Microwave power devices have recently played an important role in wireless communication systems, in which both the output power density and the device linearity are key factors in increasing the dynamic range, while satisfying the linearity requirements. The electric field profile across the channel of a PHEMT is a key factor affecting the device breakdown voltage, which dominates the device output power density. The surface states caused by DC-to-RF dispersion are another factor that affects the device linearity. A novel technology, where the electric-field is modified by a FP, has resulted in a dramatic improvement in the large-signal performance of GaAs-based microwave PHEMTs.[1–3]

Previous work on GaAs-based HEMTs also proposed increasing the device transconductance as a viable solution to improve device linearity. The advantages of increasing device transconductance have also been demonstrated for AlGaN–GaN HEMTs.[5] In these experiments, the introduction of a field-plated gate structure proved the effectiveness of reducing the dispersion phenomena and was successfully applied on AlGaAs–GaAs and AlGaN–GaN HFETs. However, among the investigations, the FP of the PHEMT is mostly connected to the gate terminal to facilitate the fabrication process of devices. The drawback is that the

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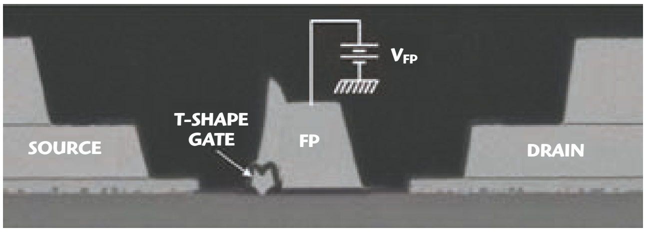
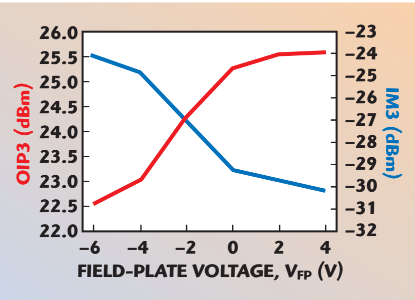
FP-induced depletion region of gate-terminated field plate PHEMTs (FP-G PHEMT) will also be modulated by the input power signal of the gate terminal, which does affect the linearity of a FP-G PHEMT.[6]

An initial study was made in the investigation of the gate terminal effects. First, the field-plate metal of the PHEMT was connected to a single pad and its gate leakage current and RF power performance were evaluated from a V_{FP} of +4 to -10 V. Due to the increasing of C_{gd} from the FP structure by a factor of 150 percent, when compared with a standard device, the result seen through simulation showed a linearity improvement of approximately 3 dB.[7] By applying more negative bias on the field-plate metal, the FP-induced surface depletion region is thicker and the carriers between drain and gate terminals are farther from the surface. Therefore, it is believed that the device DC-to-RF dispersion and linearity of a PHEMT can be improved further. Additionally, the performance of a FP PHEMT can be adjusted by applying various V_{FP} without any DC power consumption. In view of the above advantages, a two-stage 5.2 GHz RF driver amplifier was developed, in which a FP device at the output stage is employed to provide an additional mechanism of suppressing the power of the second- and third-order harmonics. A standard driver amplifier without using FP technology was implemented under identical power consumption for comparison.



▲ *Fig. 1 SEM cross-sectional photograph of the field-plate device.*



▲ *Fig. 2 IM3 and OIP3 vs. V_{FP} of an FP device at 5.2 GHz.*

FIELD-PLATE DEVICE FABRICATION AND MEASURED RESULTS

The epitaxial structure adopted in this study was a double recess design for high breakdown voltage consideration. A 12 nm undoped InGaAs channel layer was sandwiched between two Si planar δ-doped layers for high current and high power consideration. A 28 nm thick n^- AlGaAs layer was grown on an intrinsic AlGaAs spacer layer used as a Schottky layer, which improves parallel conduction at high gate voltage. Finally, a 20 nm n^- GaAs and a 25 nm n^+ GaAs cap layer were grown to improve the resistivity of the ohmic contacts. The etching stop layer between the cap layers and Schottky layer was 1.5 nm of AlAs. For device fabrication, the devices were processed by an optical stepper lithography and lift-off technology. Ohmic contacts were realized by using a Au/Ge/Ni/Au alloy, followed by a 430°C, 15-second, rapid thermal annealing (RTA) alloy. Ion-implant isolation technology was used for mesa isolation to prevent the flow of any side-wall gate leakage current. The sub-micron gate-length exposure was performed using an electron beam lithographic system; a bi-layer resist profile was also applied.

After the highly selective succinic acid chemical gate recess process, 5000 Å-thick Ti/Pt/Au-gates were deposited by a lift-off process. At this stage, the Schottky layer and channel layer beneath the gate recess region were easily oxidized by moisture and generated surface states. Therefore, before the deposition of the FP metal, a 1500 Å SiN_x was deposited by plasma enhanced chemical vapor deposition (PECVD) at 280°C for passivation and insulation between gate and FP metals. The 11000 Å-thick FP metal (Ti/Au =3000Å/8000Å) was then deposited on the SiN_x passivation layer using an electron-beam evaporator. The FP metal extension is identical to the gate recess region because the channel is close to the surface after the recess process, so that the FP induced depletion region is used to keep the carrier far away from the surface states. Finally, a dense SiN_x layer was deposited as a protection layer for improving device reliability. ***Figure 1*** shows the SEM cross-sectional view photograph of the field-plate device.

A fabricated 0.15 µm-long gate PHEMT with a 2.15 µm-long FP metal was tested on-wafer and the microwave power characteristics were evaluated by a load-pull system with automatic tuners, which provides conjugate-matched input and load impedances simultaneously for maximum output power. The microwave load-pull power performance was conducted at 5.2 GHz under a drain bias of 3 V, with various V_{FP}. The field-plate voltages were supplied by a single DC probe with its ground connected with the device source terminal to guarantee the exact field-plate biases. The gate bias was chosen for a Class AB operation. The output power density degraded, following the trends of I_{ds} at various V_{FP}. However, this is not the case for the device linearity characteristics. The third-order inter-modulation (IM3) product from the device output spectra versus the input RF power, which is an important index of the device linearity, was determined by injecting two-tone frequencies, 5.200 GHz (f_1) and 5.201 GHz (f_2). These two adjacent signals generated IM3 output power ($2f_1 - f_2$ and $2f_2 - f_1$) owing to device intrinsic nonlinearity. ***Figure 2*** shows the measured third-order output intercept points (OIP_3) as a function of V_{FP} for a single device.

The OIP_3 was determined by extracting the curves intersection point of fundamental and IM3 output versus input power. The OIP_3 is 22.8 dBm at a V_{FP} of +4 V operation and 25.5 dBm at a V_{FP} of -6 V operation. Furthermore, the IM3 output power of the device with a V_{FP} of -6 V (-30.5 dBm) outperforms the device with a V_{FP} of +4 V (-23.9 dBm) at an input power of -10 dBm. The device performed at a lower output power density at negative V_{FP}, which results in a small dynamic range. However, there are two mechanisms to explain the IM3 improvement at a negative V_{FP} operation. First of all, the gate leakage current (I_g) of a field-plate device

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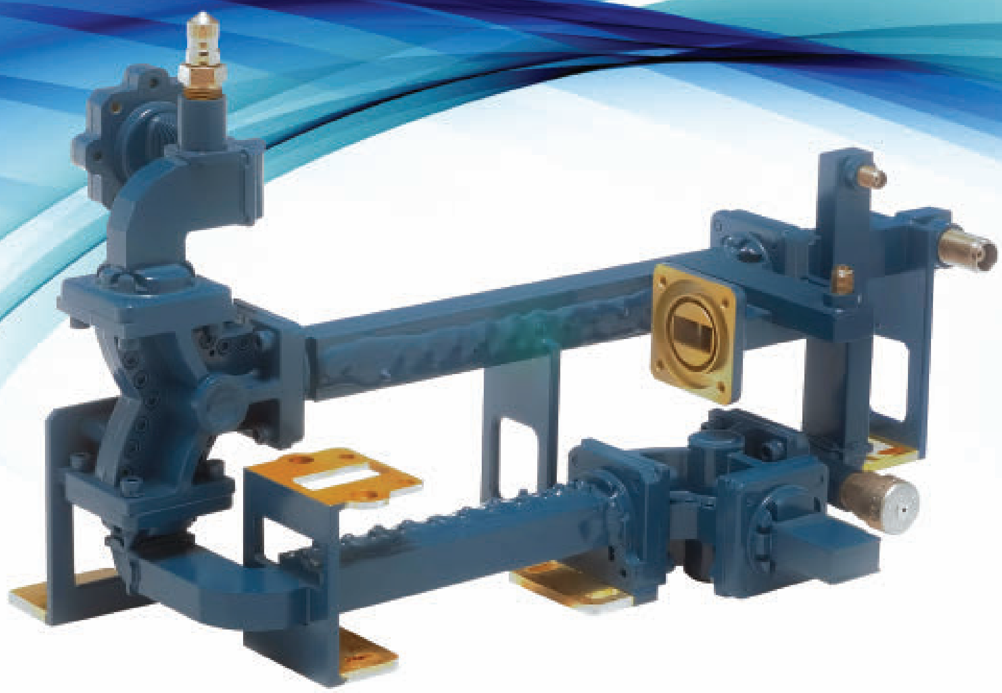

Typical Specifications

Frequency	16.0 - 17.0 GHz
Waveguide	WR62
Transmit VSWR	1.50 Max.
Transmit Loss	1.0 DB Max.
Receive VSWR	1.50 Max.
Receive Loss	1.0 DB Max.
Power (CW)	150W
Power (Peak)	300W
Pressure	15 PSIG
Material	Aluminium/Iridite

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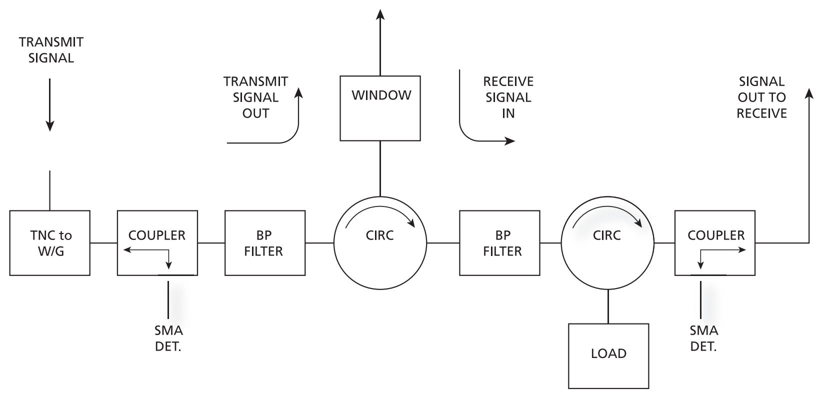

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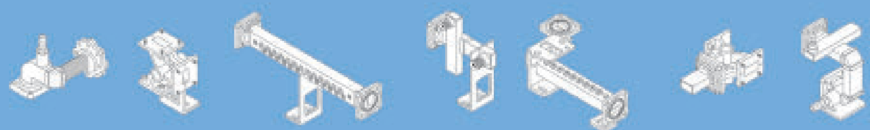

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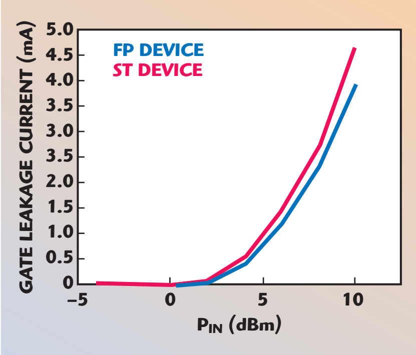
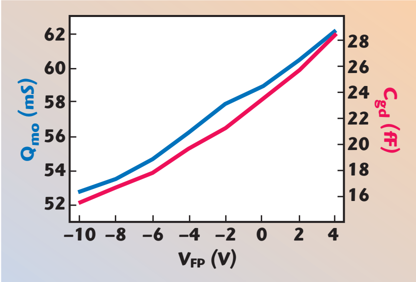


▲ *Fig. 3 Gate leakage current for an FP device and a standard device under identical drain current.*

with a negative V_{FP} is lower than a standard one. ***Figure 3*** compares the gate leakage current characteristics between a fabricated field-plate device and a standard device under identical drain current (I_d). Based on a previous investigation,[8] the higher I_g will generate extra harmonics power and degrade the device linearity.

For the observation of the gate leakage current dependence of V_{FP} in the field-plate structure, the gate leakage current was measured at a bias V_{FP} = -4 V. The measured gate leakage current level for this case is 3.9 mA at P_{in} = 10 dBm, which is 17 percent lower than the reference case of a standard device. This gate leakage current improvement can lead to an increasing of breakdown voltage. Secondly, the carrier transportation path between drain and terminals was suppressed to a deeper channel at a negative V_{FP} and the carriers were kept away from the surface traps, which resulted in small harmonic power and lower DC-RF dispersion. The tunable field-plate voltage technique can effectively adjust the device power and linearity performance in a single device. On the other hand, when developing a high-power amplifier module, the tunable V_{FP} can be applied to select various output power density and optimize their linearity instead of the complicated PHEMT epitaxial structure modification and process-related regulation (the depth or width of the gate recess region). Therefore, this technique exhibits a high potential for retrenching the fine-tuned procedure of the commercial microwave circuit modules without extra DC consumption.

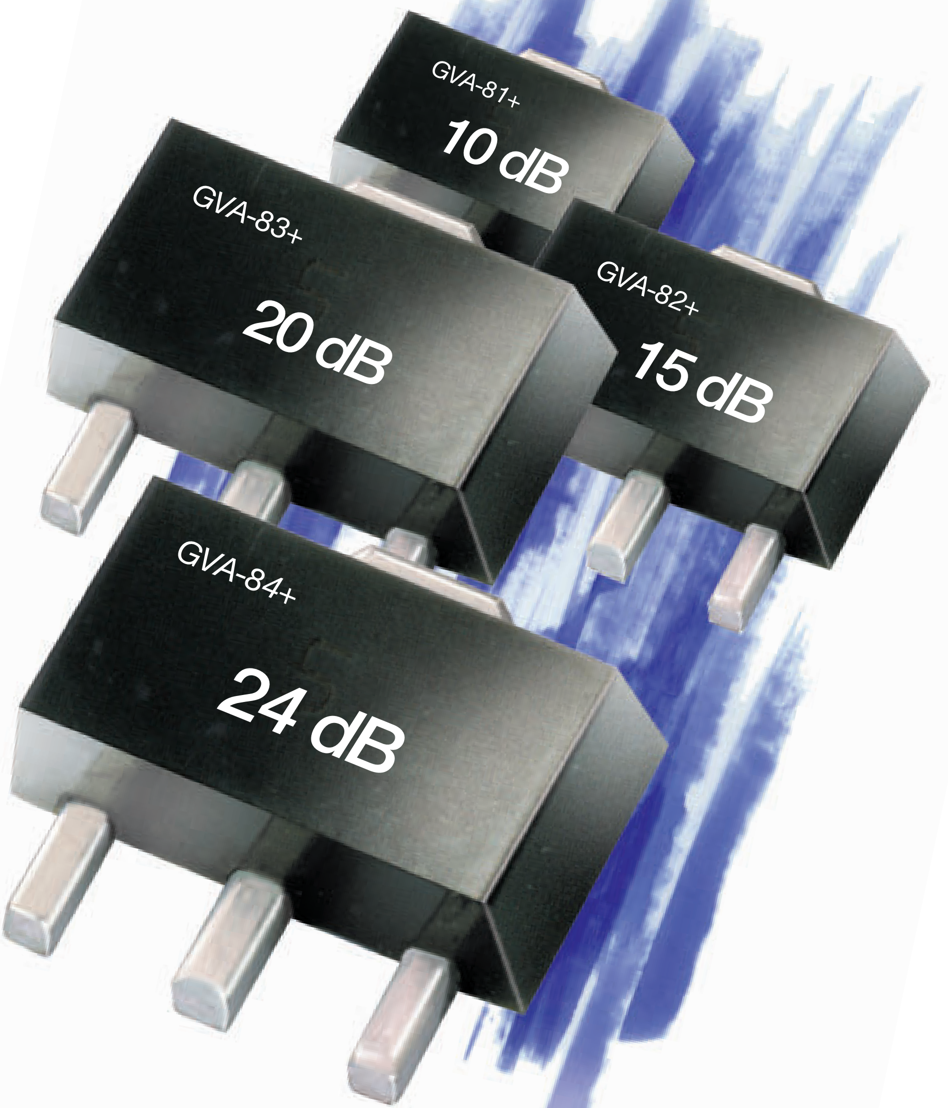
The on-wafer microwave S-parameters evaluation of a W_g = 150 µm



▲ *Fig. 4 C_{gd} and g_{mi} vs. V_{FP}.*

device was carried out in a common-source configuration with an Agilent E8364B PNA network analyzer from 0.05 to 40 GHz. By extracting the equivalent circuit model from the device S-parameters at various V_{FP}, both the gate-to-drain capacitance (C_{gd}) and intrinsic transconductance (g_{mi}) increased with $V_{FP,}$ as shown in ***Figure 4***. However, the gate-to-source capacitance (C_{gs}) was almost identical (≅400 fF) at different V_{FP}. C_{gd} and C_{ds} were strongly influenced by the thickness of the FP-induced depletion region, which is controlled by V_{FP}; this phenomenon also shows the same trend with DC measurement results. Based on the C_{gs} measured results, the gate-to-source depletion region, which is the most important factor to determine the device microwave performance, was less influenced by V_{FP}. In other words, the tunable FP voltage technology can adjust and modulate the device DC and RF characteristics with less sacrifice to the device gain-bandwidth product. Besides, the intrinsic g_m also increased from 53 to 62 mS, which is attributed to the drain current improvement from V_{FP} = -10 V to V_{FP} = +4 V.

According to a previous study,[7] using a nonlinear current method, a Volterra model is extracted from a standard GaN HEMT to predict third-order intermodulation distortion (IMD3), highlighting various distortion mechanisms, by which the dominant distortion behavior is efficiently localized. The simulation results proved that the third-order nonlinearity, arising from the gate-drain feedback capacitance C_{gd}, has a major influence on the total lower third-order intermodulation distortion (IMD3L). Besides the previous observation of developing an FP structure, by which the increasing of C_{gd} was seen through simulation by scaling C_{gd} to 150 percent, the device linearity was


GVA-81+
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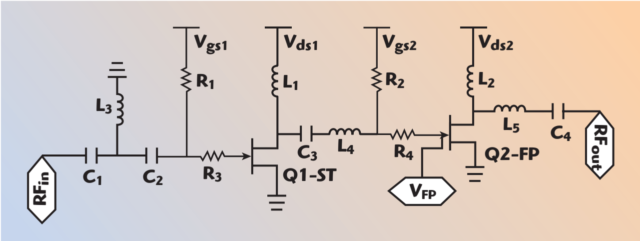
GVA-83+
20 dB
GVA-82+
15 dB
GVA-84+
24 dB



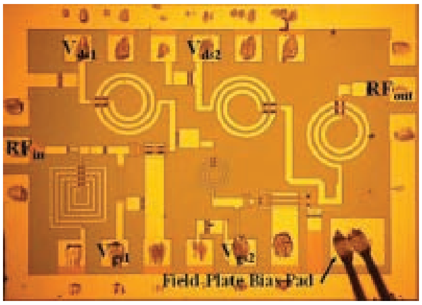
▲ *Fig. 5 Circuit topology of the proposed FP driver amplifier.*

improved by approximately 3 dB. Therefore, it can be concluded that this technology is especially attractive for high-linearity RF circuits with advantages of ease to apply and adjust a moderate V_{FP} bias, no extra DC consumption, and based on a standard fabrication process.[9]

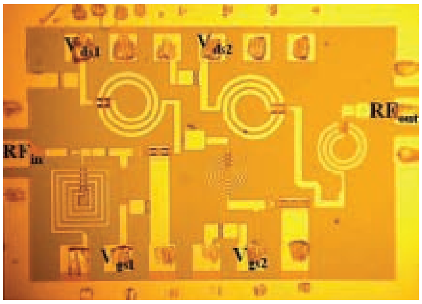
DRIVER AMPLIFIER DESIGN AND MEASURED RESULTS

A 5.2 GHz driver amplifier was demonstrated using a 0.15 µm gate length depletion-mode PHEMT process, using the tunable field-plate bias voltage technology. The FP driver amplifier circuit diagram and the corresponding photograph of the fabricated MMIC for the completed amplifier are shown in ***Figures 5*** and ***6***, respectively. The chip dimensions of the MMIC are 1.5 × 1 mm. A standard driver amplifier was also fabricated for power performance comparison, under the identical design approach as the FP one with the same size. The difference between these two amplifiers was the selection of a standard device or a FP device in the output stage. ***Figure 7*** shows the corresponding photograph of the standard driver amplifier. For both designs, the gate biases were chosen for a Class AB operation with a current of 35 mA for the first stage and a current of 47 mA for the output stage, which is a compromise by considering device output power (P_{out}).

The PA is power matched at the output matching network, which is designed to transfer maximum output power from the FET to a 50 Ω system. According to the Cripps technique,



▲ *Fig. 6 Photograph of the proposed FP driver amplifier.*

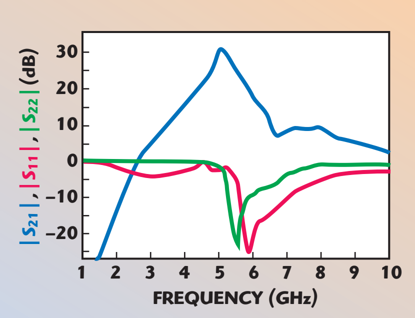


▲ *Fig. 7 Photograph of the standard driver amplifier.*

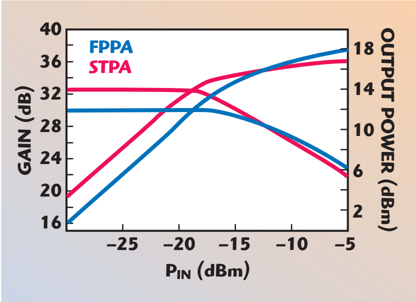
the required optimized large-signal load impedance $Z_{opt,Q2}$ is composed of $R_{opt,Q2}$ and $C_{ds,Q2}$. The output power matching network was designed to transfer the $Z_{opt,Q2}$ to 50 Ω, which comprised a series spiral inductance and a series blocking capacitance. The inter-stage matching network was designed to transfer $Gamma_{IN,2}$ to the $Z_{opt,Q1}$ in order to minimize the mismatch loss. A gate resistor is used in each stage in order to achieve a lossy match and to improve circuit stability. The circuit stability is then further confirmed by the simulation of the stability factor. Finally, the input network was designed to smooth the small-signal gain and to improve the impedance match for a better input return loss.

While considering the FP device power density degrading in terms of trends of I_{ds} with the decreasing field-plate voltage V_{FP} at the output stage, the gate bias of an FP device should be set a little higher to generate identical power density with respect to a standard device. By adjusting the gate bias of the FP device at the output stage with a difference of 0.05 V slightly higher than the standard device, the output current level and DC transconductance could be ensured as high as the standard one.

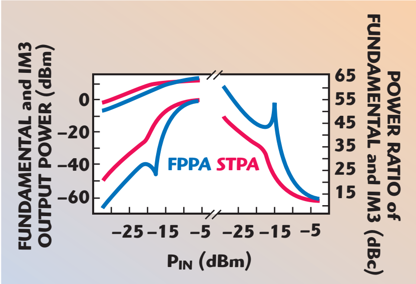
Under the bias conditions of V_{ds1} = V_{ds2} = 3 V, V_{gs1} = -0.5 V, V_{gs2} = -0.45



▲ *Fig. 8 Measured S-parameters of the proposed FP driver amplifier.*



▲ *Fig. 9 Comparison between output power and gain of an FD and standard driver amplifier.*



▲ *Fig. 10 Two-tone measurements with 5.200 and 5.201 GHz fundamental frequencies and IM3 vs. input power for standard and FP driver amplifiers.*

V and V_{FP} = -4 V, the small-signal gain of the field-plate driver amplifier was measured as 31 dB at 5.2 GHz (see ***Figure 8***). The standard driver amplifier showed a 32 dB small-signal gain under the bias conditions of V_{ds1}= V_{ds2}= 3 V, V_{gs1}= V_{gs2}=-0.5 V.

Under identical power consumption, the comparisons between a standard and a field-plate amplifier in output power and associated power gain as a function of input power at 5.2 GHz, are shown in ***Figure 9***. The 1 dB gain compression power (P_{1dB}) of the FP amplifier was 15.1 dBm with respect to the standard one of 14.2 dBm. The maximum output power of the FP amplifier was 17.8 dBm with respect to the standard one of 17 dBm. The two-tone evaluation was conducted with frequencies of 5.200 and 5.201 GHz and the results are shown in ***Figure 10***. The power ratios between fundamental and IM3 products of the FP driver amplifier and the standard driver amplifier are 43.4 dBc for the FP device and 35.3 dBc for the standard device at an input power of -20 dBm. The IM3 output powers are -40.2 and -28 dBm for FP device and standard device, respectively. The measured input power at the third-order intercept point (IIP_3) is -2 dBm for the FP amplifier; this value is -4 dBm for the standard amplifier. From the above experimental results, it is concluded that an adjustable circuit output power and linearity approach of a driver amplifier design by using a simple tunable field-plate voltage technique has been developed successfully. This approach is easily realized to suppress the harmonic powers by appropriate V_{FP} bias point selection and no extra DC consumption is required, which is attractive for high-linearity amplifier design.

CONCLUSION

Linearity performance improvement of a large-signal AlGaAs/InGaAs PHEMT was demonstrated by implementation of a field-plate structure. The benefit of an FP structure, which increases the feedback gate-to-drain capacitance, dominates the improvement in device linearity. By applying a negative bias on the field-plate metal, the FP-induced surface depletion region is thicker and the carriers between drain and gate terminals are removed from the surface, which reduces the leakage current. Therefore, the device DC-to-RF dispersion and the linearity of the PHEMT can also be improved by this factor. Through the moderate bias point selection of V_{FP}, the field-plate technology has also been demonstrated in a 5.2 GHz driver amplifier. When compared with a standard driver amplifier, it showed great promise for circuit linearity improvement. ■

ACKNOWLEDGMENT

The authors are grateful to WIN Semiconductors Corp. for device fabrication. This work is financially supported by the National Science Council (NSC-97-2221-E-182-048-MY3) and the Green Technology Research Center of Chang Gung University, Taiwan, ROC.

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A UWB BPF BASED ON A CAPACITIVELY COUPLED CROSS RESONATOR

This article introduces a novel ultra-wideband (UWB) bandpass filter (BPF) with sharp roll-off characteristics in a stripline structure. The UWB characteristic is basically obtained from a capacitive coupled cross resonator that has a λ/2 length. At the center of the resonator two stubs are loaded; one is a λ/8 short-circuited stub and the other is a λ/8 open-circuited stub. The two stubs provide two attenuation poles at lower and upper cut-off frequencies. For input and output lines, two identical capacitively coupled lines have been installed to suppress the unwanted signals in the lower and upper stop-bands. The filter has been designed for the US UWB band (3.1 to 10.6 GHz) with two transmission zeros at 2.4 and 11.1 GHz. An insertion loss less than 0.7 dB and a return loss better than 14 dB have been measured in the passband. The group delay at the center frequency is 0.27 ns and the group delay variation within the passband is less than 0.5 ns. The size of the filter is 6 × 18 × 0.6 mm.

Ultra-wideband (UWB) technology has been a key issue in the development of new high speed indoor and hand-held wireless communication systems since the unlicensed use of UWB was approved worldwide. As one of the essential components in UWB communication systems, the UWB bandpass filter (BPF), with such characteristics as compact size, good selectivity and stop-band rejection, low insertion loss and low cost, has been required. In order to meet UWB radiation limits, steep selectivity at lower and upper ends of the passband is a characteristic of UWB systems that must be obtained.[1]

After Saito first introduced a UWB BPF, a number of reports on UWB BPF research and development have been published.[2-14] In these reports, filters show steep skirt selectivity and compact size.[8,12-14] The filter characteristics, in terms of passband, circuit structure, fabrication technology, insertion loss, return loss, group delay, roll-off slope at lower transition band and size, are compared in ***Appendix A***, which also includes results of this work, using a capacitively coupled cross resonator.

A new UWB BPF with steep slopes, such as 81 dB/GHz in the lower transition band and 86 dB/GHz in the upper band, is proposed in this article. The design theory for the cross resonator-based UWB BPF is introduced. It explains how to obtain two attenuation poles based on a capacitively coupled cross resonator, how to add input and output lines, and how to obtain the UWB BPF for the frequency range from 3.1 to 10.6 GHz using an ABCD matrix method and ADS simulation. The HFSS simulation and measurement results for the BPF are given and compared.

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Kyung Hee University, South Korea


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DESIGN THEORY

The configuration of the filter developed in this study is shown in ***Figure 1***. The filter consists of a λ/2 long resonator, capacitively cross coupled with a λ/8 open-circuited stub on one side and a λ/8 short-circuited stub on the other side. The two stubs are located at the center of the resonator. Two identical λ/4 capacitively coupled lines are used at the input and output ports. The filter has been designed for the US UWB band, with a 6.85 GHz center frequency. The filter circuit is designed in a two-layer structure to obtain the capacitive coupling.

The filter design starts with the analysis of the even- and odd-modes for the coupling structure between the main line (empty section) and the cross resonator (shaded section), as shown in ***Figure 2***. It also shows the one-port circuit model for the circuit structure under even-mode excitation. In this case, the symmetrical plane becomes a perfect magnetic wall. The characteristic impedances for the short-circuited stub and open-circuited stub are doubled ($2Z_1$, $2Z_2$) and the main line on the upper layer becomes open-circuited. Therefore, the input impedance (Z_{ine}) can be derived, as shown in Equation 1

$$Z_{ine} = \frac{j}{2\sin\theta}\frac{\left(Z_{c-}^2 - Z_{c+}^2\cos^2\theta\right)Z_A + Z_{c+}Z_1Z_2\sin 2\theta}{Z_{c+}Z_A\cos\theta - 2Z_1Z_2\sin\theta} \quad (1)$$

where

$$Z_A = \frac{Z_2\cos\theta_1\cos\theta_2 - Z_1\sin\theta_1\sin\theta_2}{2\cos\theta_1\sin\theta_2}$$

$$Z_{c+} = Z_{ce} + Z_{co}$$

$$Z_{c-} = Z_{ce} - Z_{co}$$

Z_{ce} and Z_{co} are the even- and odd-mode impedances of the coupled line, Z_1 and Z_2 are the characteristic impedances, and θ_1 and θ_2 the electrical lengths of the short-circuited and open-circuited stubs, respectively.

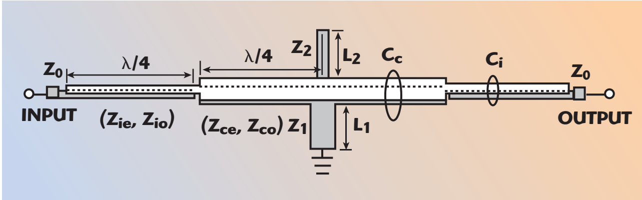
Under the odd-mode excitation, the coupling structure is also expressed as a one-port network. In this case, the circuit at the symmetrical plane can be simply considered as short-circuited, since the strip conductors at the center are grounded via virtual electric wall. Therefore, the input impedance (Z_{ino}) can be obtained from Equation 2

$$Z_{ino} = j\frac{\tan\theta}{2}Z_{c+} \quad (2)$$

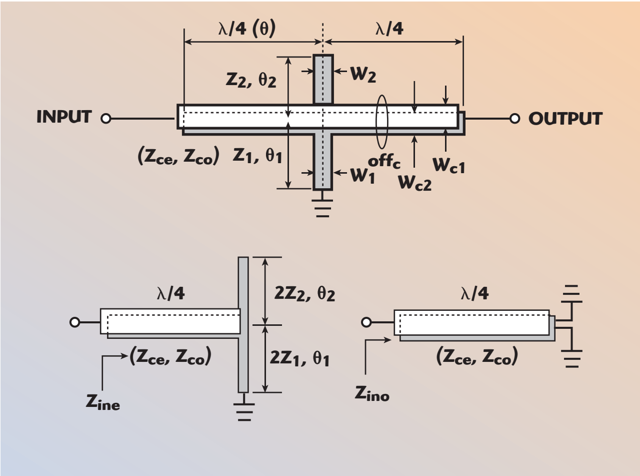
$$\Gamma_e = \left(Z_{ine} - Z_0\right)/\left(Z_{ine} + Z_0\right) \quad (3)$$
$$\Gamma_o = \left(Z_{ino} - Z_0\right)/\left(Z_{ino} + Z_0\right)$$

$$S_{11} = \left(\Gamma_e + \Gamma_o\right)/2 \quad (4)$$
$$S_{21} = \left(\Gamma_e - \Gamma_o\right)/2$$

$$Z_A\cot\theta = \frac{2Z_{c+}Z_1Z_2}{\left(Z_{c+}^2 - Z_{c-}^2\right)} \quad (5)$$

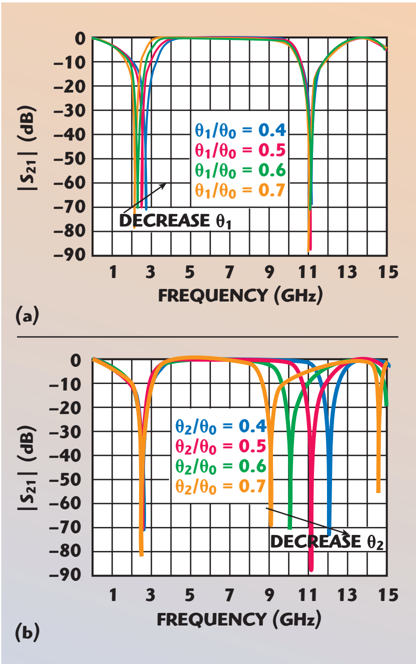


▲ *Fig. 1 Schematic of the proposed filter.*

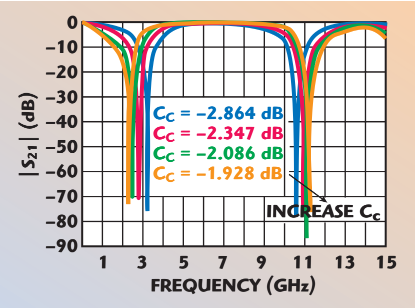


▲ *Fig. 2 Capacitive coupling between the mainline and the cross resonator structure.*

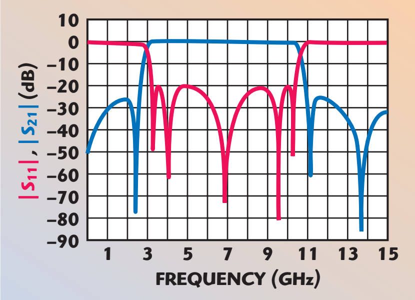
Next, the reflection coefficients for the even-mode (Γ_e) and the odd-mode (Γ_o) can be determined from Equation 3. S_{11} and S_{21} of the capacitive coupled cross resonator structure can then be extracted from Equation 4. At the transmission zeros frequencies, S_{21} is equal to one. Therefore, the locations of the transmission zeros of the proposed filter are obtained from Equation 5. These transmission zeros depend on the coupling coefficient between the main line and the cross resonator and the impedances and lengths of the stubs. As shown in ***Figure 3***, the location of the lower transmission zero can be controlled by the electrical length θ_1 of the short-circuited stub and the upper transmission zero by the electrical length θ_2 of the open-circuited stub, where $\theta_0 = \pi/2$ at the center frequency. The smaller the value of θ_1, the higher the frequency of the lower transmission zero. In contrast with θ_1, the small-



▲ *Fig. 3 Locations of lower and upper transmission zeros depending on the electrical lengths of the stubs: (a) short-circuited stub and (b) open-circuited stub.*



▲ *Fig. 4 Location of the lower and upper transmission zeros depending on the coupling coefficient C_c.*



▲ *Fig. 5 ADS simulation results for the proposed filter.*

er the value of θ_2, the lower the frequency of the upper transmission zero. The other circuit parameters are: $W_{c1} = W_{c2} = 0.35$ mm, $off_c = 0$ mm, $W_1 = W_2 = 0.5$ mm and $\theta_0 = \pi/2$. ***Figure 4*** shows the location of the lower and upper transmission zeros depending on the coupling coefficient C_c between the main line and the cross resonator when the other parameters are $W_{c1} = W_{c2} = 0.15$ to 0.45 mm, $off_c = 0$ mm, $W_1 = W_2 = 0.5$ mm, $\theta_0 = \pi/2$ and $\theta 1 = \theta 2 = \pi/4$.

Finally, the input and output lines coupled with the main line of the coupling structure have been adopted to suppress the unwanted signals in the lower and upper stop-bands. To obtain rejection bands better than 25 dB, the impedances of the even- and odd-modes of the input/output coupled lines are set at 90.3 and 22.96 Ω, respectively. Then, the 50 Ω input and output transmission lines are connected to the coupled lines. In this study, the stripline structure with a substrate thickness of 0.6 mm, a dielectric constant of 7.8, a conductor thickness of 10 µm and a capacitive coupling gap of 43 µm were used. By choosing $Z_{ce} = 55.87\ \Omega$ and $Z_{co} = 5.95\ \Omega$, $Z_1 = Z_2 = 25.51\ \Omega$, $\theta_1 = \theta_2 = \pi/4$, the two transmission zeros have been placed at 2.5 and 11.1 GHz.

$$\left[ABCD\right]_i = \begin{bmatrix} \frac{Z_{i+}}{Z_{i-}}\cos\theta & j\frac{Z_{i-}^2 - Z_{i+}^2\cos^2\theta}{2Z_{i-}\sin\theta} \\ j\frac{2\sin\theta}{Z_{i-}} & \frac{Z_{i+}}{Z_{i-}}\cos\theta \end{bmatrix} \quad (6)$$

where $Z_{i+} = Z_{ie} + Z_{io}$ and $Z_{i-} = Z_{ie} + Z_{io}$

$$\left[ABCD\right]_T = \left[ABCD\right]_i \times \left[ABCD\right]_c \times \left[ABCD\right]_i \quad (7)$$

The $[ABCD]_c$ matrix of the capacitively coupled cross resonator structure can be calculated from its S-parameter in Equation 4.[15] The $[ABCD]_i$ matrix of the coupled lines at the input or output can be written as Equation 6, where Z_{ie} and Z_{io} are the even- and odd-characteristic impedances of the coupled lines. Correspondingly, the $[ABCD]_T$ matrix of the whole filter can be obtained by Equation 7, which is the multiplication of the transmission matrix of the cross resonator structure $[ABCD]_c$ and those of the input/output coupled lines with Equation 6 in sequence. Finally, the scattering matrix for the whole filter structure can be obtained.[15] ***Figure 5*** shows the ADS simulation results for the proposed bandpass filter. The filter shows a bandwidth from 3.1 to 10.6 GHz with the two transmission zeros at 2.5 and 11.1 GHz.

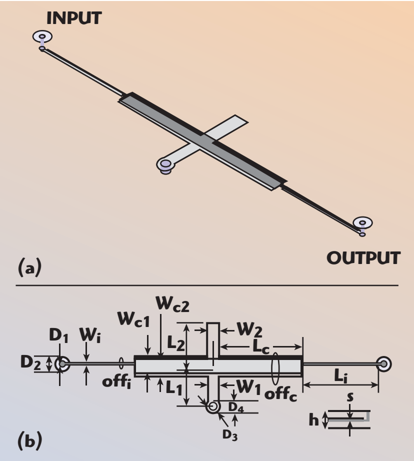
The ADS (Agilent, 2008) simulation results of the filter show a flat and wide passband characteristic for US UWB applications and effectively suppressed unwanted passbands in the lower and upper stop-bands.

FIELD SIMULATION AND MEASUREMENT RESULTS

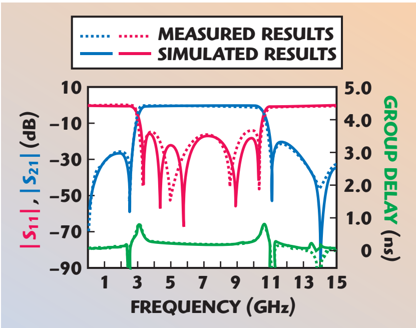
The filter structure with the cross resonator, shown in ***Figure 6***, was simulated and tuned with the HFSS program (Ansoft, v.11). Its dimensions are: $W_i = 70$ µm, $off_i = 0$ mm, $L_i = 3.9$ mm, $W_{c1} = W_{c2} = 0.5$ mm, $off_c = 60$ µm, $L_c = 3.8$ mm, $W_1 = 0.5$ mm, $L_1 = 1.7$ mm, $W_2 = 0.55$ mm, $L_2 = 2$ mm, $D_1 = 0.2$ mm, $D_2 = 0.75$ mm, $D_3 = 0.4$ mm, $D_4 = 0.55$ mm, h = 0.6 mm and s = 43 µm.

The structure consisted of 14 layers; each layer had a thickness of 43 µm and a dielectric constant of 7.8. The filter patterns were located on the sixth and seventh layers. Via holes were added to the structure instead of solid walls in order to reduce the effects of interference. Due to the limitations of the LTCC manufacturing process used, the distance between two adjacent vias needed to be larger than 0.35 mm. This led to a slight deterioration of the performance of the filter such as the disappearance of the fourth transmission poles in the passband.

The filter characteristics were measured with the Anritsu ME7808A network analyzer and the Cascade Microtech Summit 12971B probe station. The measurement results were compared with the simulation results. The input/output striplines were connected to input/output circular ports, which have inner and outer diameters of 200 and 750 µm, respectively, by solid vias (via diameter of 120 µm). The measurement probes with a 400 µm pitch size were used to measure the filter. ***Figure 7*** shows the comparisons between the simulation and measurement results in terms of S-parameters and group delay for the filter. The dotted line indicates



▲ *Fig. 6 The structure of the cross resonator filter: (a) 3-D view and (b) top view.*

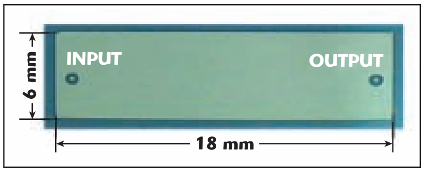


▲ *Fig. 7 Comparison between measured and simulated results for the proposed filter.*

APPENDIX A COMPARISON OF CHARACTERISTICS FOR VARIOUS UWB BPFs WITH STEEP SHIRT SELECTIVES					
Reference/ Parameters	***[8]***	***[12]***	***[13]***	***[14]***	***This work***
Pass band (GHz)	3.5-10.6	3.1-10.6	3.2-4.8	3.1-10.6	3.1-10.6
Circuit structure	Composite microstrip/ coplanar waveguide	Edge-coupled microstrip/ stepped impedance open stub	Left handed property's interdigital coupled line	$5\lambda_0/4$ SIR/short stub	Capacitively coupled cross resonator
Technology	PCB	PCB	PCB	PCB	LTCC
Insertion loss (dB)	0.48	0.5	1.0	0.65	0.6
Return loss (dB)	17.2	18	13	18	14
Group delay (ns)	0.5	0.21	0.49	0.5	0.25
Roll-off slope at lower transition band (dB/GHz)	64	50	46	65	81
Size (mm^2)	8 × 11.9	18.6 × 13.5	20 × 20	10 × 18.82	6 × 18

the simulation results. The simulation results show a bandwidth of 7.5 GHz (3.1 to 10.6 GHz). The return loss is better than 15 dB, and insertion loss is less than 0.3 dB in the passband. The group delay of the filter is approximately 0.26 ns at 6.85 GHz and has a variation within 0.25 ns from 3.5 to 10.2 GHz. The attenuation slopes in the lower and upper transition bands are 94 and 95 dB/GHz, respectively. The filter has two transmission zeros at 2.45 and 11.05 GHz, respectively.

The solid line shows the measurement results. Due to the limitation of the LTCC fabrication process mentioned before, the second and third poles were smeared, so only four poles instead of five poles can be observed within the passband in the measurement result. A return loss better than 14 dB and an insertion loss less than 0.6 dB were measured. The group delay is 0.26 ns at the center frequency and the group delay variation from 3.5 to 10.2 GHz is less than 0.25 ns. The

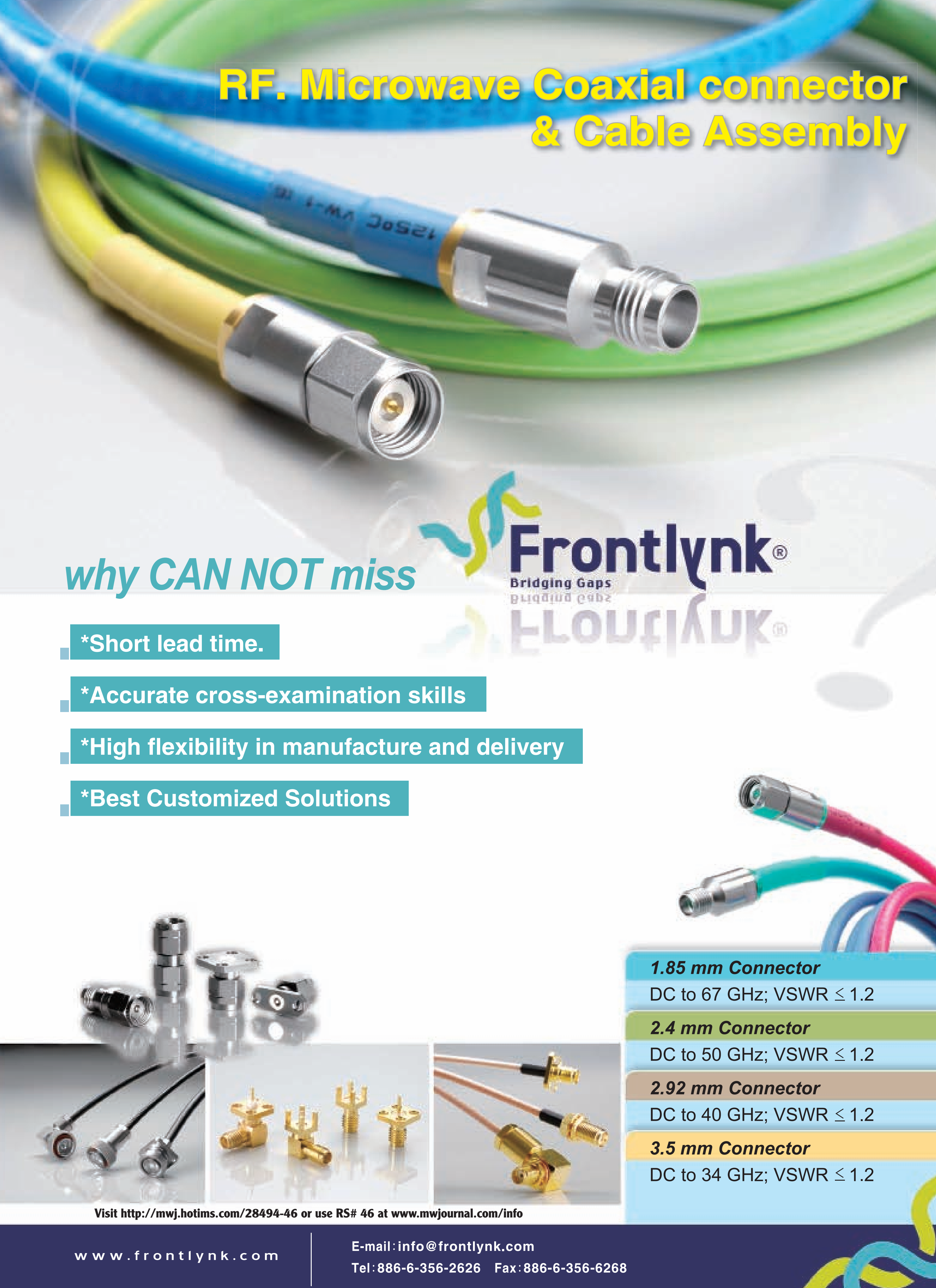


▲ *Fig. 8 Top view of the fabricated bandpass filter.*

attenuation slope in the lower transition band is 80 dB/GHz and that in the upper transition band 86 dB/GHz. The proposed filter has a size of 6 × 18 × 0.6 mm^3 and shows very sharp skirt characteristics with transmission zeros at the lower and upper stop-bands. ***Figure 8*** shows the top views of the fabricated bandpass filter.

CONCLUSION

In this article, a UWB bandpass filter with sharp frequency characteristics for the US band was introduced in LTCC technology. It is shown that the capacitive coupling of the cross resonator provides ultra-wideband characteristics. Locations of two transmission zeros in the lower and upper transmission bands of the filter can be controlled by the capacitive coupling coefficient between the main line and the cross resonator, and the lengths of the short-/open-circuited stubs. The HFSS simulation results agree well with the measurement results. It is expected that the sharp roll-off characteristics and simple structure of the filter make it very suitable for UWB systems, particularly in mobile home network applications. ■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ACKNOWLEDGMENTS

The authors wish to acknowledge the financial support of LG Innotek and the measurement assistance of the Korea Electronics Technology Institute (KETI).

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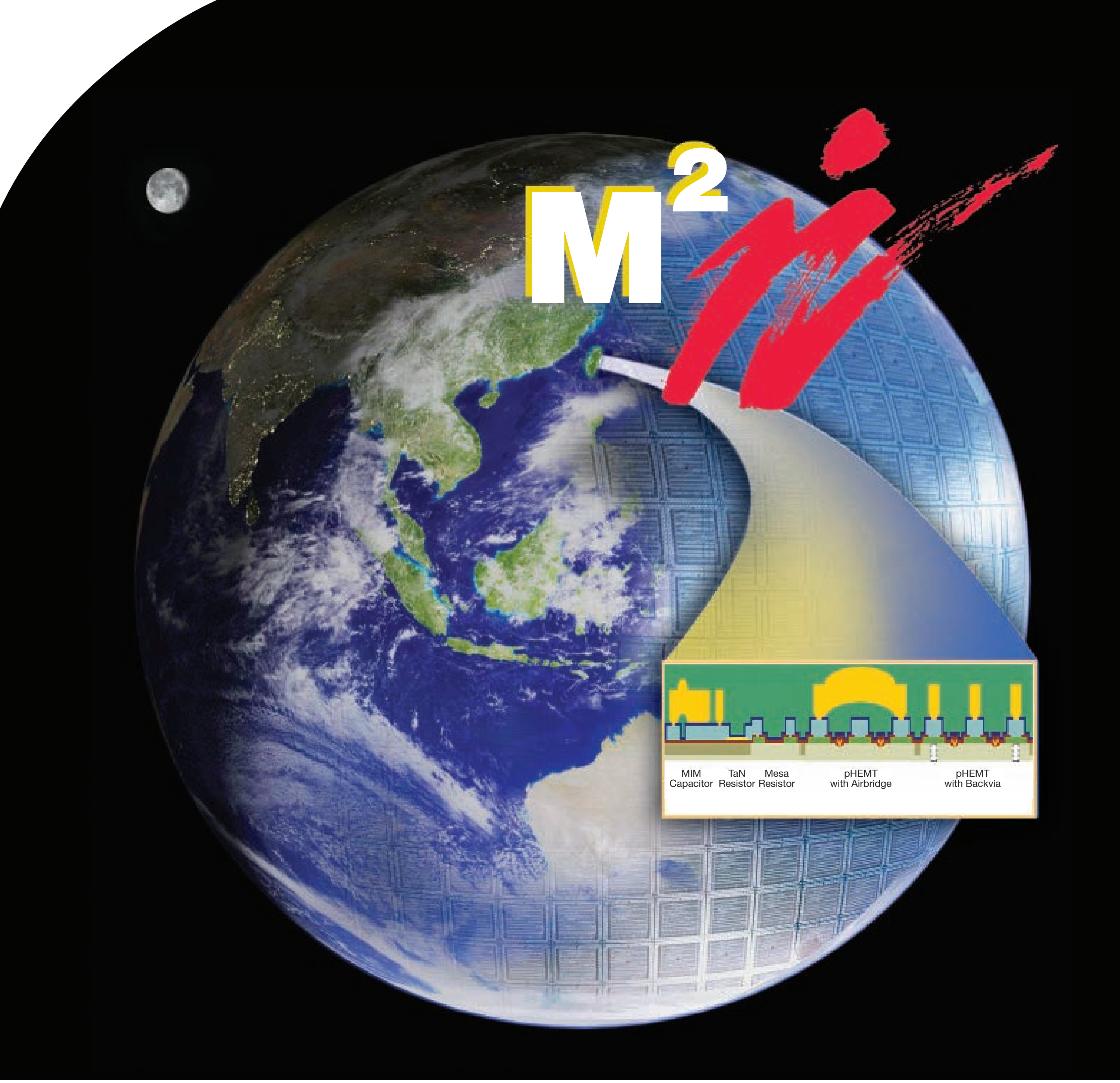

M2
MIM Capacitor
TaN Resistor
Mesa Resistor
pHEMT with Airbridge
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Planar Rhombic Arm Dipole Antenna with Parasitic Elements for Wireless Applications

A printed dipole, with integrated parasitic elements, features a broad operating bandwidth. A conventional antenna design was implemented and the single-band characteristics (2.4 to 2.9 GHz) were measured. The insertion of symmetrical parasitic elements at the side of the radiating elements was then investigated. A proposal is made to use a rhombic radiation patch with parasitic elements to increase the resonance modes of a printed dipole-type antenna for wideband operation. Wireless applications were obtained by optimizing the dimensions of the printed dipole-type antennas. For WLAN systems, a broadband antenna with two inverted-L slits in the parasitic elements was also studied. In addition, detailed design steps and experimental results for the designs were investigated.

There has recently been an exponential growth in worldwide wireless communications. The IEEE 802.11 group has been responsible for setting up standards, including those for wireless local area networks (WLAN), and dual-band communication at 2.4 GHz (2400 to 2483.5 MHz) and 5.2 GHz/5.8 GHz (5150 to 5350 MHz and 5725 to 5825 MHz). In particular, printed dipole-type antennas exhibit many attractive features, such as a simple structure, excellent pattern, easy integration with monolithic microwave integrated circuits (MMIC) and low radiation losses. The design for a planar dual-band dipole antenna with chamfers for dual-band resonances at 2.4 and 5 GHz has been described.[1]

In addition, a planar open-sleeve dipole (ELPOSD) and an end-load planar open-sleeve dipole antenna (ELPOSD) with parasitic elements[2] have been designed and their increased bandwidth and length reductions have been demonstrated. An ultra-wideband printed dipole antenna[3] with a tapered slot feed has been proposed and a broadband bandwidth from 3.1 to 10.6 GHz was obtained. The distance from the parasitic element to the feeding aperture adjusts the impedance matching. A broadband printed dipole antenna with an asymmetrical radiating patch operating in the DTV band was also shown.[4] The dual-band operation of a printed dipole antenna[5] with U-slotted arms has also been presented. The operating bands are 2.4/5.2 GHz WLAN bands for IEEE 802.11a/b. A CPW-fed monopole antenna with parasitic elements was used to generate wideband characteristics.[6] The gap between the parasitic element and ground plane was an important parameter affecting impedance matching. In addition, microstrip-fed dipole antennas[7-9] possess various advantages, such as a wide impedance bandwidth, low profile, easy manufacture and low cost.

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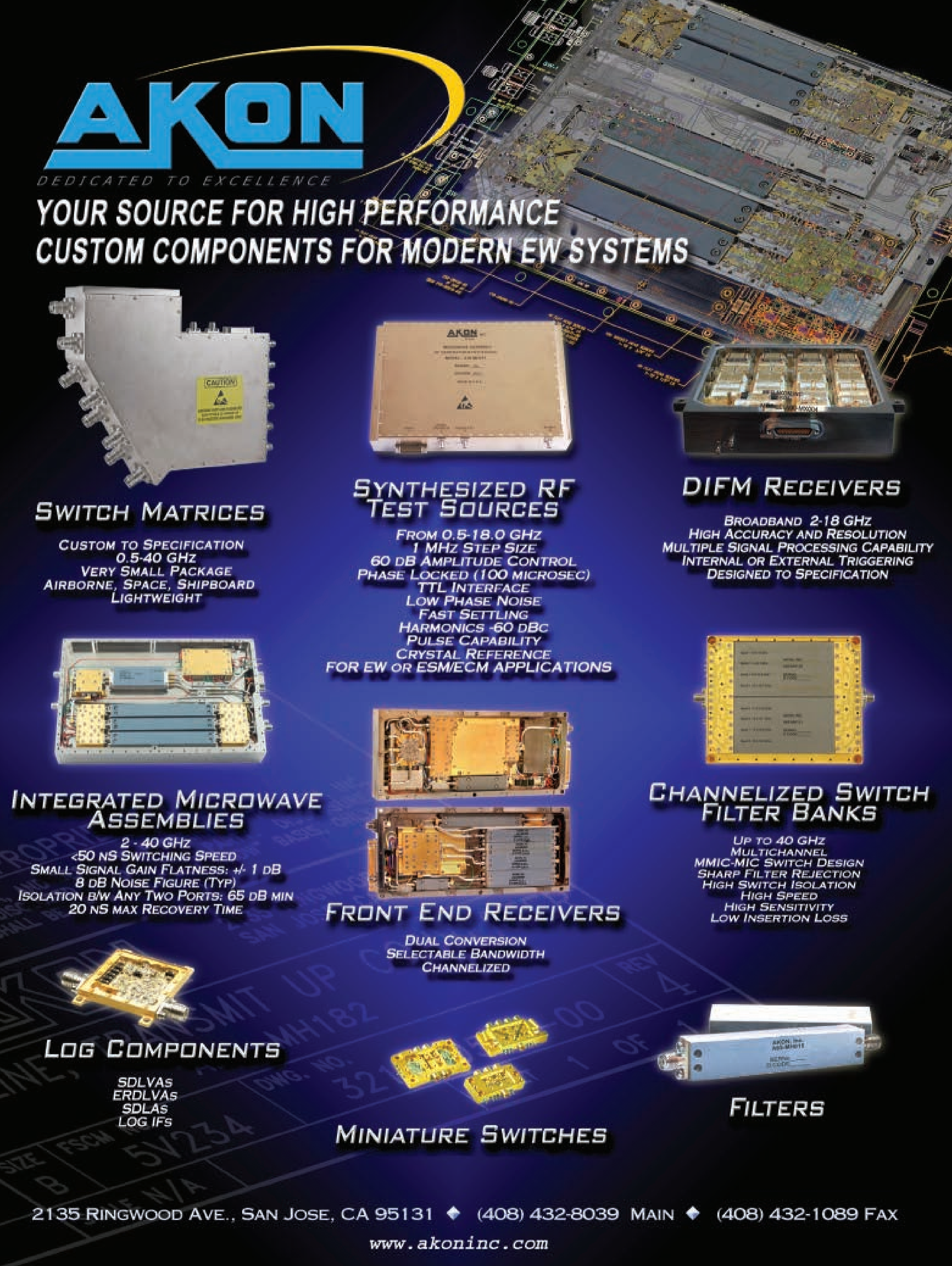
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A printed microstrip-fed dipole antenna[7,8] is created using a small patch etched on the ground plane. The dual-band bandwidth of a microstrip-fed dipole antenna corresponds to the frequency range in IEEE 802.11.a/b. To achieve triple-frequency operation, a microstrip-fed dipole antenna using two parasitic elements as additional resonators was demonstrated.[9] These studies indicate that planar dipole-type antennas with parasitic elements have various advantages, such as a wide bandwidth, low profile and compact size.

This article proposes some designs for a dual-band and broadband planar dipole-type antenna with parasitic elements. The symmetrical parasitic elements were able to produce a resonant mode. By integrating the parasitic elements into the rectangular dipole antenna, a dual-band operation was realized. Further, by changing the radiation elements by adding a rhombic shape, broadband operation could be obtained. For WLAN application, a broadband antenna embedding L-shaped slits at the proper locations in the parasitic elements could produce a band-rejection characteristic. The novel design of the rhombic dipole antenna with parasitic elements is suitable for application in the WLAN (2.4 to 2.4835, 5.15 to 5.825 GHz) bands. Detailed design configurations for the proposed antennas are described. The results of the fabricated antennas are also presented and discussed.

ANTENNA CONFIGURATION AND DESIGN

Figure 1 depicts the geometry of a dipole antenna with parasitic elements. The antenna was designed on an FR4 substrate with a dielectric constant ε_r = 4.4, a thickness H = 0.8 mm and an overall compact size of W_{sub} (mm) × L_{sub} (mm). In the z-direction, the feed gap G is between the two antenna arms. The two arms of the antenna have the same width W_f and length L_f. The length L_f can be used to determine the first resonance mode. To increase the resonant modes, symmetrical parasitic elements were embedded beside the rectangular dipole arms. The two rectangular parasitic elements are placed on the substrate, symmetrically on either side of the antenna arms with a gap W_s, and have dimensions of W_1 (mm) 3 L_1 (mm).

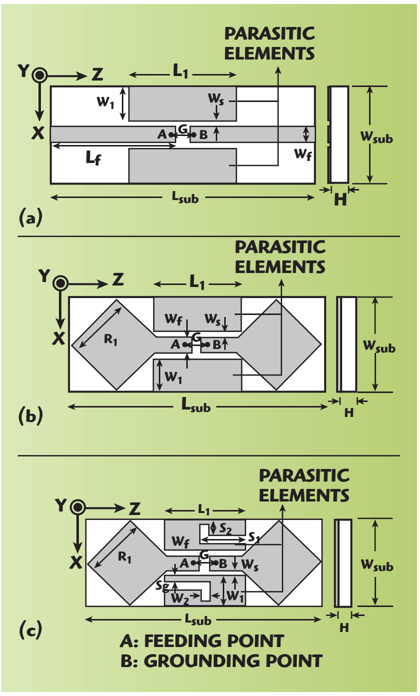


Fig. 1 Geometry of the proposed dipole antennas: (a) rectangular arms, (b) rhombic arms, (c) rhombic arms and parasitic elements with slits.

With the gap width G fixed at 0.5 mm, a good impedance matching was obtained. The parasitic elements are coupled to the dipole arms to generate a new resonant band. The operating frequency is varied with the length L_1. Therefore, a dipole antenna with parasitic elements for dual-band operation is formed. When a rhombic-shaped plate was used to replace the two ends of the rectangular dipole arms of the printed dipole antenna, it was possible to generate a broadband characteristic such as the one described by Zhang and Spence.[1,2]

The figure shows the planar rhombic arm dipole antenna with the parasitic elements. It could produce a wider bandwidth performance. A rhombic shape was selected for the radiation plate with a dimension R_1 = 9.9 mm. It reduced the total length of the antenna structure and lowered the resonant frequency in comparison with rectangular arms. The dipole antenna with the rhombic arms could generate a lower frequency band and a higher frequency band when coupled with the parasitic elements to enhance the operating bandwidth.

The figure also shows the planar rhombic arm dipole antenna with the parasitic elements embedded with two anti-symmetrical L-type slits. To

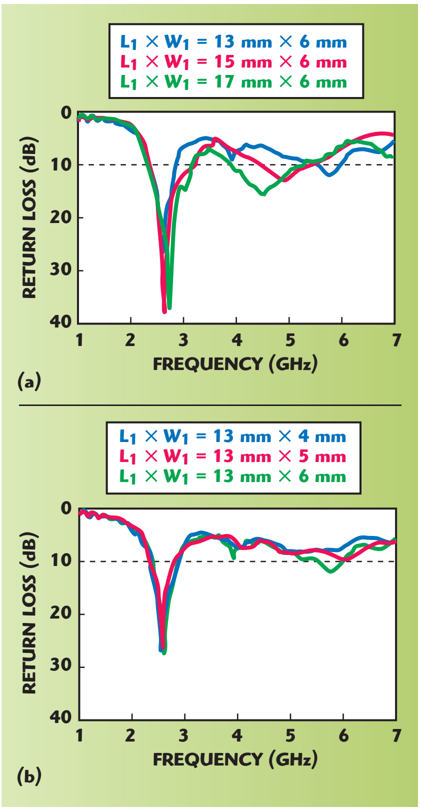


Fig. 2 Measured return loss of the rectangular arm dipole antenna: (a) as a function of L_1 and (b) as a function of W_1.

decrease the interference between the WLAN and existing wireless systems, a broadband antenna with a band-rejection characteristic should be used. In this study, the total length of the slits (S_1+S_2) in the parasitic elements was selected as 10 mm with a width W_2 = 1 mm, which could generate a band-rejection characteristic at 4.2 GHz. This total length was approximately a quarter-wavelength of the center frequency of the rejected band. The gap S_g between the slit and the feeding-line was used to adjust the impedance matching of the higher band to IEEE 802.11a. Thus, with the lower and higher operating bands obtained, a dual-band rhombic arm dipole antenna for IEEE 802.11a/b was achieved.

EXPERIMENTAL RESULTS AND DISCUSSIONS

Some antennas were fabricated to examine their performance. ***Figure 2*** depicts the return loss with different lengths and widths for the parasitic elements in the rectangular arm antenna, with the other dimensions set at L_{sub} = 41 mm, W_{sub} = 15 mm, W_s = 0.5 mm, W_f = 2 mm, L_f = 23 mm and

G = 2 mm. It was found that the second resonance mode shifts to a lower frequency as the length L_1 increases, and that the length L_1 of the strip is approximately a quarter-wavelength at the center resonant frequency in free space. As the width W_1 is increased from 4 to 6 mm, the impedance matching at the higher-band gradually improved. ***Figure 3*** shows the return loss in terms of various lengths for L_1, for the antenna with rhombic arms, with the other dimensions set at L_{sub} = 41 mm, W_{sub} = 15 mm, W_1 = 6 mm, W_s = 0.5 mm, W_f = 2 mm, G = 2 mm and R_1 = 9.9 mm.

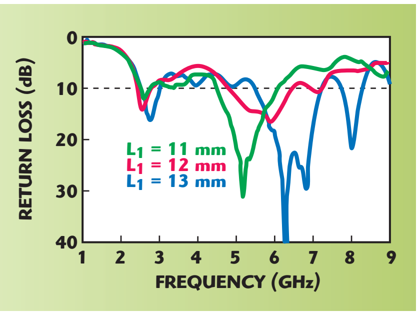


Fig. 3 Measured return loss for the rhombic arm dipole antenna for different L_1.

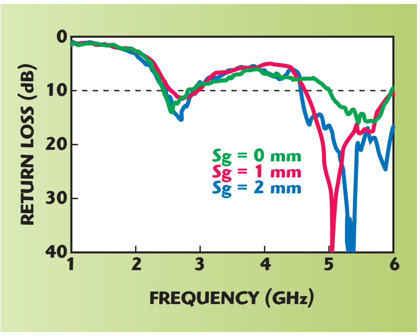


Fig. 4 Measured return loss of the rhombic arm dipole antenna with slits as a function of the gap Sg.

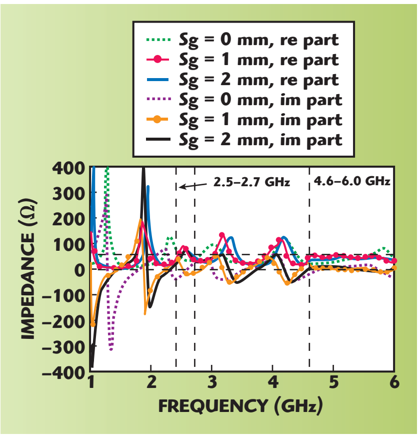


Fig. 5 Measured impedance of the rhombic arm dipole antenna with slits as a function of Sg.

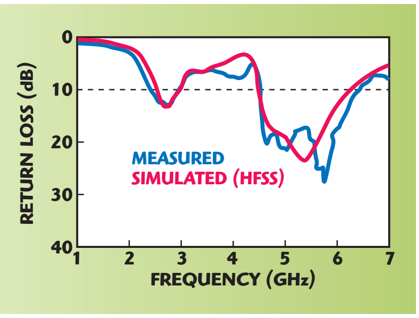


Fig. 6 Measured and simulated return loss of the rhombic arm dipole antenna with parasitic elements with slits.

The second resonance frequency was affected by the length of the parasitic elements. It was observed that by using the rhombic arms in the antenna structure, a wideband operation from 2.37 to 8.33 GHz could be achieved (for a VSWR ≤ 2.5). Embedding a slit in the parasitic elements was also studied and is discussed below. The measured return loss, in terms of gap S_g, between the slit and feeding line is shown in ***Figure 4***, with the other dimensions set at L_{sub} = 41 mm, W_{sub} = 15 mm, W_1 = 6 mm, W_s = 0.5 mm, W_f = 2 mm, L_1 = 13.mm, G = 2 mm, S_g = 2 mm, S_1 = 8 mm and S_2 = 2 mm and R = 9.9 mm.

Figure 5 shows the measured impedance versus frequency. The results show that varying the size of the gap S_g affects the higher band impedance matching. A larger gap S_g can result in improved impedance matching for the antenna's higher band. This behavior is due to the generation of a higher resonance mode from the coupling between the feeding line and the symmetrical parasitic elements. The gap change will also affect the magnitude of the reactance. Therefore, a dual-band rhombic arm dipole antenna with parasitic elements is formed.

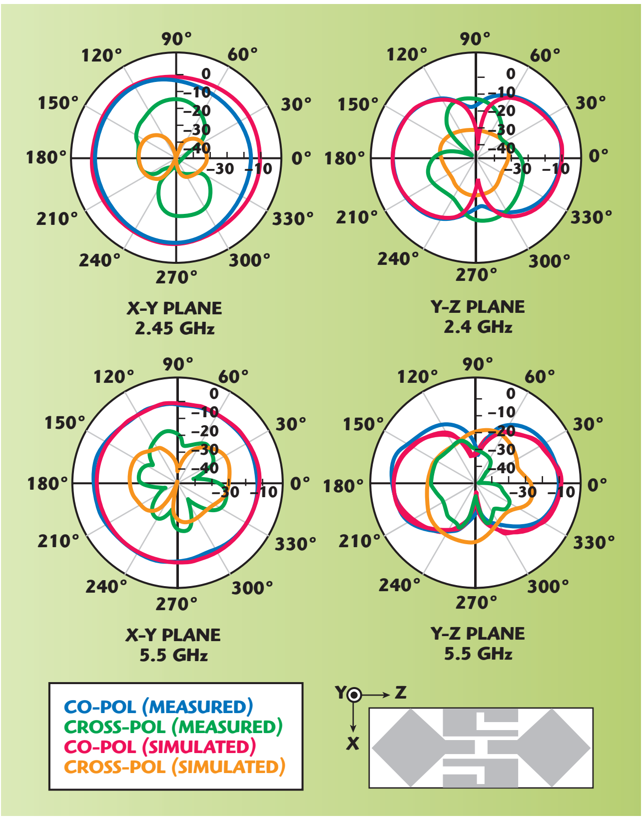
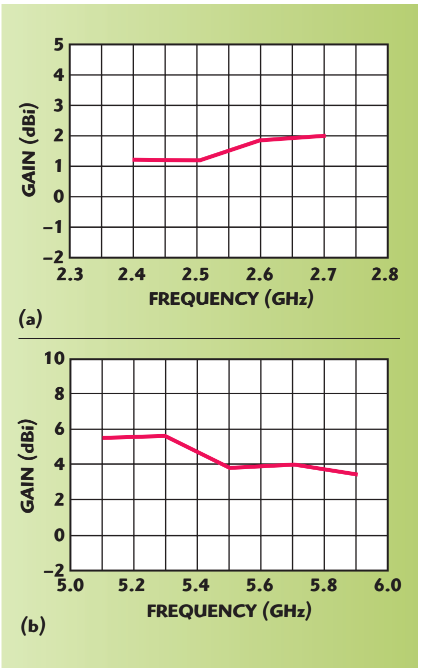


Fig. 7 Measured and simulated radiation patterns for the proposed antenna.

Figure 6 shows that there was good agreement between the measured and simulated return losses for the proposed antenna. The final antenna dimensions were L_{sub} = 41 mm, W_{sub} = 15 mm, W_1 = 6 mm, W_s = 0.5 mm, W_f = 2 mm, L_1 = 13 mm, G = 2 mm, S_g = 2 mm, S_1 = 8 mm, S_2 = 2 mm and R_1 = 9.9 mm. The proposed dual-band operating bandwidths are from 2.4 to 2.92 GHz (19.5 percent) and 4.5 to 6.4 GHz (36.4 percent), which covers the IEEE 802.11 a/b/g bands.

Figure 7 plots the measured and simulated radiation patterns at 2.45 and 5.5 GHz. In the X-Y plane, good omni-directional radiation patterns were obtained. It could be observed that coupling between the parasitic elements and the rhombic dipole arms led to a slightly directional cross-polar pattern. In the Y-Z plane, the co-polar pattern is donut-like. Although the two slits embedded in the parasitic elements had slight effects on the radiation patterns, they were acceptable for most wireless applications. ***Figure 8*** shows the measured antenna peak gains against frequency. The measured gain variation in the lower oper-



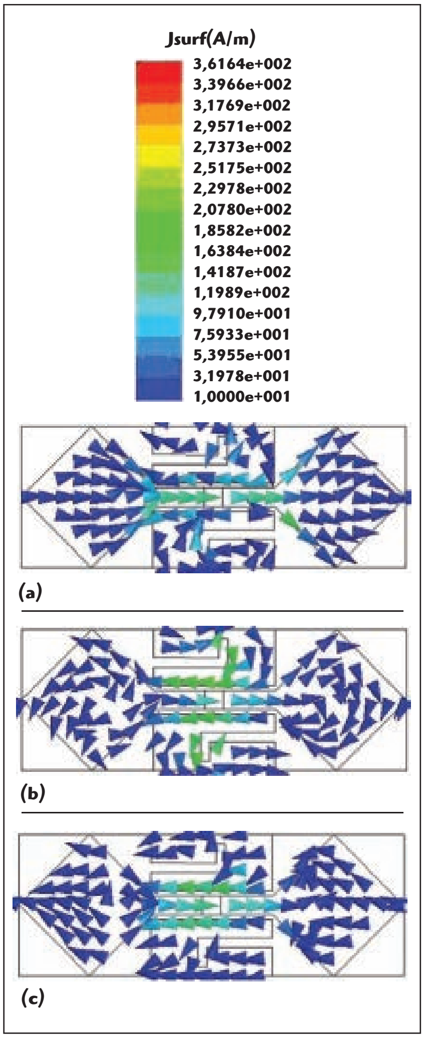
▲ *Fig. 8 Measured antenna gain for the proposed antenna: (a) 2.4 to 2.7 GHz and (b) 5.1 to 5.9 GHz.*

ating band of 2.4 to 2.7 GHz was from 1.18 to 1.95 dBi; in the higher operating band of 5.1 to 5.9 GHz it was from 3.51 to 5.63 dBi. This represents gain variations of less than 3 dB. As seen in these results, the proposed dipole antenna has good impedance matching and excellent radiation characteristics.

Figure 9 shows the simulated current distribution using the HFSS for the dual-band antenna at 2.6, 4.2 and 5.5 GHz, respectively. It can be observed that the current is mainly focused on the rhombic dipole arms to generate a lower resonant frequency of 2.6 GHz. This allowed the antenna to easily cover the IEEE 802.11b band (2.4 to 2.4835 GHz). At 4.2 GHz, the current is seen on the side of the quarter-wavelength slit in the parasitical patch, which represents a band-rejection characteristic. At 5.3 GHz, the two parasitic elements affect the electromagnetic coupling with the feed-line, which leads to the generation of a new resonance mode at IEEE 802.11 a (5.15 to 5.35, 5.725 to 5.825 GHz).

CONCLUSION

A novel design has been proposed for a printed rhombic arm dipole antenna with parasitic elements and a band-rejection characteristic for dual-band WLAN applications. This was fabricated with a compact size of only



▲ *Fig. 9 Simulated surface current distribution of the proposed antenna: (a) 2.6 GHz, (b) 4.2 GHz and (c) 5.3 GHz.*

15 × 41 mm. To obtain a larger bandwidth, the coupling between the parasitical patches and feeding line was optimized by parameter analysis. This broadband antenna can be applied to wireless applications. Furthermore, a broadband antenna with two narrow inverted-L slits embedded in the parasitic elements yielded a band-notch characteristic. A dual-band operation from 2.4 to 2.92 GHz and 4.5 to 6.4 GHz and with good radiation performance was obtained. The proposed antenna should be attractive for WLAN applications. ■

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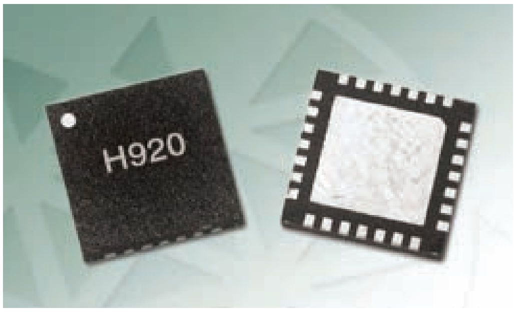

MONOLITHIC SOLUTION FOR CLASS A AMPLIFIER BIASING: HITTITE ACTIVE BIAS CONTROLLER

Commercially available RF, microwave and optical driver amplifiers provide their best performance under specific bias conditions. The quiescent current of such amplifiers affects critical performance parameters such as efficiency, inter-modulation distortion products and noise figure. Therefore, it is crucial to bias these amplifiers accurately for best performance. Some amplifier manufacturers provide optimum bias conditions via conventional integrated self-biasing schemes such as resistor division. Although simple in implementation, these solutions cannot compensate for the amplifiers' process, part to part and temperature variations, sacrificing performance and efficiency.

In order not to degrade performance, RF engineers usually employ an active bias control scheme. The active bias control circuit measures the current passing through the amplifier to allow compensation for any possible drift. Such control circuits are complicated and require not only multiple external components (LDOs, charge pumps, voltage sequencing and protection circuits), but also expensive calibration cycles in production. Such implementations occupy a large PCB area, usually much larger than the amplifier itself. Since each amplifier requires a different drain (collector) and gate (base) bias setting, the external bias circuitry is often redesigned for each amplifier, significantly increasing time to market. The HMC920LP5E houses all the necessary operation blocks in a compact 5 × 5 mm QFN SMT package. This results in PCB area reduction of up to 70 percent, compared to the discrete biasing implementations, by eliminating multiple IC and external component requirements.

In order to increase efficiency, many systems use amplifiers operating in saturation where they require large gate currents in deep saturation (P3dB). Moreover, many amplifiers' gate current changes direction when it is pushed into deep saturation. When the amplifier is in

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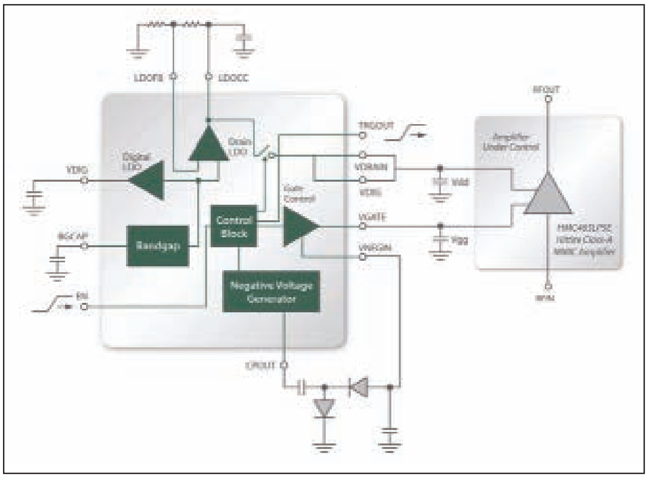


▲ *Fig. 1 HMC920LP5E applications block diagram.*

TABLE I		
FEATURE LIST OF THE HMC920LP5E		
Feature	***Benefit***	***Configuration Type***
Active Bias Control Loop	Constant quiescent current over temperature, system supply voltage and aging	Standard
LDOCC High Voltage LDO	Low noise supply rail	Standard
Automatic Power-up Sequence	Ensure safe start-up	Standard
Current Alarm	Quiescent bias current monitoring of the amplifier under control	Optional
Under Voltage	System supply voltage monitoring	Optional

the linear region, the current is negative (i.e., out of the gate). However, when the amplifier goes into saturation, the Schottky diodes turn on, reversing the direction (into the gate) for the exponentially growing current. Hence, the bias circuitry should be able to handle both current sink and source to the gate.

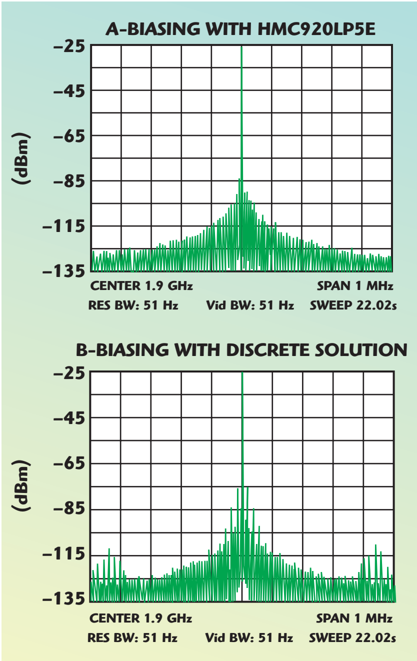
With all these design challenges, designing the bias section for the amplifier chain is generally the most time consuming step in development. Hittite has recognized this problem and successfully developed the industry's first monolithic biasing solution: the HMC920LP5E Active Bias Controller. This new IC provides a compelling combination of an active bias controller that generates a regulated drain and gate voltage, along with an on-chip negative voltage generator that can be utilized when a negative voltage is needed (e.g., depletion mode devices). This unique and timely solution by Hittite is offered in a compact 5 × 5 mm QFN leadless package. A behavioral block diagram of the HMC920LP5E with the external and connections for standard set of features are given in ***Figure 1***.

The HMC920LP5E requires only a dual schottky, and a few external passive components in standard configuration. The main feature, active bias control loop, continuously monitors the current through the external amplifier to generate the gate voltage VGATE. The provided feedback control scheme is thus enforcing constant quiescent bias for the amplifier under control. ***Table 1*** provides a complete list of standard and optional features of the HMC920LP5E and its benefits.

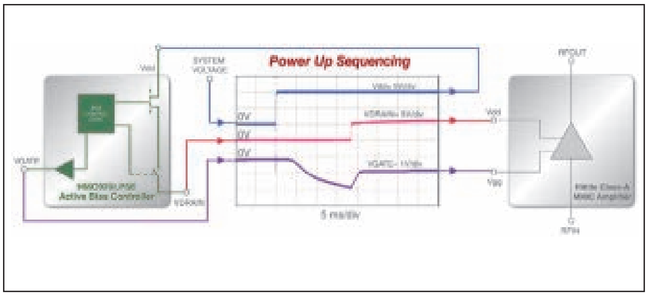
The HMC920LP5E achieves excellent bias stability over system supply (+4 to +16.5 V), temperature (-40° to +85°C) and process variations, eliminating the otherwise required calibration procedures. The HMC920LP5E is a versatile turn-key bias solution, for biasing any enhancement and depletion type amplifier operating in a Class A regime with drain voltages (VDRAIN) from +3 to +15 V and drain currents (IDRAIN) up to 500 mA. The user-adjustable VDRAIN output is used as the regulated supply rail for the amplifier. The VGATE driver is designed to handle both source and sink currents up to ±4 mA to ensure proper bias control even in deep saturation.

The HMC920LP5E includes a regulated charge-pump to produce a negative supply rail of -2.5 V (VNEGIN) for the gate driver. The smart control of the integrated charge pump provides low ripple regulated output with limited spike currents. The on-chip gate driver has an excellent PSRR and rejects the inherent ripple on the VNEGIN even further. This unique feature of the HMC920LP5E provides a spur-free RF spectrum, giving better noise performance compared to discrete biasing solutions. ***Figure 2*** shows the comparison of the RF spectrum for the same amplifier biased with HMC920LP5E versus a discrete biasing circuitry.

The HMC920LP5E ensures the safety of the amplifier under control by a special power-up sequence either



▲ *Fig. 2 HMC920LP5E's excellent PSRR provides spur-free RF spectrum (A) compared to discrete biasing spectrum (B).*



▲ *Fig. 3 HMC920LP5E active bias controller driving a HMC465LP5E amplifier.*

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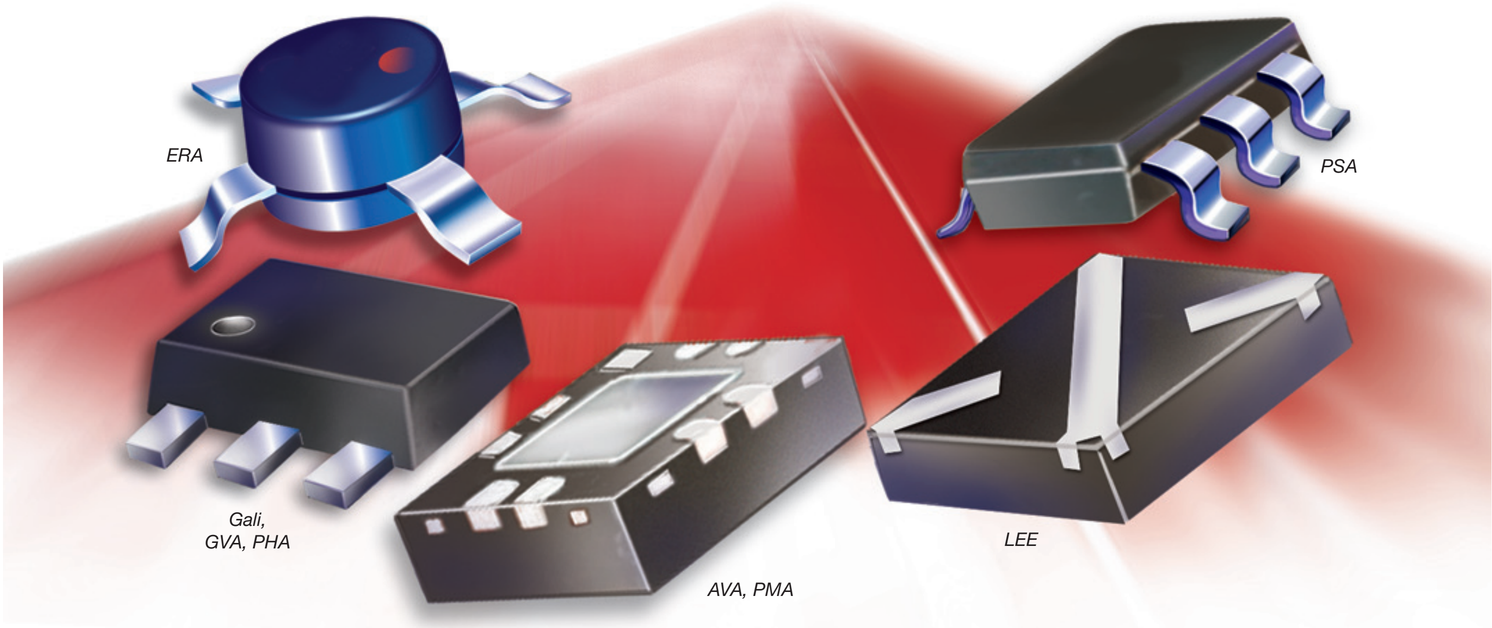

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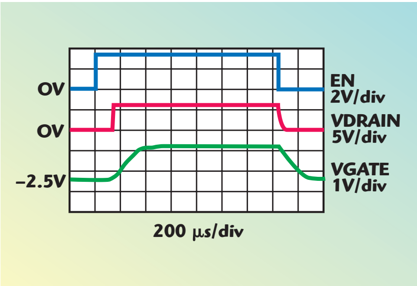
from a fresh start-up, as seen in ***Figure 3***, or enabling the active bias control by toggling enable pin (EN), as seen in ***Figure 4***. At start-up, V-DRAIN is pulled down to GND until the VNEGIN settles down to -2.5 V. VGATE is then pulled down to the most negative supply available to ensure that the amplifier under control is completely turned off. Once VGATE reaches VNEGIN, VDRAIN is turned on and active bias loop is enabled. The final phase of the power-up sequence is increasing the VGATE linearly until the target value for IDRAIN is reached.

The amplifier under control can be enabled or disabled using the EN pin of the HMC920LP5E, as shown in Figure 4. When disabled through this pin, only the VGATE and VDRAIN outputs will be affected; the rest of the chip (negative voltage generator, bandgap, high voltage LDO output LDOCC) will remain operational.

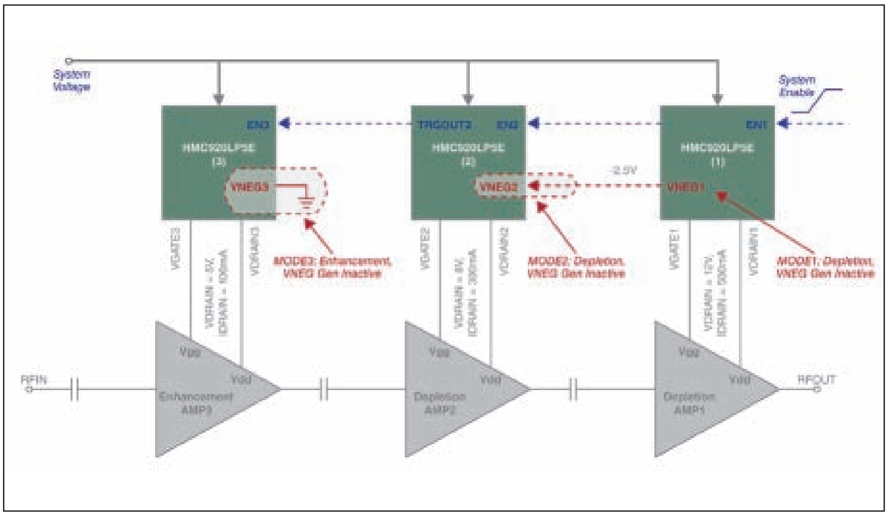
The HMC920LP5E has multiple operation modes and can be configured to control both enhancement and depletion mode devices. In the depletion mode configuration the HMC920LP5E is capable of internally generating a negative voltage as well as operating from an external negative supply voltage. The HMC920LP5E also allows designers to implement custom daisy-chain power-up sequencing in cascaded amplifier systems, as shown in ***Figure 5***. In this example, three cascaded amplifier stages are triggering one another from right to left when quiescent bias is achieved. The HMC920LP5E will thus ensure a safe and controlled turn on/off of the cascaded amplification stages.

The HMC920LP5E incorporates multiple warning and protection features that could not be easily implemented using discrete components. The HMC920LP5E continuously monitors the quiescent current of the amplifier and the digital alarm signal, CURALM, output flags when an under/over condition is detected. Similarly, the VDDALM digital output is an indicator for under-voltage condition on the main system supply. The HMC920LP5E also utilizes automatic protection features like power fold back and short circuit protection to ensure both its own and the amplifier's safety. Under fault conditions such as shorts on VDRAIN, VGATE or VNEGIN, the system goes to the stand-by mode until the fault condition is removed.

Ideal for biasing Class A amplifiers in cellular/3G, WiMAX/4G, VSAT, MW radio, military, fiber optics and test equipment applications, the HMC920LP5E active bias controller is housed in a compact, RoHS compliant 5 × 5 mm QFN SMT package, and is specified for operation from -40° to +85°C (see ***Table 2***). Built on a robust, production qualified, high volume CMOS process, and with its patent-protected unique features, the HMC920LP5E is an excellent solution for various biasing needs. Samples and evaluation PC boards are available from stock. Data sheets and supporting information for the HMC920LP5E and all Hittite products are available online.



▲ *Fig. 4 Enable/disable waveform.*



▲ *Fig. 5 Daisy chain operation.*

TABLE II

A SELECTION OF HITTITE AMPLIFIERS THAT WILL BENEFIT FROM ACTIVE BIAS CONTROLLER HMC920LP5E

Low Noise Amplifiers	Gain Blocks & Driver Amplifiers	Linear & Power Amplifiers	Wideband (Distributed) Amplifiers	Wideband Power Amplifiers	Optical Modulator Driver Amplifiers
HMC490LP5E	HMC633LC4	HMC442LM1	HMC406LC5	HMC464LP5E	HMC870LC5
HMC504LC4B	HMC634LC4	HMC442LC3B	HMC462LP5E	HMC619LP5E	HMC871LC5
HMC594LC3B	HMC635LC4	HMC498LC4	HMC463LP5E	HMC637LP5E	
HMC609LC4		HMC499LC4	HMC465LP5E	HMC659LC5	
HMC753LP4E		HMC608LC4	HMC633LC4	HMC797LP5E	
HMC752LC4			HMC634LC4		
HMC772LC4					
HMC902LP3E					

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

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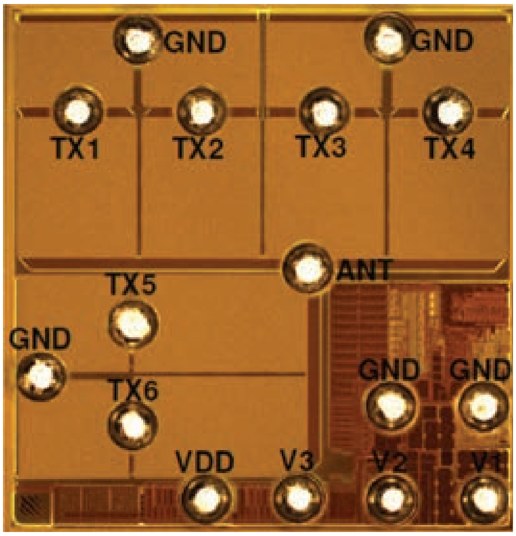


ULTRACMOS™ FULLY SYMMETRIC SP6T RF SWITCH FOR 3G DESIGN FLEXIBILITY

The increasing content of today's smartphones dictates shrinking form factors and increased flexibility in the RF Front-End (RFFE). Mainstream cellular devices support two bands of W-CDMA for home network data access and four bands of GSM/GPRS/EDGE for worldwide mobility. Focus on cost has driven the industry to reuse the W-CDMA duplexers for reception of two of the GSM RX bands to eliminate the two SAW filters, requiring an SP6T switch to manage RFFE signal routing (see ***Figure 1***). Due to the higher loss of W-CDMA duplexers versus dedicated GSM RX filters, additional pressure is placed on achieving low insertion loss in the RFFE switch.

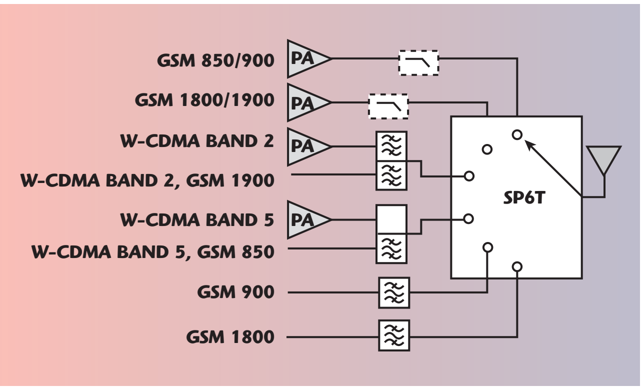
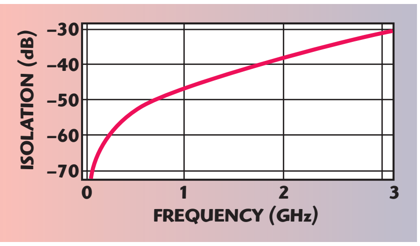


Fig. 1 SP6T switch configuration in RF front-end.

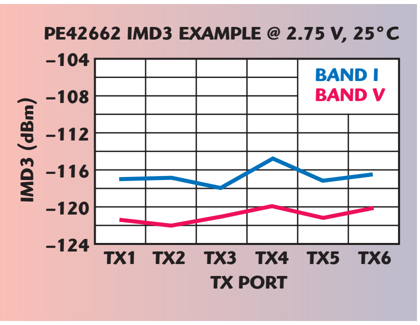
A multitude of chipset I/O arrangements and handset form factors create product development difficulties for the RFFE components industry due to the wide diversity of configurations. A common platform that can support "any mode, any band" on all paths has to date been difficult to achieve due to stringent requirements of the RFFE switch such as isolation of 35 dB between paths and IIP3 of > +65 dBm (see ***Figure 2***). This has also served as a barrier to higher levels of integration with the RX and duplexing filters for realizing the most compact and streamlined RFFE solution for handset designers.

The industry's first fully symmetric 3G single pole six throw (SP6T) RF switch, the PE42662 from Peregrine Semiconductor,

PEREGRINE SEMICONDUCTOR CORP.
San Diego, CA



▲ *Fig. 2 Isolation between paths of PE42662 SP6T switch.*



▲ *Fig. 3 IMD3 performance of PE42662.*

is the latest release in Peregrine's UltraCMOS™ silicon-on-sapphire (SOS) mobile wireless switch portfolio to address these needs. Built on the STeP3 UltraCMOS process, the PE42662 delivers design flexibility to manufacturers of 3G front-end modules used in multi-band GSM/EDGE/W-CDMA handsets. The switch incorporates six fully symmetric transmit ports that, for the first time, allow designers to develop cleaner layouts with a common universal die, and freely configure any combination of transmit/receive ports for GSM, EDGE and W-CDMA. This new capability makes it easier to design for the multiple modules and 3G handset variations required without compromising increased feature integration, ruggedness and high performance. The new device is available in flip-chip form, which enables single-pass module assembly with CSP filters for reduced manufacturing costs.

The 50-ohm switch features Peregrine's HaRP™ technology enhancements to deliver high linearity and harmonic performance of better than 2fo = -40 dBm and 3fo = -40 dBm with +35 dBm applied at 900 MHz (see ***Figure 3***). The PE42662 switch surpasses the market requirement with an IIP3 of > +68 dBm at Band I, II, V and VIII; low transmit insertion loss of 0.5 dB at 900 MHz, 0.6 dB at 1900 MHz; and very high isolation of 38 dB at 900 MHz, 33 dB at 1900 MHz. The switch handles maximum +35 dBm input power into any load condition with ESD tolerance of 4000 V HBM at the ANT port, and 2000 V HBM on all ports.

Additional features of the PE42662 switch include an on-chip CMOS decode logic that facilitates three-pin low voltage CMOS control and low-power standby state, as well as on-chip SAW filter over-voltage protection devices. As with all SOS-based UltraCMOS RFICs, no blocking capacitors are required. The PE42662 SP6T switch offers many advantages to the designer for performance and flexibility in the design of RFFEs.

Peregrine Semiconductor Corp., San Diego, CA (858) 731-9400, www.psemi.com.

RS No. 304

GIGA-LOW HANDY PROBE™ ENABLED BY ADVANCED TRANSMISSION LINE TECHNOLOGIES

RFCONNEXT Inc. has developed a family of advanced high speed, wideband transmission lines, comprising patent pending PMTL™, VMTL™ and SMTL™, that provide new possibilities for cables and connectors, high speed PCB routing, electronic packaging interconnects, test and measurement probing, and RF/microwave and wireless communication applications. These advanced transmission lines are being embedded in many modern electronic components and systems to improve speed and bandwidth, using the traditional manufacturing processes. One of the applications of these transmission lines is the development of new probing technologies, as to provide high speed interconnects between the test instrumentation and the test point on the PCB, in the form of Single Ended and Differential Pairs tips, with the highest level of signal integrity.

Giga-Low Handy Probe™ provides a single action connection to unplanned or pre-planned surface-mount pads (SMT) or traces with a single action. The new product, while providing excellent electrical performance to 50 GHz and beyond (including clean, sharp edge TDR), eliminates the need for bulky and expensive xyz tables with mounting probes stations (see ***Table 1***). It provides its own patent pending alignment "whiskers" that secures the probe to the strategic proximity of the test points SMT pads; a gentle push down of the Hand Probe exposes the otherwise hidden and protected tips of the probe and connects it to the SMT of the PCB under test. The full bandwidth, flex TEM transmission line practically eliminates the probe tip parasitic, while providing variable pitch Diff Pair testing capability.

Existing Handy Probes are limited to the use of coaxial line flexes to achieve similar bandwidth and traditional connectors, and present challenging interconnect issues in terms of Single Ended and Differential Pair connectivity. The Giga-Low Handy Probe uses the full bandwidth RFCONNEXT Giga-Low uFlex™, TEM flexible cable with advanced connector and interface technologies that provide ample flexibility and re-configurability to the PCB probing. One of the clear advantages is the provision of readily achievable SOLT and

RFCONNEXT INC.
San Jose, CA

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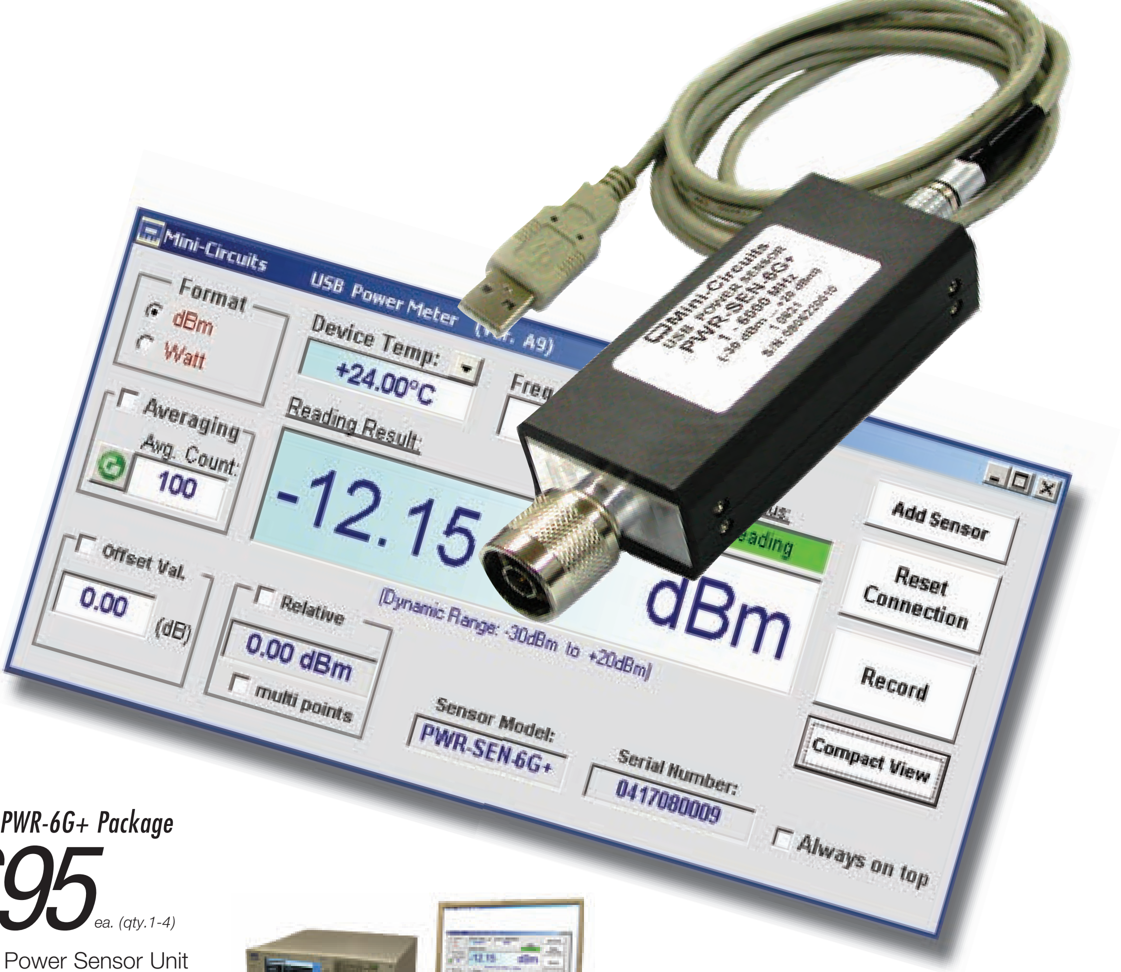

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U.S. patent 7739260

IF/RF MICROWAVE COMPONENTS

457 rev K

TABLE I

GIGA-LOW HANDY PROBE FEATURES

Uses New Printed Circuit Coaxial-like Technology
Provides High Speed, Wideband, DC-65 GHz and Beyond
Single End or Differential Pairs tip
Fixed, and or variable pitch tips
Normally Hidden and Protected Probe Tips
Single Action Alignment and Probe Connection
Patent Pending Reconfigurable Probe Alignment "Whiskers"
Ease of Use, ZIF SMT connectivity
More complex, Multiple Tip Arrays
Can Use Standard Calibration SOLT, LRL, etc.
Can be mounted on existing Manipulator arm
Can accumulate various instrumentations
- Spectrum Analyzer
- Eye Diagram Scope
- TDR Scope
- VNA
- Pattern Monitors
Low Loss, Low Cross talk
Hard and Flex PCB combinations

TABLE II

GIGA-LOW HANDY PROBE APPLICATIONS

Real Time TDR Probing
Eye Diagrams, and Constellation Testing
Digital and Real time Scopes
Signal Integrity Probing
Full Bandwidth VNA S-par Testing
Optical Baseband Channel Testing
Protocol Testing, USB, DVI, HDMI, XAUI, Ethernet
High Fidelity Testing Connectivity
Testing of PCB in Servers, Routers, Super Computers
High Speed Backplane and Plug in Probing
Testing Phased Arrays, Antennas
Testing RF/Microwave/Optical Boards

LRL and other types of calibration of the probe to the tips.

Another feature is the provision of reconfigurable tips, "whisker" alignment pins and other SMT configurations, with simple alignment holes on the PCB, providing many improvements for the PCB probing. Additionally, the Handy Probes can be designed with high speed connectors, such as 3.5, 2.92, 2.4, 1.85 and 1 mm, etc., or be provided with an integrated Giga-Low uFlex extension, or as a separate add-on. Either way, the use of PMTL technologies provides many possible configurations in printed circuit technologies that are impossible to achieve with the traditional methods and extruded coaxial lines. For example, with RFCONNEXT's printed PMTL micro coax technology, an array of probe tips can easily be accommodated for more complex SMT probing, for manual or automatic operation (see ***Table 2***).

The flexibility and re-configurability of the PMTL technologies provides many possibilities for improved PCB probing, for TDR, VNA, and SE and DP signal testing. In addition to manual operation, the Handy Probe can be mounted on traditional manipulating arms for full automatic testing.

RFConnext Inc.,
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(408) 981-3700,
info@rfconnext.com,
www.rfconnext.com.

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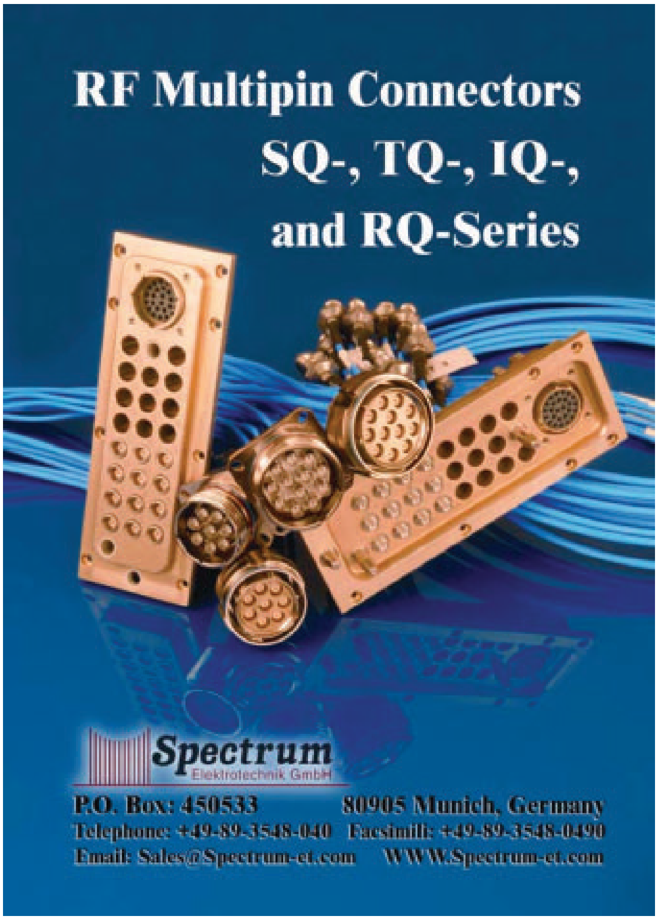
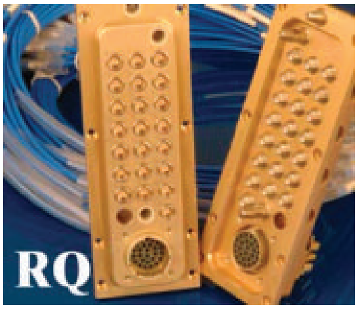
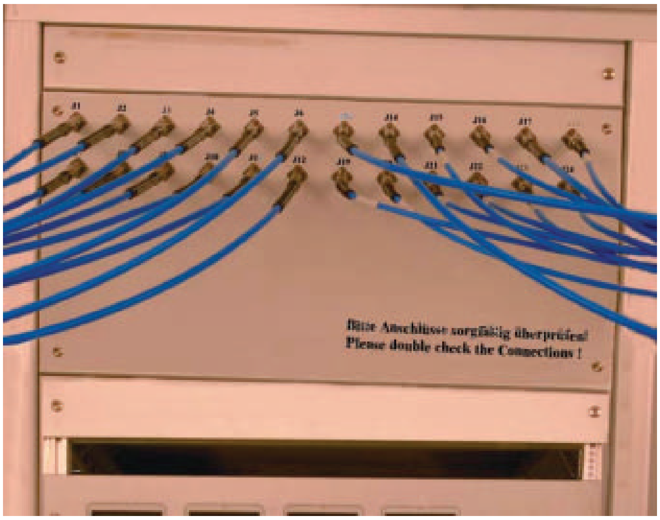
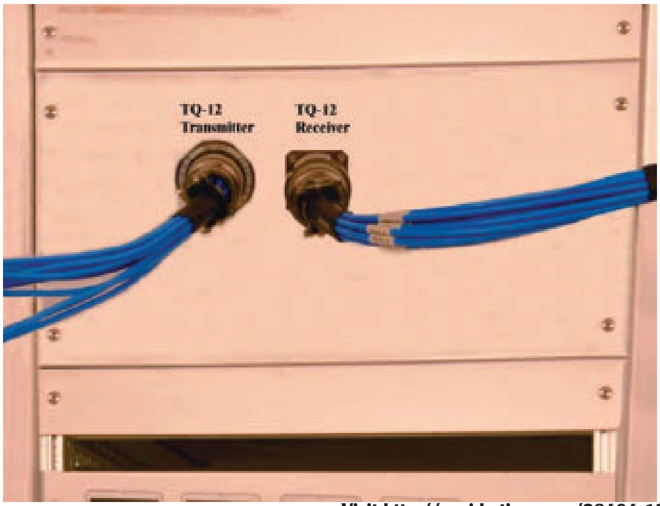


Catalogue RF Multipin Connectors
52 pages showing in detail 4 coaxial Multipin Connector Series, demonstrating how to connect and disconnect up to 23 coaxial lines in seconds and saving space.





The Problem: In various applications many coaxial microwave links have to be connected and disconnected. This means threadening and unthreadening, torquing and untorquing. Very dense packaging is not possible, as there is still room needed for manual threadening and for the use of a torque wrench. In helicopters and aircrafts all connectors usually have to be safely secured, wiring the coupling nuts of the connectors, using wire holes, a time-consuming process.



The Solution: Spectrum's Multipin Connectors are available with four (4), seven (7), eight (8), twelve (12) and twenty three (23) coaxial inserts (terminating the coaxial cable assemblies) at the Multipin end, and connecting all the coaxial cable assemblies at once and in seconds with no need of a torque wrench, no need for safety wires and using minimum space.

Spectrum Elektrotechnik GmbH
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Email: Sales@Spectrum-et.com www.Spectrum-et.com

XINGER®-III FAMILY OF 3 dB HYBRID AND DIRECTIONAL COUPLERS

Anaren Inc. has officially launched its Xinger®-III brand family of 3 dB hybrid and directional couplers for wireless infrastructure applications. The two new passive devices offer improved power handling, lower loss and other electrical performance metrics of interest at only ¼ the size of the company's previous-generation Xinger-II components (which will remain in production). Suitable applications include balanced-power amplifiers, low-noise amplifiers and other equipment used in 2/3/4G communications.

The new components cover bands within the range of 0.6 to 2.9 GHz, handle up to 225 W, and feature patent-pending softboard design and materials advances that make the couplers (available in 0.25 × 0.2" or 0.56 × 0.2" footprints) an attractive alternative to ceramic equivalents; they can be implemented without the risk of cracked solder joints that ceramics can create when their thermal expansion characteristics do not match the PCB they are mounted to. Because the new parts are softboard, the co-efficient of thermal expansion (CTE) disparity does not exist, liberating designers to specify ordinary PCBs without having to worry about CTE mismatch. Xinger-III components are compatible with FR4, G-10, RF-35, RO4003 and Polyimide.

Compared to the previous Xinger-II brand parts, the new Xinger-III hybrid coupler line offers 52 to 66 percent lower insertion loss (down to 0.12 dB), 5.35 times the power handling, 25 to 28 percent higher isolation, 63 to 71 percent better amplitude balance, and equal phase balance. At ¼ the size of their predecessors, the new Xinger-III brand directional coupler family delivers 37 to 64 percent lower insertion loss (down to 0.05 dB), 50 percent higher power handling and equal directivity. Both Xinger-III parts are also RoHS-compliant, are shipped on tape-and-reel for automated assembly system, and are available through Anaren's authorized distributors.

Anaren Inc.,
East Syracuse, NY
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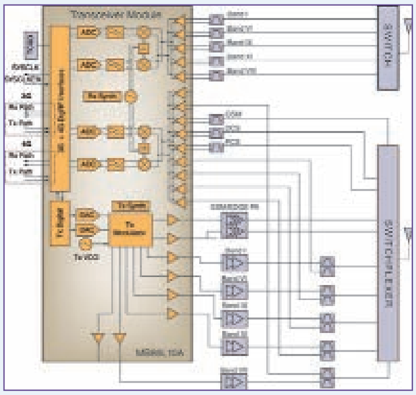

FUJITSU SHIPS FIRST 3G AND LTE SAW-LESS TRANSCEIVER

With cell phone makers ready to transition to the Long-Term Evolution (LTE) standard later this year, designers require advanced transceiver technology that supports a broad range of industry basebands including 2G and 3G, in addition to LTE. Designers also need an efficient, compact, highly integrated transceiver to reduce total component count, board space and BOM.

The Fujitsu MB86L10A transceiver meets those requirements. Designed for multimode, multiband LTE, UMTS and EDGE mobile handsets, the transceiver eliminates external LNAs and inter-stage SAW filters from the TX and RX paths of 3G and LTE lineups. The MB86L10A incorporates anti-aliasing filters, digital channel filters, digital gain control and high-dynamic-range ADCs. A proprietary high-level programming model can control the radio using the 3G and 4G DigRF/MIPI interfaces, supporting a broad range of industry basebands.

Because the MB86L10A supports 3G and 4G interfaces, it can be paired with one or two baseband processor ICs. The MB86L10A supports GSM (GSM850, EGSM900, DCS1800, PCS1900), W-CDMA (bands I, II, III, IV, V, VI, VIII, IX, X and XI) and LTE (FDD bands 1, 3, 4, 6, 7, 8, 9, 10, 11, 13, 17 and TDD bands 38 or 40).

The MB86L10A builds on the short-cycle RF programming method developed for Fujitsu's MB86L01A RF transceiver. The programming capability enables the MB86L10A to speed RF subsystem implementations with simplified layer-one programming and embedded intelligence. An MCU core unit simplifies timing and control. SPI and/or GPOs control PAs, switching regulators and the antenna switch.

The transceiver can be used in mobile phones and Internet devices, data cards and embedded modules. It comes in a compact 6.5 × 9.0 × 1.0 mm LGA package. For details, visit www.fujitsu.com/downloads/MICRO/fma/pdf/RFTrans_MB86L10A.pdf.

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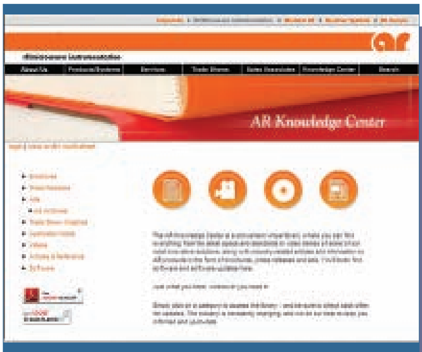
RF and Microwave Filters

VENDORVIEW

Anatech Electronics launched two new websites—anatechelectronics.com (for custom products) and AMCrf.com (Web store for online purchases)—that provide technical information for designers and make it easier to specify the company's RF and microwave filters. The anatechelectronics.com site describes Anatech's custom filter design fabrication capabilities. The AMCrf.com site offers hundreds of standard products that are available from stock in a very short time.

Anatech Electronics,
70 Outwater Lane, Garfield, NJ 07026

www.anatechelectronics.com



AR's Knowledge Center

VENDORVIEW

The AR Knowledge Center is a convenient virtual library featuring the company's complete educational and informative offerings including software and software updates, application notes, newsworthy articles and exciting product demonstrations. All materials are available for download including the Orange Book of Knowledge.

AR RF/Microwave Instrumentation,
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Power Amplifiers

CTT Inc.'s website offers a wide selection of low-noise and high-power amplifiers designed for applications including: ESM, radar systems, missiles, UAVs, seekers, decoys, tactical common data links (TCDL) and commercial communications systems. Offerings include low-noise drop-in configurations, connectorized hermetically-sealed packages, and rack-mount high power designs. A new family of low-noise amplifiers from 1 to 18 GHz that covers more than four octaves has been added. CTT's products are designed to provide the best price versus performance combination for each customer.

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Interactive Product Catalog

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

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Hittite's redesigned website includes a dynamic homepage featuring full specifications for over 850 products across 28 product lines, press releases and featured articles. Comprehensive Individual Product "Splash Pages" containing in-depth product information and technical content are located on one easy to navigate page. Engineers will find improved Product Support and streamlined Quality & Reliability pages containing invaluable reference materials.

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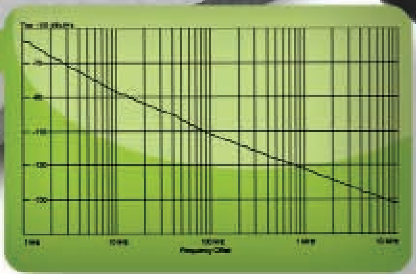
DCO7075-3	700 - 750	0.5 - 3	+3 @ 10 mA	-108	0.3 x 0.3 x 0.1
DCO80100-3	800 - 1000	0 - 3	+3 @ 15 mA	-105	0.3 x 0.3 x 0.1
DCO80100-5	800 - 1000	0.5 - 8	+5 @ 21 mA	-111	0.3 x 0.3 x 0.1
DCO100200-5	1000 - 2000	0.5 - 24	+5 @ 30 mA	-95	0.3 x 0.3 x 0.1
DCO1198-8	1195 - 1205	0.5 - 8	+8 @ 24 mA	-115	0.3 x 0.3 x 0.1
DCO170340-5	1700 - 3400	0.5 - 24	+5 @ 24 mA	-90	0.3 x 0.3 x 0.1
DCO200400-5 DCO200400-3	2000 - 4000	0.5 - 18	+5 @ 35 mA +3 @ 35 mA	-90 -89	0.3 x 0.3 x 0.1
DCO300600-5 DCO300600-3	3000 - 6000	0.5 - 18	+5 @ 35 mA +3 @ 35 mA	-80 -78	0.3 x 0.3 x 0.1
DCO400800-5 DCO400800-3	4000 - 8000	0.5 - 18	+5 @ 35 mA +3 @ 35 mA	-78 -76	0.3 x 0.3 x 0.1
DCO432493-5 DCO432493-3	4325 - 4950	0.5 - 11	+5 @ 17 mA +3 @ 17 mA	-88 -86	0.3 x 0.3 x 0.1
DCO450820-5	4500 - 8200	0.5 - 14	+5 @ 22 mA	-77	0.3 x 0.3 x 0.1
DCO473542-5 DCO473542-3	4730 - 5420	0.5 - 22	+5 @ 20 mA +3 @ 20 mA	-88 -86	0.3 x 0.3 x 0.1
DCO490517-5 DCO490517-3	4900 - 5175	0.5 - 5	+5 @ 22 mA +3 @ 22 mA	-88 -86	0.3 x 0.3 x 0.1
DCO495550-5 DCO495550-3	4950 - 5500	0.5 - 12	+5 @ 22 mA +3 @ 22 mA	-87 -85	0.3 x 0.3 x 0.1
DCO579582-5	5780 - 5880	0.5 - 10	+5 @ 27 mA	-91	0.3 x 0.3 x 0.1
DCO608634-5 DCO608634-3	6080 - 6340	0.5 - 5	+5 @ 22 mA +3 @ 22 mA	-86 -84	0.3 x 0.3 x 0.1
DCO615712-5 DCO615712-3	6150 - 7120	0.5 - 18	+5 @ 22 mA +3 @ 22 mA	-85 -83	0.3 x 0.3 x 0.1

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

Features

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



RoHS COMPLIANT

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

Visit Our Website At WWW.SYNERGYMWAVE.COM

High Speed Interconnect Technologies

RFCONNEXT Inc.'s web page provides extensive information about the new high speed interconnect technologies PMTL™, VMTL™ and SMTL™, which together provide increased bandwidth for any high speed interconnects, thus help advancing the High Speed Interconnect Ecosystem. In addition, the web page provides a large number of white papers and information that will be of great interest to RF/microwave engineers.

RFCONNEXT Inc.,
20415 Almaden Station,
San Jose, CA 95160-0415

www.rfconnext.com

RF Components

VENDORVIEW

Visit www.rfmd.com to see RFMD's enhanced website. The homepage features new links and organizes information under Function and Market columns for convenient scanning. Also look for new category filters, updated parameter data, new "product group" overview pages, and updated Browse and Buy dropdown menu for easy product searching and purchasing.

RFMD,
7628 Thorndike Road,
Greensboro, NC 27409

www.rfmd.com

Chinese Website

Richardson Electronics Ltd. announced the launch of a fully translated version of its recently redesigned website to better serve its growing customer base in mainland China. The new Chinese website provides all of the vital product information and resources found in the English version released in September 2009, including online design resources to help engineers improve time to market. The Chinese site also utilizes Richardson Electronics' unique Engineer-Focused Navigation™ system.

Richardson Electronics,
40W267 Keslinger Road,
LaFox, IL 60147

www.rell.com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EuMW
in Paris, France
Booth 42
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Are Measured In Microns
Thin Film Engineering. DLI has extensive experience and can assist in tailoring ceramic/metallization systems to your design to achieve maximum performance. DLI is capable of meeting as small as 0.0005" line width and spacing with 0.0001" tolerance.
Lithography | Thickness | Pattern line & width spacing
Gold | ≤150 µ" | ≤0.5 ± 0.1 mil
Gold | 150-300 µ" | 1.0 ± 0.2 mil
Copper | 50-600 µ" | 3.0 ± 0.4 mil
Nickel | 50-125 µ" | 3.0 ± 0.4 mil
All filters employ DLI's high-K ceramics which allow for size reduction and extreme temperature stability compared to alumina and PWB materials. Solder surface mount and chip and wire filters are all possible.
DLI DIELECTRIC LABORATORIES
A DOVER COMPANY
CMP
www.dilabs.com
Dielectric Laboratories, Inc.
2777 Route 20 East, Cazenovia, NY 13035 USA
Phone: (315) 655-8710
Fax: (315) 655-0445
Email: sales@dilabs.com
DLI is the preeminent global supplier of Single-Layer and Multi-Layer Capacitors, Build to Print Thin Film circuits and Custom Thin Film application-specific ceramic components such as Filters, Gain Equalizers and Resonators.
Visit http://mwj.hotims.com/28494-33 or use RS# 33 at www.mwjournal.com/info

The following booth numbers are complete as of August 4, 2010.

Handheld Spectrum Analyzer

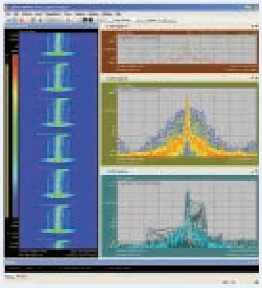
VENDORVIEW

Agilent Technologies introduced the N9342C handheld spectrum analyzer (HSA), a powerful and straightforward instrument designed for RF technicians and engineers performing installation, maintenance and surveillance of RF systems in the field. The N9342C HSA makes field testing easier by providing faster, more precise measurements, ease of use, and a range of user customization and ergonomic features. Agilent's N9342C HSA provides fast and accurate measurement of RF and microwave equipment and RF environments from 100 kHz to 7 GHz, tunable to 9 kHz. RF and microwave equipment measurements include transmitter and component test, receiving path signal monitoring and antenna tuning. RF environment measurements include band clearance, signal coverage and interface hunting.

Agilent Technologies Inc., Microwave & Communications Division, Santa Clara, CA (800) 829-4444, www.agilent.com.
Booth 62 **RS No. 216**

Next Generation VSA software

VENDORVIEW



Agilent's next generation of 89600 vector signal analysis is a window into what's happening inside complex wireless devices. The software features like 20:20 trace/marker capability providing 20 traces with 20 markers each, provide views of virtually every facet of a problem, helping R&D engineers see the "why?" New troubleshooting features to help engineers find the root cause of a problem, include VSA digital persistence trace for viewing bursts and transients that occur on a regular basis, and a cumulative history trace for evaluating spurs, transients and bursts that occur intermittently or at very long intervals. For LTE TDD a new antenna pattern trace evaluates the nulls and lobes of beam forming signals before they go to the transmitters. A new flexible OFDM option provides architects of custom OFDM signals a way to test the performance of their new signal with high performance OFDM evaluation tools.

Agilent Technologies Inc., Microwave & Communications Division, Santa Clara, CA (800) 829-4444, www.agilent.com.
Booth 62 **RS No. 217**

Ultra-low Phase Noise for PSG Signal Generators

VENDORVIEW

Agilent has developed a new Option UNY for enhanced ultra-low phase noise for the PSG high-performance signal generators. Compared to the existing low phase noise, Option UNX, Option UNY provides a 5 dB improvement at very close in (< 10 Hz) offsets and up to 12 dB improvement in the pedestal region (10 to 100 kHz offsets). Low phase noise sources are especially useful for a wide range of applications, including use as a reference source in phase noise test systems, LO substitution in advanced radar system development and demanding receiver measurements of adjacent channel performance and blocking tests. To further tailor the PSG's performance for different applications, Option UNY offers two optimization modes.

Agilent Technologies Inc., Microwave & Communications Division, Santa Clara, CA (800) 829-4444, www.agilent.com.
Booth 62 **RS No. 218**

PLL Synthesizer

This new phase locked loop (PLL) synthesizer is designed for a variety of applications, including microwave point-to-point systems, private mobile radio (PMR), very small aperture terminals (VSAT), test and instrumentation equipment, and aerospace systems. The ADF4150HV 4.4 GHz fractional-N or integer-N PLL synthesizer features a 30 V charge pump. A charge pump capable of 30 V drive level represents the highest voltage IC PLL charge pump available on the market today. Because the device can be used to directly drive high tuning-voltage external voltage controlled oscillators (VCO), it removes the need for active loop filters, thereby simplifying system design, improving performance and reducing bill of materials cost.

Analog Devices Inc., Norwood, MA (781) 329-4700, www.analog.com.
Booth 111 **RS No. 220**

Handheld Spectrum Analyzer

VENDORVIEW

Anritsu Co. introduces the MS272xC Spectrum Master series that provides the broadest frequency range ever available in a handheld spectrum analyzer. Providing frequency coverage up to 43 GHz in an instrument that weighs less than 8 lbs., the MS272xC series is also designed with an assortment of applications to test the RF physical layer, making it easier than ever for field technicians, monitoring agencies and engineers to monitor over-the-air signals, locate interferers, and detect hidden transmitters. Five models, with high-end frequency coverage of 9, 13, 20, 32 and 43 GHz, respectively, are available in the new family.

Anritsu Co., Morgan Hill, CA (800) 267-4878, www.anritsu.com.
Booth 85 **RS No. 221**

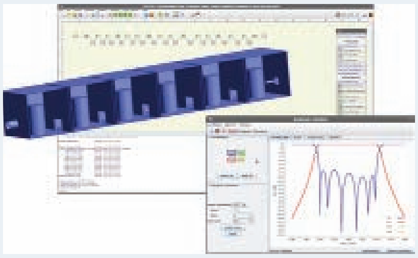
High Frequency EDA

VENDORVIEW

Visit AWR in Booth #84 during European Microwave Week 2010 for a review of its 2010 software releases. Microwave Office® highlights include support for nonlinear behavioral modeling for Agilent's X-parameters®, Mesuro's Cardiff model, NMDG's S-functions and more, connectivity tracker/tracer, linear stability analysis, new modules of iFilter™ for lumped and distributed filter synthesis, and AWR Connected™ for Cadence for Allegro PCB co-design. Also new for 2010 are Visual System Simulator™ (VSS) TDNN™ memory effect modeling, as well as AXIEM™ antenna analysis and post-processing capabilities. Learn more at www.awrcorp.com and www.awr.tv.

AWR Corp., El Segundo, CA (310) 726-3000, www.awrcorp.com.
Booth 84 **RS No. 222**

Software Tool



FEST3D version 6.6 offers new features for the analysis and design of passive waveguide components. Among these new capabilities a new synthesis tool for dual-mode filters has been developed, the synthesis tools for low pass and bandpass filters have been extended, and the possibility to analyze broadband combline filters has been added. Multipactor multicarrier analysis is now also possible. This new version fosters FEST3D performance thanks to the 64 Bit support and to multi-threading at network level. Additionally, an interface with FEKO has been included in order to import the Generalized Scattering Matrix from FEKO to FEST3D and to export from FEST3D the impressed modes for the feeding of antenna elements to FEKO. For a full DEMO version freely downloadable, please visit: www.fest3d.com/download.php.

Aurora Software and Testing, Valencia, Spain +34 963 714 257, www.fest3d.com.
Booth 113 **RS No. 223**

Ceramic Mixers

300 MHz-12 GHz

- *New gold connections*
- *Ceramic package gives superior reliability*
- *High performance at a lower price*

from **$2.95** *ea. (qty. 1000)*

The patented **MCA1T** series of ceramic mixers now feature castellated gold-over-nickel plate connections. These drop-in replacements have the same footprint as our leaded models and offer the same high level of wideband performance with an even higher level of reliability.

Pick from 16 models with LO levels from 4 to 17 dBm and isolation up to 40 dB. **MCA1T** mixers contain their circuitry in a compact, tough-as-nails ceramic package, making them temperature-stable and able to withstand most environmental conditions. And the variety of wideband models means you can use these mixers in many different applications.

Detailed technical specifications are available at *minicircuits.com*. And, as always, Mini-Circuits is ready to help with quick, off-the-shelf shipments, fast turnaround, and even custom design.

Mini-Circuits...Your partners for success since 1969

MODEL	LO Level (dBm)	Freq. Range (MHz)	Conv. Loss (dB)	LO-RF Isol. (dB)	Price $ ea. (Qty.10-49)
MCA1T-85L+	4	2800-8500	6.0	35	7.95
MCA1T-12GL+	4	3800-12000	6.8	38	10.45
MCA1T-24+	7	300-2400	6.1	40	4.95
MCA1T-42+	7	1000-4200	6.1	35	5.95
MCA1T-60+	7	1600-6000	6.2	32	6.45
MCA1T-85+	7	2800-8500	5.6	37	7.45
MCA1T-12G+	7	3800-12000	6.2	38	9.45
MCA1T-24LH+	10	300-2400	6.5	40	5.45
MCA1T-42LH+	10	1000-4200	6.0	38	5.95
MCA1T-60LH+	10	1700-6000	6.6	35	6.95
MCA1T-80LH+	10	2800-8000	6.0	35	8.45
MCA1T-24MH+	13	300-2400	6.1	40	5.95
MCA1T-42MH+	13	1000-4200	6.2	35	6.45
MCA1T-60MH+	13	1700-6000	6.4	27	7.45
MCA1T-80MH+	13	2800-8000	5.7	27	9.45
MCA1T-80H+	17	2800-8000	6.3	35	10.45

Dimensions: (L) 0.35" x (W) 0.28" x (H) 0.09"
U.S. Patent # 7,027,795

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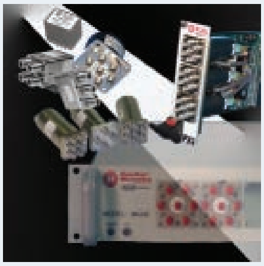
U.S. patent 7739260

IF/RF MICROWAVE COMPONENTS

479 Rev A.

New Waves

Switches for RF Test Applications



Dow-Key's new product catalog offers a wide range of RF switches. For smaller test applications, 5-million cycle, miniature sized and pin-mount PCB switches are perfect, and for larger setups PXI modules and GPIB/Ethernet/RS-232 controlled matrices are available.

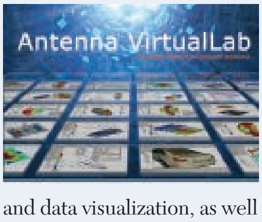
Dow-Key Microwave,
Ventura, CA (805) 650-0260,
www.dowkey.com.
Booth 42 **RS No. 224**

SP2T Microwave Switch

This family of USB-compatible microwave switches is designed for test bench and lab application. Without any external power supply, these switches cover the frequencies from DC to 26.5 GHz, with excellent isolation and low loss. Built in robust aluminum package, it can be used in various applications. Customizations are available for unique requirements.

ELHYTE,
Nozay, France
+33 (0) 1 69 01 68 51,
www.elhyte.fr.
Booth 30 **RS No. 225**

Antenna Simulation



The work of EMCoS Ltd. focuses on the generation of special simulation software for electromagnetic field calculation and data visualization, as well as on consultation with EM problems. EMCoS helps its customers with complex simulation problems by offering appropriate tools, or the company supports them with processing of the complex data. EMCoS Antenna VirtualLab is a powerful program package especially suited for antenna calculations. The program package allows in a very convenient way to design and model complicated antenna structures, calculate them accurately and easily process the results. It provides very convenient tools for comfortable and flexible CAD data processing. Various material properties can be assigned. Antennas can be loaded or fed with many kinds of circuits.

EMCoS Ltd.,
Tbilisi, Georgia
995-32-389091,
www.emcos.com.
Booth 18 **RS No. 226**

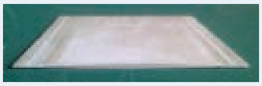
Comprehensive Electromagnetic Solutions

FEKO
Comprehensive Electromagnetic Solutions

On an annual basis, new major FEKO releases are made available, with smaller updates in-between. This month, FEKO Suite 6.0 was released, the highlight of which is the "accelerated MoM", i.e. several improvements around the Method of Moments to make this faster and more memory economical. Specific extensions include GPU support, better parallel performance and in particular memory scaling for shared memory parallel processing, and also a new matrix compression technique. On the electromagnetic side, many new extensions have been made such as a large element Physical Optics solver, aperture slot modelling, frequency dependent materials, integrated spice circuit modelling, error estimation, or a new hybridisation of FEM with MLFMM.

EM Software & Systems GmbH,
Böblingen, Germany +49 (0)7031 714 5200,
www.emss.de.
Booth 25 **RS No. 227**

Multi-layered LTCC Substrates



Hirai SK Corp. provides its featured foundry service of multi-layered LTCC substrates. Hirai targets higher Q, dimensional precision and the high yield for RF and mm-wave applications. Displayed in the exhibition are a mm-wave antenna integrated LTCC transceiver module, miniaturized BPF with low loss, tapered LTCC substrate and hermetically-sealed LTCC package for micro- and mm-wave applications. Hirai ships samples in a week after the design freeze and provides RF test and design services. The design kit CD is also available.

Hirai SK Corp., Shibuya-Ku, Tokyo, Japan +81.334991351, www.hirai.co.jp/index_e.html.
Booth 129 ***RS No. 228***

Synthesized Signal Generator

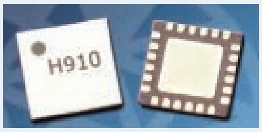
VENDORVIEW

Priced at only $19,498.00, the HMC-T2240 is a 10 MHz to 40 GHz synthesized signal generator that provides the highest output power, lowest harmonic levels and broadest frequency range. Ideal for use in automated test and measurement environments, research and development laboratories, the HMC-T2240 is a compact and lightweight frequency generator that delivers up to +29 dBm at 1 GHz of CW output power in 0.1 dB steps over a 60 dB dynamic range. Harmonic rejection is better than -30 dBc and spurious products are better than -60 dBc at integer frequencies and better than -45 dBc at fractional frequencies. Phase noise is -96 dBc/Hz at 10 kHz offset at 10 GHz. The HMC-T2240 also delivers frequency resolution of 1 Hz and fast switching speed of 500 µs.

Hittite Microwave Corp., Chelmsford, MA (978) 250-3343, www.hittite.com.
Booth 57 ***RS No. 229***

Broadband Time Delay Product Line

VENDORVIEW



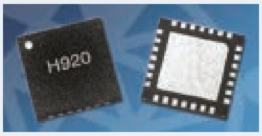
The HMC910LC4B is the first product in the company's new Broadband Time Delay product line. The HMC910LC4B is a DC to 24 GHz time delay product that is ideal for timing adjustment in complex digital applications, including clock and data recovery, edge detection, NRZ-to-RZ conversion, data restoration and Mux/Demux applications. The HMC910LC4B provides a continuously variable time delay from 0 to 70 ps while maintaining a constant differential output voltage swing. The device accepts either single-ended or differential input data, while the differential output swing is easily programmed with a DC voltage. The HMC910LC4B provides a time delay that is linearly monotonic with respect to the delay control voltage, VDC, which may be varied from 1.1 to 2.3 V.

Hittite Microwave Corp., Chelmsford, MA (978) 250-3343, www.hittite.com.
Booth 57 ***RS No. 230***

Class-A Amplifier

VENDORVIEW

The HMC920LP5E is the industry's first complete Class-A amplifier biasing and monitoring solution, and is ideal for power management and control in automotive telematics, Cellular/3G, LTE/WiMAX/4G, broadband, military and test equipment applications. The HMC920LP5E is an active bias controller that can be used to bias depletion and enhancement mode amplifiers operating in Class-A regime. This unique IC houses an integrated LDO to regulate the drain supply of the targeted amplifier and a negative voltage generator for depletion mode devices. The gate voltage of the targeted amplifier is automatically adjusted to keep the quiescent current of the amplifier constant over supply, temperature and threshold drifts.



Hittite Microwave Corp., Chelmsford, MA (978) 250-3343, www.hittite.com.
Booth 57 ***RS No. 231***

New Waves

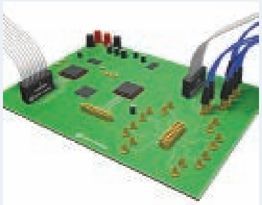
Phase Noise Analyzers

Holzworth's new cross correlation phase noise analyzers target high performance applications that require the fastest data acquisition times. These analyzers are ideal for improving turnaround during product development as well as manufacturing test applications where test system throughput is crucial. Holzworth cross correlation phase noise analyzers can achieve a measurement noise floor of -180 dBc/Hz in less than one minute of correlations. These systems are available in both fixed and tunable frequencies. Holzworth products are also known for their highly intuitive interfaces and cost-effective pricing.

Holzworth Instrumentation Inc.,
Boulder, CO (303) 325-3473,
www.holzworth.com.
Booth 52 **RS No. 234**

40 GHz Multicoax Solution

HUBER+SUHNER launches the new 40 Gbps multicoax solution MXP especially suited for high speed digital test applications. A comprehensive CAE product library with modelling data (Agilent ADS), footprints and 3D files supports engineers in designing printed circuit boards. The ganged multicoax series MXP offers a true 40 Gbps coaxial-to-PCB transition while using less space on boards. Its reliable mating and ease of use make it especially suited for bench-top test systems as well as interconnect within automated test equipment. A broad range of configurations with highly flexible cable assemblies and compact PCB connectors are available. Features include: Operating range up to 40 Gbps; Pitch 4 mm (0.16"); Via-in-pad capable; 0.7 mm (0.028") pin size allows easy matching to smallest trace width; and extensive technical support, libraries and footprints.



HUBER+SUHNER,
Herisau, Switzerland +41 (0) 71 353 41 11,
www.hubersuhner.com.
Booth 72 **RS No. 235**

RF Probe

With the new series HFS-865 from INGUN also signals in the microwave range can be detected or applied – due to the fact that this probe provides very good signal transfer characteristics at frequencies as high as 12 GHz. Excellent return loss and transmission characteristics guarantee reliable signal detection. In combination with the MMPX Cable Assembly you get a unique solution for the whole measurement path. Further advantages are very homogeneous impedance characteristics and the fact that the number of dielectric parts could be reduced dramatically. Long airline structures inside the Probe enhance the capability of transmitting highest frequency signals. Also the precision MMPX – input interface from INGUN's partner Huber+Suhner plays a vital role in achieving such good RF characteristics.

INGUN Prüfmittelbau GmbH,
Konstanz, Germany +49 7531 8105-62,
www.ingun.com.
Booth 72A **RS 251**

Record and Replay System

IZT launches the record and replay system IZT RecPlay suitable for recording received scenarios in different countries with minimum degradation of signal quality. The replay generator IZT S1000 covers the frequency range from 9 kHz to 3 GHz with a bandwidth of 120 MHz. The system is the ideal platform for RF-receiver design validation for radio, video and GNSS applications. It offers greatly reduced costs for field testing, repeatable tests in the lab and fidelity in reproducing real RF environment allowing a much faster time to market.

Innovationszentrum für
Telekommunikationstechnik GmbH IZT,
Erlangen, Germany +49 9131 4800 181,
www.izt-labs.de.
Booth 195 **RS No. 236**

20 W Multiband Amplifier

The Linwave LWA10248 (30 to 512 MHz) is an ultra compact combined multiband integrated transmit booster amplifier and high quality receive LNA with fast DAMA compatible Tx/Rx switching and automatic bypass upon power failure. Designed to work seamlessly with any tactical half duplex radio or radio repeater with a minimum transmit power of 0.5 W, the unit can be configured to work with AM, FM and all types of digital modulation. Transmit band selection is fully automatic, with Tacsat, LNA On/Off and terrestrial FM and AM modes being selected by a single rotary switch. Tough and rugged, the unit is equipped with a Gortex™ breather and designed for use in the most challenging of environments.

Linwave Technology Ltd.,
Lincoln, UK +44 (0) 1522 681811,
www.linwave.co.uk.
Booth 191 **RS No. 237**

Laser System

The LPKF ProtoLaser S system structures complete layouts on printed circuit boards without chemicals. Conductor widths of 25 µm and spacings of 50 µm can be created on ceramic material. With its outstanding repeatability for precise geometries, the laser system is suitable for the manufacturing of printed circuit boards based on aluminum-coated PET films, copper-coated FR4 or even ceramic and RF substrates. The system requires less than 20

NEW WAVES

minutes for a complex digital circuit measuring 229 × 305 mm.

LPKF Laser & Electronics AG,
Garbsen, Germany +49 (0) 5131 7095-0,
www.lpkf.com.
Booth 128 **RS No. 238**

Surface-mount and Connectorized Diplexers

Marki's popular low pass/high pass diplexers are now offered in both surface-mount and connectorized packages. These miniature, low cost, high performance diplexers can be used in a variety of applications requiring the routing/multiplexing of signals including transmit/receive architectures and antennas. These diplexers can also be used as excellent, non-reflective low pass (or high pass) filters in systems requiring broadband 50 ohm impedance match.

Marki Microwave,
Morgan Hill, CA
(408) 778-4200,
www.markimicrowave.com.
Booth 81 **RS No. 240**

Mixed-signal Active Load Pull System

The Maury Microwave MT2000-series mixed-signal active load pull system, powered by Anteverta Microwave, is currently available in 6, 18 and 26 GHz versions. As an active load pull system, the MT2000 is extremely fast, with measurement speeds of up to 1000 points per minute in CW and pulsed environments. When operating in a modulated signal environment, the system has the capability to control up to 120 MHz of instantaneous wideband impedances. Source and load matching at fundamental and harmonic frequencies is available for all stimuli. MT2000 is a turnkey load pull system and does not require any external instrumentation. Key features include: broadband system concept (e.g., 0.4 to 18 GHz); reconfigurable hardware; single-ended, differential and number of controlled harmonics; high speed and dynamic range; and embedded measurement of (pulsed/isothermal) DC parameters.

Maury Microwave Corp.,
Ontario, CA (909) 987-4715,
www.maurymw.com.
Booth 62 **RS No. 239**

2300 to 2550 MHz High Power Amplifier

VENDORVIEW

ZHL-30W-262+ is a ruggedized high power amplifier that delivers 30 W signals covering the 2400 MHz ISM, WLAN and S-Band radar bands. This amplifier supports a variety of applications from communication, radar to critical test and measurement systems and includes over-temperature self-protect and alarming circuits as well as internal protection circuits to prevent damage due to operation into an open or short under full RF power. The Big Deal: high power output of 30 W; capable of operating at rated power into an open or short; and integrated protection and alarm functions.

Mini-Circuits,
Brooklyn, NY (718) 934-4500,
www.minicircuits.com.
RS No. 254

Vector Network Analyzer

The NI PXIe-5630 is a 6 GHz two-port vector network analyzer (VNA), the automated test industry's first VNA available in a compact PXI form factor. With support for full vector analysis of transmission and reflection (T/R) parameters, precision automatic calibration and flexible software-defined architecture, the new VNA is ideally suited for automated design validation and production test. Its modular PXI architecture and small, two-slot footprint make it possible for test engineers to incorporate vector network analysis into their test systems without the added cost and large footprint of traditional benchtop VNAs. The NI PXIe-5630 is optimized for automated test with a mature feature set including automatic precision calibration, full vector analysis on both ports, reference plane extensions and a flexible LabVIEW API that is ideal for parallel test.

National Instruments,
Austin, TX (800) 258-7022,
www.ni.com.
Booth 31 **RS No. 241**

GaN Epitaxial Wafers

NTT Advanced Technology Corp. (NTT-AT) is providing GaN epitaxial wafers on a variety of substrates–Si, Sapphire, SiC and GaN. These wafers come in several sizes and recently NTT-AT has released 6" GaN wafer on a silicon substrate with total epitaxial layer thickness of up to 5 μm. NTT-AT's GaN epitaxial wafers have excellent properties both for "high frequency devices" and "high power devices", which will allow the development and deployment of compact and superior devices to conventional standard devices.

NTT Advanced Technology Corp.,
Shinagawa-ku, Tokyo, Japan
+81 3 5843 0927,
www.ntt-at.com.
Booth 33 **RS No. 242**

Oven-controlled Crystal Oscillators

Precision Devices will unveil new oven-controlled

IMS2011 in Baltimore: A Perfect Match

IEEE

Final Call for Papers

MTT-S

Deadline for Paper Submission: Friday, December 3, 2010

IEEE MTT-S 2011 International Microwave Symposium
Baltimore Convention Center
June 5-10, 2011
www.ims2011.org

The IEEE Microwave Theory & Techniques Society (MTT-S) International Microwave Symposium for 2011 (IMS2011) will be held in Baltimore, Maryland, as the centerpiece of Microwave Week 2011, and is scheduled from Sunday, June 5 through Friday, June 10, 2011.

IMS2011 offers technical paper sessions, interactive forums, plenary and panel sessions, workshops, short courses, industrial exhibits, application seminars, historical exhibits, and a wide array of other technical and social activities including a guest program. The Awards Banquet and Crab Feast are two of the highlights of the social activities. Collocated with IMS2011 are the RFIC Symposium (www.rfic2011.org) and the ARFTG Conference (www.arftg.org), which comprise the Microwave Week 2011 technical program.

PAPER SUBMISSION INSTRUCTIONS: Authors are invited to submit technical papers describing original work on radio-frequency, microwave, and millimeter-wave theory and techniques. The deadline for submission is **December 3, 2010**. **Late papers will not be reviewed.** Please refer to the IMS2011 website (www.ims2011.org) for complete submission information.

INVITATION TO SUBMIT PAPERS IN EMERGING TECHNICAL AREAS: IMS2011 enthusiastically invites submission of papers that report state-of-the-art progress in technical areas that are outside the scope of the listed areas below, or that may be new to the Symposium but are of interest to our attendees. Authors who have other original research results that are of interest are encouraged to submit to IMS2011 by selecting one of the Emerging Technical Areas.

STUDENT PAPER COMPETITION: Students are encouraged to submit papers which will be evaluated using the same standards as all contributed papers, and will be eligible for the Student Paper Competition. Please consult the IMS2011 website (www.ims2011.org) for full details.

INVITATION TO SUBMIT PROPOSALS FOR SPECIAL SESSIONS, WORKSHOPS, AND SHORT COURSES: The Symposium invites proposals for Special Sessions (including focused, honorary, etc.), Workshops, Panel and Rump Sessions, and Short Courses (ranging from introductory to expert level). Special Sessions on topics that will be of high interest to the Symposium or particular relevance to the microwave community in the Washington DC/Baltimore area are solicited. Please consult the IMS2011 website (www.ims2011.org) for instructions on preparing a proposal. Proposals must be received by **September 17, 2010.**

Some Important Dates

Sep. 17, 2010	Dec. 3, 2010	Jan. 31, 2011	Mar. 11, 2011	Mar. 18, 2011	Jun. 5-10, 2011
Friday	*Friday*	*Monday*	*Friday*	*Friday*	*Sun. – Fri.*
Proposal Submission Deadline	**Paper Submission Deadline**	**Paper Disposition Notification**	**Manuscript Submission Deadline**	**Notes Submission Deadline**	**Microwave Week**
for Workshop, Short Course, Special Session, Panel and Rump Session	*all submissions must be made electronically*	*authors will be notified via e-mail and on the website*	*for the final manuscript of accepted papers and copyrights*	*electronically upload both color and B&W versions of Workshop Notes*	*IMS2011, RFIC2011, 77th ARFTG, and Exhibition*

Visit www.ims2011.org
for an expanded description of these Technical Areas

Microwave Field and Circuit Techniques
1. Field Analysis and Guided Waves
2. Frequency-Domain EM Analysis Techniques
3. Time-Domain EM Analysis Techniques
4. CAD Algorithms and Techniques
5. Linear Device Modeling
6. Nonlinear Device Modeling
7. Nonlinear Circuit and System Simulation

Passive Components
8. MEMS Components and Technologies
9. Transmission Line Elements
10. Planar Passive Filters and Multiplexers
11. Non-planar Passive Filters and Multiplexers
12. Active, Tunable, and Integrated Filters
13. Ferroelectric, Ferrite, and Acoustic Wave Components
14. MEMS Components and Technologies

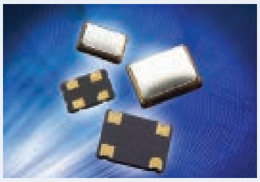
Active Components
15. Semiconductor Devices and Monolithic ICs
16. Signal Generation
17. Frequency Conversion and Control
18. HF, VHF, and UHF Technologies and Applications
19. Power Amplifier Devices and Circuits
20. High-Power Amplifiers
21. Low-Noise Components and Receivers
22. Millimeter-Wave and THz Components and Technologies

Systems and Applications
23. Microwave Photonics
24. Signal Processing Circuits at GHz Speeds
25. Packaging, Interconnects, MCMs and Integration
26. Instrumentation and Measurement Techniques
27. Biological Effects and Medical Applications
28. Arrays as Antennas and Power Combiners
29. Radar and Broadband Communication Systems
30. Wireless and Cellular Communication Systems
31. Sensors and Sensor Systems
32. RFID Technologies
33. High Power Microwave Industrial Applications

Emerging Technical Areas
34. RF Nanotechnology
35. New Technologies and Applications
36. Innovative Systems

NEW WAVES

crystal oscillators (OCXO) at the European Microwave Week exhibition. The company will also be showing its range of frequency control products, including sinewave OCXOs and high-end temperature compensated crystal oscillators (TCXO) targeted at microwave applications. As well as the new OCXOs, the products on display will include the TS07 ultra-tight tolerance TCXO. This oscillator has no warm-up time and uses less power compared to low-end OCXOs, making it more suitable for many applications that require high accuracy. The TS07 has a tolerance of only 0.14 ppm over an operating temperature range from -20° to +70°C, and 0.28 ppm over an extended operating temperature range from -40° to +85°C. It covers a frequency range from 5 to 26 MHz, and measures only 7 by 5 by 2 mm in a compact SMD package.



Precision Devices Inc., Cambridge, UK +44 (0) 1223 834444, www.pdixtal.com.
Booth 139 **RS No. 243**

Prepreg Teams with Laminates

VENDORVIEW

Rogers Corp. has developed the perfect match for its popular RO4360™ laminate: RO4460™ prepreg. Both materials feature dielectric constant (Dk) of 6.15 ± 0.15 and low dielectric loss of 0.003 at 2.5 GHz. Together, they form an ideal system for fabricating compact, cost-sensitive multilayer high frequency circuits where space is at a premium. As with RO4360 laminates, RO4460 prepregs are ceramic-filled, thermoset materials reinforced by woven glass for excellent mechanical stability. The laminate and prepreg supports smaller size circuits with excellent thermal conductivity of 0.8 W/m-K for effective thermal management. RoHS-compliant RO4360 laminate and RO4460 bondply materials offer low coefficient of thermal expansion (CTE) of 30 ppm/°C in the z-axis for reliable plated through holes (PTH) in multilayer circuits.

Rogers Corp., Chandler, AZ (480) 961-1382, www.rogerscorp.com.
Booth 106 **RS No. 244**

Spectrum Analyzers

VENDORVIEW

The R&S FSVR real-time spectrum analyzer is the first instrument to combine the functions of an all-purpose signal and spectrum analyzer with a real-time spectrum analyzer. In real-time mode, the R&S FSVR detects everything, from sporadic events to ultra-short signals. Measurement without blind times is a major advantage for developers of RF components for commercial transmission systems such as LTE, WiMAX™, WLAN, Bluetooth® and RFID, and for general RF applications such as radar and frequency hopping transmission. Designed on the basis of the R&S FSV, the R&S FSVR provides the full functionality of a signal and spectrum analyzer – with a measurement speed up to five times faster than any other analyzer on the market.

Rohde & Schwarz GmbH & Co. KG, Muenchen, Germany +49 89/4129-0, www.rohde-schwarz.com.
Booth 70 **RS No. 245**

P-SMP Connectors

Rosenberger introduces the new P-SMP (Power-SMP) RF coaxial connector series that combines the advantages of SMP connectors - minimum board-to-board spaces - and of SMA connectors - high performance and high power rating. Minimum board-to-board distances from 12.6 mm can be realized by using bullets of different lengths. In these applications, P-SMP connectors are designed for high power loads up to 200 W at frequencies of 2.2 GHz (maximum frequency 15 GHz). Applications include board-to-board connections in base stations, or board-to-cable connections in power amplifier filter units. Other series characteristics are very high density in board-to-board connections and high flexibility due to misalignment (axial ± 1 mm, radial 4°).

Rosenberger Hochfrequenztechnik GmbH & Co. KG, Tittmoning, Germany +49 (0) 8684 18 263, www.rosenberger.com.
Booth 144 **RS No. 252**

End Launch Connectors

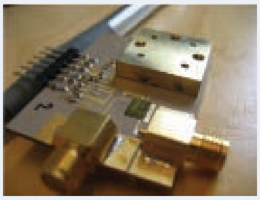
Southwest Microwave announced a low profile version of its popular End Launch connectors to accommodate growing market acceptances. The low profile version recesses the mounting screws providing a lower silhouette and prevents objects from snagging on the screw heads. Electrical performance and the other dimensions are identical to the original End Launch connectors, which, if needed, allow the original End Launch connector to be interchanged with the low profile version. SMI's End Launch connectors are intended to provide microwave design engineers with a quick and simple approach to evaluate board and product prototype designs.

NEW WAVES

Southwest Microwave Inc., Tempe, AZ (480) 783-0201, www.southwestmicrowave.com.
Booth 108 **RS No. 246**

Non-reinforced Microwave Substrate

Taclamplus is a cost-effective, non-reinforced microwave substrate of typically 100 micron thickness that can be used to create very low-loss structures both with single dielectric layers and multiple layers. Exceptional copper-foil adhesion allows small-feature resolution. Its



unique composition of the dielectric, basically the absence of any glass in the substrate material, facilitates clean laser ablation for micro-via and component-cavity formation. The use of metal-plate such as 1 mm copper helps maintain dimensional stability and provides a sound ground plane and heat-sink. Features include: > 40 GHz no packaged MMICs; designers need to use MMIC die and wirebonds; dies need to be placed in cavities to keep wires short as possible; and substrate losses need to be the lowest.
Taconic Advanced Dielectric Division, Co. Westmeath, Ireland +353 44 93 95600, www.taconic-add.com.
Booth 63 **RS No. 247**

X-band Signal Generator

Vaunix Technology Corp. announced the introduction of an X-band signal generator to its Lab Brick® product line. The LMS-123 operates from 8 to 12 GHz, and boasts low phase noise, fast 100 microsecond switching time and fine 100 Hz frequency resolution. The LMS series also offers advanced operating features such as phase-continuous linear frequency sweeping, optional modulation formats and internal/external triggering. Other previously released models in the LMS family include the LMS-802 covering 4 to 8 GHz and the LMS-103 covering 5 to 10 GHz. Lab Brick signal generators are known for their compact size, low power consumption and Universal Serial Bus (USB) compatibility. Each Lab Brick® signal generator measures 4.90" × 3.14" × 1.59" and weighs less than 1 lb. (0.45 kg).
Vaunix Technology Corp., Haverhill, MA (978) 662-7839, www.labbrick.com.
Booth 30 **RS No. 248**

Foundry Services

WIN Semiconductors Corp. is the world's largest pure-play 6-inch GaAs foundry. WIN has established two advanced GaAs wafer fabs for high volume, RF GaAS MMICs (monolithic microwave ICs). WIN provides foundry services to fabless design houses and IDM partners. WIN supplies leading-edge HBT and PHEMT MMIC fabrication services to worldwide IC manufacturers, using state-of-the-art GaAs process technology.
WIN Semiconductors Corp., Tao Yuan Shien, Taiwan +886-3-397-5999, www.winfoundry.com.
Booth 97 **RS No. 249**

EM Modeling and Simulation

WIPL·D Pro
3D Electromagnetic Solver

WIPL-D Pro 8.0 brings significant kernel enhancements that enable faster simulations on multi-core computers, automated solver selection based on available system resources and enhanced tools for result convergence studies. The most important new features are: complete parallelization for multi-core CPUs (using OpenMP to fully exploit the multi-core CPU performance; the speed-up on; a quad-core CPU is about three times for matrix fill-in stage and almost four times for iterative solver, MLFMM solver, near field and radiation computation); optimized out-of-core solver algorithm; automated solver selection based on available system resources; increased convergence control through user defined reference frequency, maximum size of model patch and choice of basis functions used.
WIPL-D d.o.o., Belgrade, Serbia +381 11 2289 350, www.wipl-d.com.
Booth 130 **RS No. 250**

Voltage-controlled Oscillator

Z-Communications Inc. announces a new RoHS compliant VCO (voltage-controlled oscillator) model CRO2477A-LF in S-band. The CRO2477A-LF operates at 2440 to 2540 MHz with a tuning voltage range of 0.5 to 4.5 VDC. This VCO features a typical phase noise of -108 dBc/Hz at 10 kHz offset and a typical tuning sensitivity of 30 MHz/V. The CRO2477A-LF is designed to deliver a typical output power of 3.5 dBm at 5 VDC supply while drawing 21 mA (typical) over the temperature range of -40° to 85°C. This VCO features typical second harmonic suppression of -20 dBc and comes in Z-Comm's standard MINI-16-SM package measuring 0.5" × 0.5" × 0.22".
Z-Communications Inc., San Diego, CA (858) 621-2700, www.zcomm.com.
Booth 201 **RS 253**

2010 Asia-Pacific Microwave Conference

APMC 2010

December 7-10, 2010 Pacifico Yokohama, Yokohama, Japan

http://www.apmc2010.org

APMC 2010
Dec.7-10 YOKOHAMA JAPAN

EiC

" Novel Technology Waves from Historical Port "

Final Call for Papers

The 2010 Asia-Pacific Microwave Conference (APMC 2010) will be held at the Pacifico Yokohama, Yokohama, Japan, on December 7-10, 2010. This conference is organized and sponsored by the Institute of Electronics, Information and Communication Engineers (IEICE), and is cooperatively sponsored by IEEE MTT-S, EuMA, IEEE AP-S, URSI, IEEE MTT-S Japan Chapter and IEEE MTT-S Kansai Chapter.
Regular papers accepted by APMC 2010 will appear in IEEE Xplore and extended version can be published in a Special issue of IEICE Transactions on Electronics.

CONFERENCE TOPICS

A Active Devices and Circuits

Low-Noise Devices and Circuits, High-Power Devices and Circuits, Microwave Tubes, Control Circuits (MIX, OSC., SW, etc.), MMICs, RFICs and HMICs (Receivers, Transmitters, etc.), Active and Adaptive Antennas, Others

B Passive Components

Filters and Resonators, Ferrite and Acoustic Wave Components, Packaging, Waveguides and Striplines, Optical Components, Metamaterial, RF MEMS, LTCC Devices, Directional Couplers and Hybrids, Others

C Systems

Wireless and Cellular Communication Systems, Signal Processing Circuits and Systems, Microwave Medical and Biological Applications, EMC, Radars and Sensors, Satellite Systems, Digital Broadcasting, MIMO Systems, Optical Fiber Systems, Others

D Basic Theory and Techniques

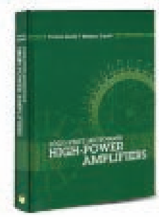
Scattering and Propagation, Electromagnetic Field Theory and CAD, Antenna Theory, Microwave Antennas, Microwave Photonics, Microwave Superconductivity, Measurement Techniques, Others

Time Table

Paper Submission Deadline: May 31, 2010
Notification of Acceptance: August 10, 2010
Final PDF file with Camera-Ready Manuscript Deadline: September 15, 2010

ALL SUBMISSIONS MUST BE IN PDF FORMAT.
HARD COPIES NOT ACCEPTED

The Book End



Solid-State Microwave High-Power Amplifiers

Franco Sechi and Marina Bujatti

Solid-State Microwave High-Power Amplifiers covers only solid-state power amplifiers (SSPA) and focuses on the highest powers reachable with solid-state technology. This ranges from a few watts for multioctave bandwidths to hundreds of watts for narrow band devices concentrating on the 1 to 50 GHz frequency range. The book therefore covers such topics as power combining and heat management in addition to broader amplifier concepts that could apply in general to lower power devices. The primary applications targeted include radar, electronic warfare (EW), telecommunications equipment and special test systems.

The book starts with the physics of active devices, device characterization, modeling and phase noise subjects before moving on to amplifier configurations, power combiners/dividers and general design. It then covers more specific amplifier types like high-efficiency amplifiers, linear power amplifiers and special device types like Doherty. There are also full chapters on bias circuits and thermal management. In addition, the book contains quite a bit of solid-state and device physics, which can be skipped if this area is not of interest or one already has knowledge in that area.

The author uses his *Solid-State Microwave High-Power Amplifiers* as a concentrated book of knowledge dedicated specifically to high SSPAs covering device physics to amplifier design. The book is aimed at mostly compound semiconductors for high-power use, but the concepts are useful for general amplifier design techniques and knowledge.

To order this book, contact:

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

320 pages; $129, £69
ISBN: 978-1-59693-319-4

Advertising Index

RS No.	Advertiser	Page No.	Web Address
1	Advanced Switch Technology	186	http://mwj.hotims.com/28494-1
2	Aeroflex / Metelics, Inc.	9	http://mwj.hotims.com/28494-2
3	Aeroflex / Weinschel, Inc.	109	http://mwj.hotims.com/28494-3
4	Aethercomm	127	http://mwj.hotims.com/28494-4
5	Agilent Technologies, Inc.	63	http://mwj.hotims.com/28494-5
6	Akon, Inc.	151	http://mwj.hotims.com/28494-6
7	American Technical Ceramics	31	http://mwj.hotims.com/28494-7
8	AML Communications Inc.	65	http://mwj.hotims.com/28494-8
	Analog Devices	45	www.analog.com
9	AnaPico AG	64	http://mwj.hotims.com/28494-9
10	Anaren Microwave	105	http://mwj.hotims.com/28494-10
11	Anatech Electronics, Inc.	138	http://mwj.hotims.com/28494-11
12	Ansoft Corporation	27	http://mwj.hotims.com/28494-12
	APMC 2010	189	www.apmc2010.org
13	Applied Radar, Inc.	188	http://mwj.hotims.com/28494-13
14	AR RF/Microwave Instrumentation	123	http://mwj.hotims.com/28494-14
	Artech House	191	www.artechhouse.com
15	Astrolab, Inc.	171	http://mwj.hotims.com/28494-15
16	AWR	11	http://mwj.hotims.com/28494-16
17	AWT Co., Ltd.	66	http://mwj.hotims.com/28494-17
18	B&Z Technologies, LLC	29	http://mwj.hotims.com/28494-18
19	Boonton Electronics (a Wireless Telecom Group Company)	COV 2	http://mwj.hotims.com/28494-19
20	Carlisle Interconnect Technologies	13	http://mwj.hotims.com/28494-20
21	Cernex, Inc.	26	http://mwj.hotims.com/28494-21
22	Channel Microwave Corporation	18	http://mwj.hotims.com/28494-22
23	Ciao Wireless, Inc.	48	http://mwj.hotims.com/28494-23
24	Cobham Defense Electronic Systems	43	http://mwj.hotims.com/28494-24
25	Coilcraft	15	http://mwj.hotims.com/28494-25
26	COMSOL, Inc.	117	http://mwj.hotims.com/28494-26
27	CPE Italia	186	http://mwj.hotims.com/28494-27
28	CPI Beverly Microwave Division	91	http://mwj.hotims.com/28494-28
29	CST of America, Inc.	25	http://mwj.hotims.com/28494-29
30	Daico Industries, Inc.	41	http://mwj.hotims.com/28494-30
31	Damaskos Inc.	186	http://mwj.hotims.com/28494-31
32	dBm, LLC	94	http://mwj.hotims.com/28494-32
33	Dielectric Laboratories Inc.	177	http://mwj.hotims.com/28494-33
34,35	Ducommun Technologies	58,170	http://mwj.hotims.com/28494-34
36	Eastern Wireless TeleComm, Inc.	20-21	http://mwj.hotims.com/28494-36
37	Elektrobit Ltd.	96	http://mwj.hotims.com/28494-37
38	Elisra Electronic Systems Ltd. (Microwave Division)	100	http://mwj.hotims.com/28494-38
39	EM Research, Inc.	66	http://mwj.hotims.com/28494-39
40	Empower RF Systems, Inc.	129	http://mwj.hotims.com/28494-40
41	Endwave	115	http://mwj.hotims.com/28494-41
42	ES Microwave, LLC	172	http://mwj.hotims.com/28494-42
43	ETS-Lindgren	44	http://mwj.hotims.com/28494-43
	EuMW 2010	82	www.eumweek.com
44	Fairview Microwave	97	http://mwj.hotims.com/28494-44
45	Freescale Semiconductor, Inc.	125	http://mwj.hotims.com/28494-45
46	Frontlynk Technologies Inc.	147	http://mwj.hotims.com/28494-46
47	G.T. Microwave Inc.	40	http://mwj.hotims.com/28494-47
48	GigaLane	172	http://mwj.hotims.com/28494-48
49	Herotek, Inc.	36	http://mwj.hotims.com/28494-49
50	Hirai SK Corporation	168	http://mwj.hotims.com/28494-50
51,52,53	Hittite Microwave Corporation	99,101,103	http://mwj.hotims.com/28494-51
54	Holzworth Instrumentation	90	http://mwj.hotims.com/28494-54
55	Huber + Suhner AG	71	http://mwj.hotims.com/28494-55
	IEEE MTT-S International Microwave Symposium	185	www.ims2011.org
	IEEE WAMICON 2011	181	www.wamicon.org
56	IMST GmbH	83	http://mwj.hotims.com/28494-56
57	IMT (a Vitec Group Company)	153	http://mwj.hotims.com/28494-57
58	International Manufacturing Services, Inc.	74	http://mwj.hotims.com/28494-58
59	ITT Microwave Systems	50	http://mwj.hotims.com/28494-59
60	IW Inc. (Insulated Wire)	141	http://mwj.hotims.com/28494-60
61	JFW Industries, Inc.	143	http://mwj.hotims.com/28494-61
62	JQL Electronics Inc.	6	http://mwj.hotims.com/28494-62
63	K&L Microwave, Inc.	7	http://mwj.hotims.com/28494-63
64	Krytar	102	http://mwj.hotims.com/28494-64
65	Linear Technology Corporation	59	http://mwj.hotims.com/28494-65
66	Linwave Technology Ltd.	92	http://mwj.hotims.com/28494-66
67	LNX Corporation	24	http://mwj.hotims.com/28494 67

RS No.	Advertiser	Page No.	Web Address
68	Lorch Microwave	51	http://mwj.hotims.com/28494-68
69,70	M/A-COM Technology Solutions	34,35	http://mwj.hotims.com/28494-69
71	Massachusetts Bay Technologies, Inc.	89	http://mwj.hotims.com/28494-71
72,73,74	Maury Microwave Corporation	28,114,119	http://mwj.hotims.com/28494-72
75	MECA Electronics, Inc.	80	http://mwj.hotims.com/28494-75
76	MIcable Inc.	137	http://mwj.hotims.com/28494-76
77	MiCIAN GmbH	76	http://mwj.hotims.com/28494-77
78	Microsemi	157	http://mwj.hotims.com/28494-78
79	Microwave Development Laboratories	133	http://mwj.hotims.com/28494-79
	Microwave Journal	176,180,187,188,190	www.mwjournal.com
80	Milmega Limited	81	http://mwj.hotims.com/28494-80
81,82,83, 84,85,86, 87,88,89, 90,91, 92,93	Mini-Circuits	4-5,16,55, 56,67,135, 145,155,161, 167,173, 179,193	http://mwj.hotims.com/28494-81
94,95,96	MITEQ Inc.	3,107,183	http://mwj.hotims.com/28494-94
97,98	Modco, Inc.	184,188	http://mwj.hotims.com/28494-97
99,100	Narda Microwave-East, an L3 Communications Co.	38,165	http://mwj.hotims.com/28494-99
101	Nexyn Corporation	128	http://mwj.hotims.com/28494-101
102	NoiseWave Corp.	8	http://mwj.hotims.com/28494-102
103	Norden Millimeter Inc.	70	http://mwj.hotims.com/28494-103
104	OML Inc.	159	http://mwj.hotims.com/28494-104
105	OMMIC	78	http://mwj.hotims.com/28494-105
106	Pascall Electronics Limited	54	http://mwj.hotims.com/28494-106
107	Programmed Test Sources, Inc.	COV 3	http://mwj.hotims.com/28494-107
108	Pulsar Microwave Corporation	42	http://mwj.hotims.com/28494-108
	QuinStar Technology, Inc.	93	www.quinstar.com
109	R&K Company Limited	168	http://mwj.hotims.com/28494-109
110	Radiall	182	http://mwj.hotims.com/28494-110
111	Rakon Ltd.	62	http://mwj.hotims.com/28494-111
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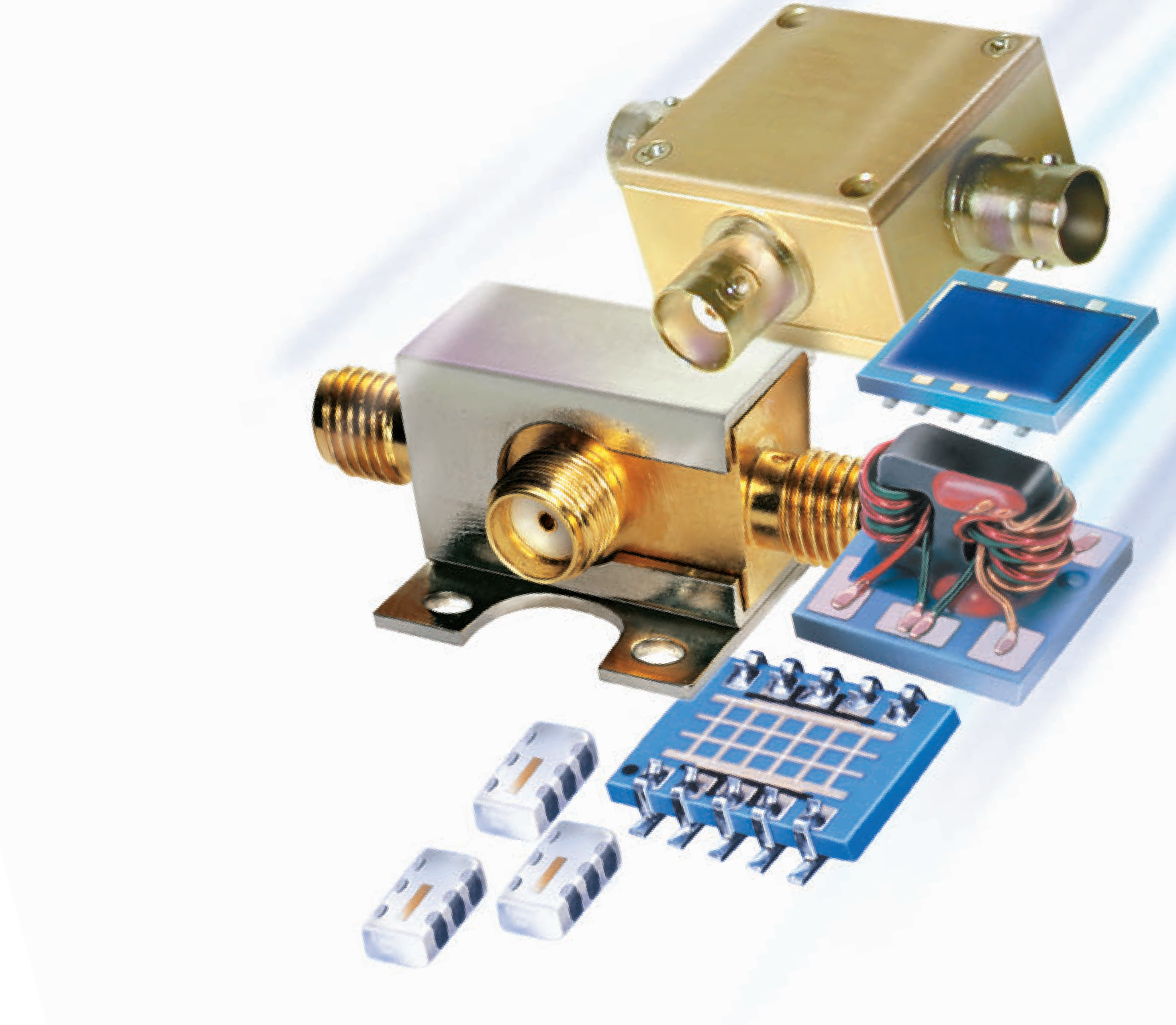

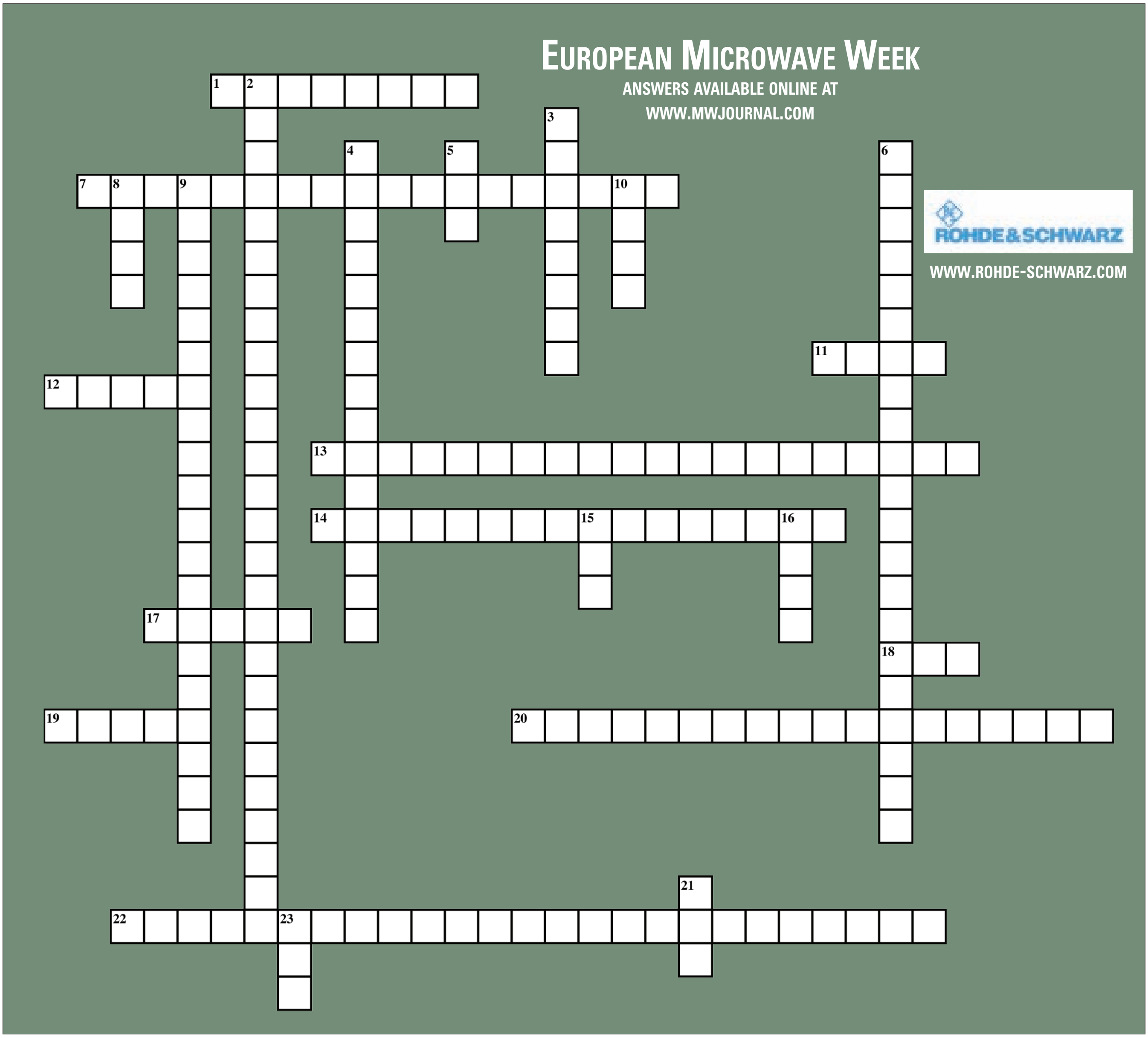

ACROSS

1 A component frequency of the signal that is an integer multiple of the fundamental frequency

7 A property of some electric circuits where an increase in the current entering a port results in a decreased voltage across the same port (2 words)

11 Universal Mobile Telecommunications System

12 Process that integrates HBTs with FETs on the same GaAs substrate

13 PAE (3 words)

14 BAW (3 words)

17 Wideband Code Division Multiple Access

18 Third-order intercept point

19 Pseudomorphic high electron mobility transistor

20 Type of oscillator where the feedback signal is taken from a voltage divider made by two capacitors in series (2 words)

22 Occurs when the nonlinearity of a device with multiple input frequencies causes undesired outputs at other frequencies (2 words)

DOWN

2 A piece of test equipment used to generate electrical waveforms of various types (3 words)

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

4 FEM (3 words)

5 A diode with an intrinsic semiconductor region between a p-type and an n-type semiconductor region

6 Describes the amplitude of a reflected wave relative to an incident wave (2 words)

8 Enhanced Data rates for Global Evolution

9 A circuit where the average output signal level is fed back to adjust the gain to an appropriate level for a range of input signal levels (3 words)

10 Complementary metal-oxide-semiconductor

15 Surface acoustic wave

16 Voltage-controlled crystal oscillators

21 Global System for Mobile Communications

23 Short for machine-to-machine communications

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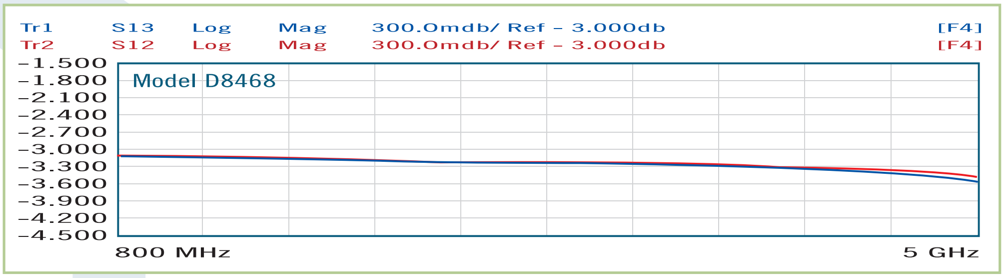
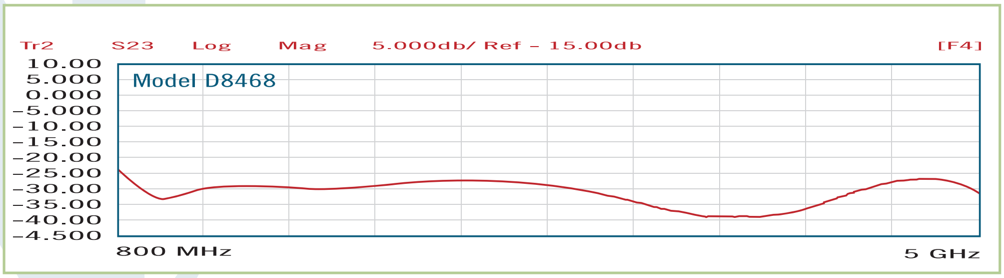


Isolation



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D7823	2-Way	500-2500	200	0.4	1.35:1	15	4.7 x 2.0 x 0.8
D8414	2-Way	600-3000	200	0.5	1:35:1	15	4.0 x 1.9 x 1.0
D8378	2-Way	500-2000	800	0.4	1:35:1	15	4.0 x 1.9 x 1.37
D8468	2-Way	800-5000	150	0.6	1:35:1	15	3.4 x 1.4 x 0.87
D8294	2-Way	1000-4000	100	0.5	1:30:1	15	3.7 x 1.9 x 0.87

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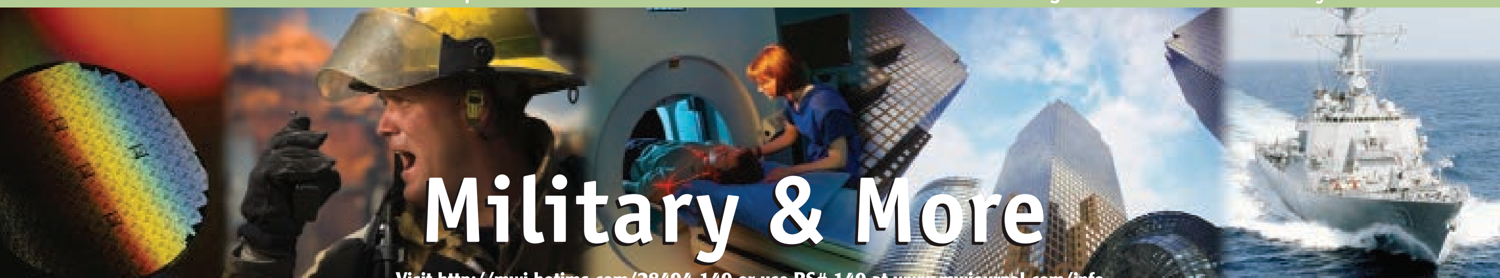

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