
Vol. 53 • No. 6
June 2010
Microwave Journal
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As
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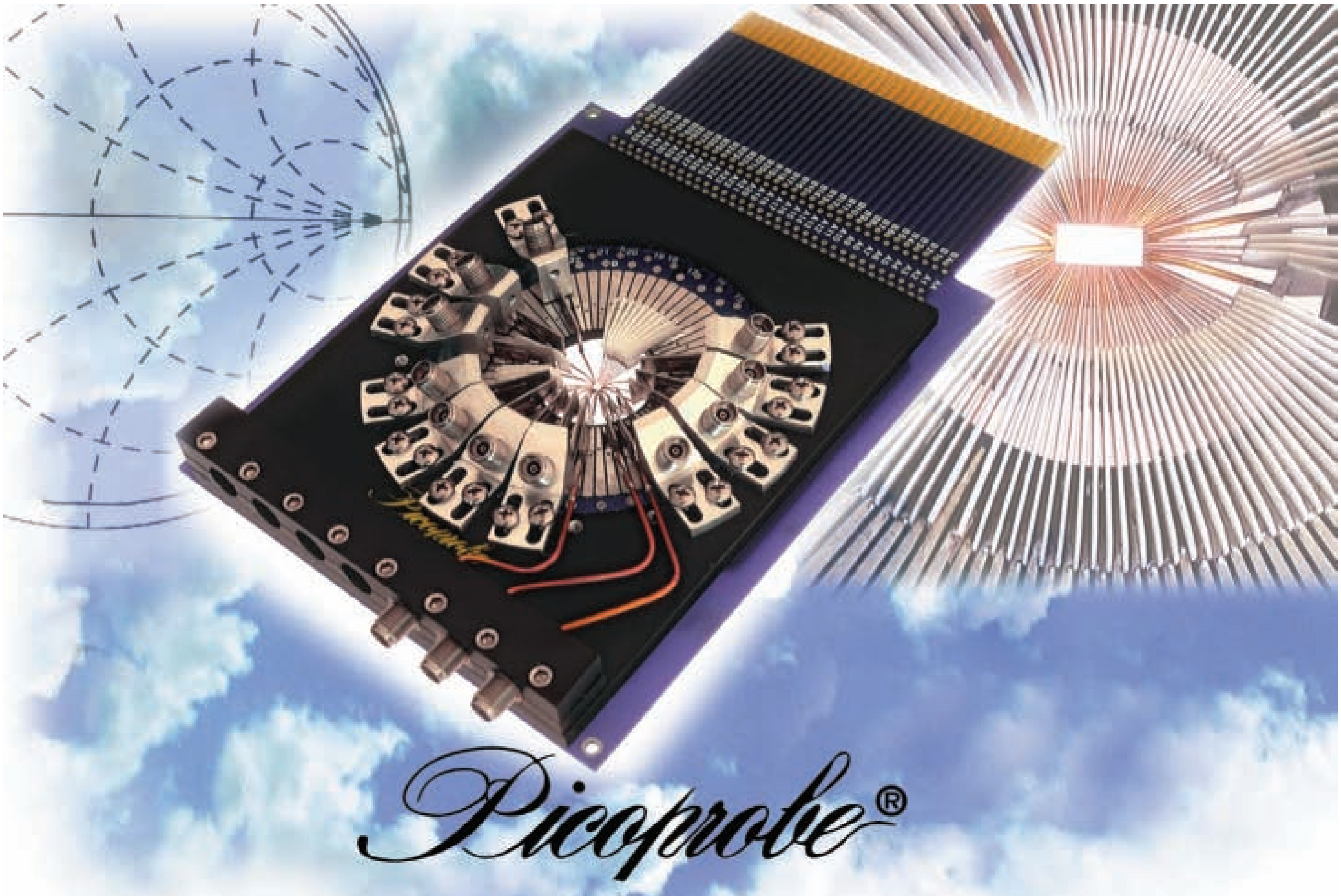

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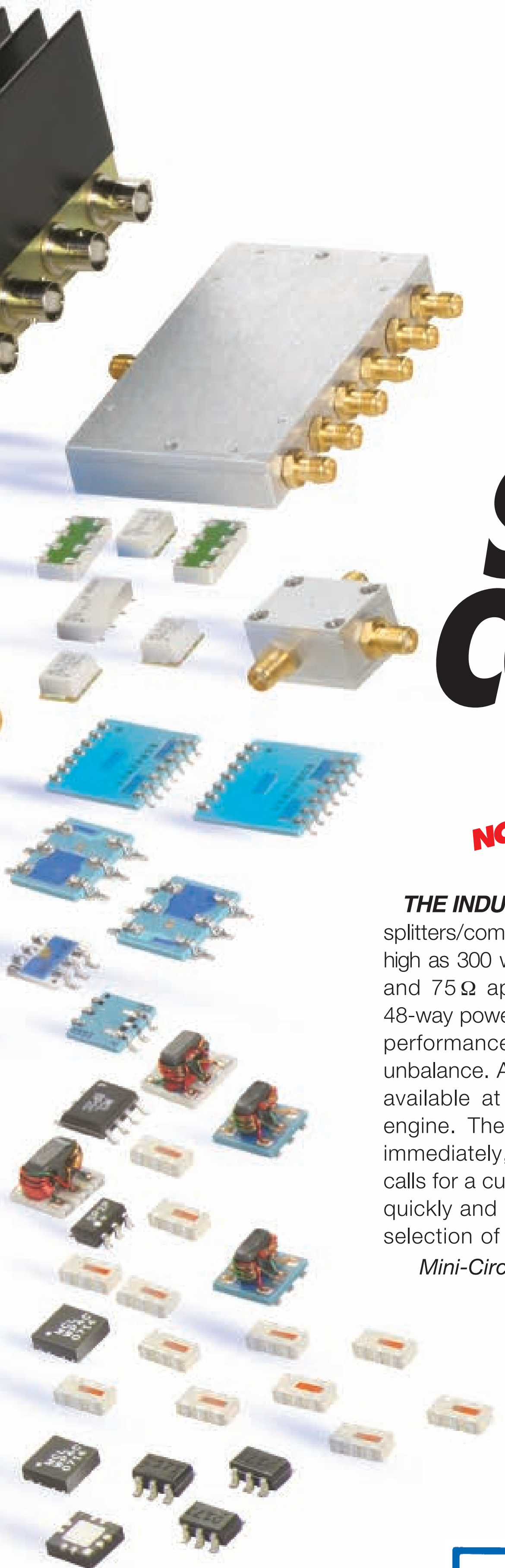

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Executive Interview

YC Wang, VP of Marketing, **WIN Semiconductor**, talks about his company's success as the world's leading pure-play GaAs foundry, his customers' benefits of being fabless, their process technology roadmap and which growth markets are showing the greatest potential.

Expert Advice

Derek Smith, Director of Marketing and Sales at **OMMIC**, considers the standing of III-V processes in the technological landscape, both now and in the future. He considers how higher performance, higher integration and integrated options, together with more stringent requirements, have not only made III-V devices essential today, but are ensuring that they will remain so for many years to come.

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MarketWatch

Mario Rivas, President and CEO of **Anadigics**, talks about his company's 25th anniversary, their GaAs technology and their relationship with WIN Semiconductor, the handset and cable markets, and the advantage of GaAs-based 3G power amplifiers over competing technologies.

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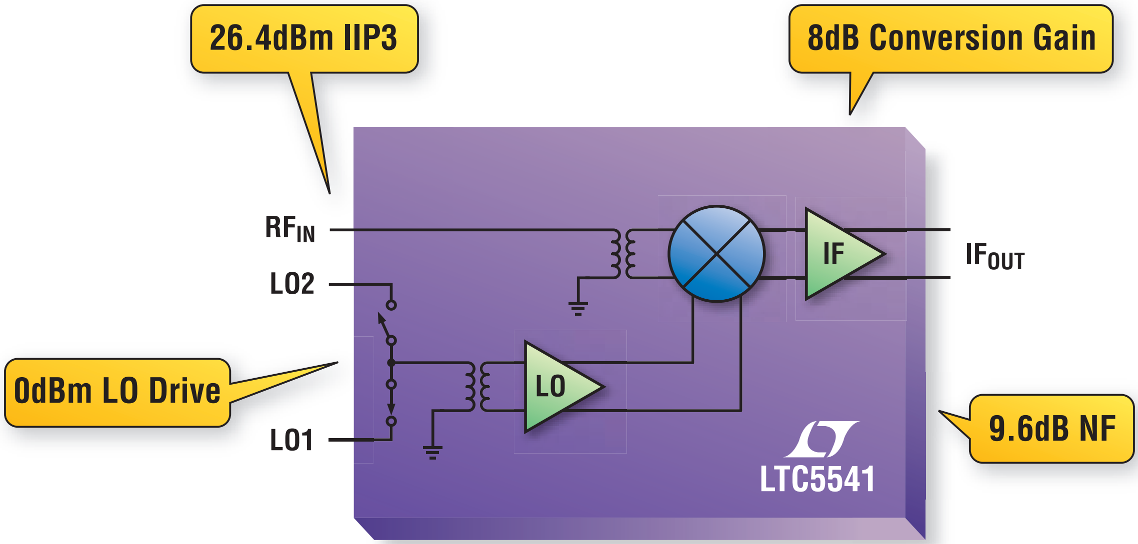

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4	5 14th International Symposium on Antenna Technology and Applied Electromagnetics (ANTEM) & the American Electromagnetics Conference (AMEREM) Ottawa, Ontario, Canada	6	7 ANSOFT **HFSS Product Training** Boston, MA	8	9	10
11 **IEEE International Symposium on Antennas and Propagation** Toronto, Ontario, Canada	12	13	14 **44th Annual Microwave Power Symposium** Denver, CO	15 Agilent Technologies **MIMO Array Antenna Design Tools and Techniques** At your PC	16	17
18 **PhD Research in Microelectronics and Electronics (PRIME)** Berlin, Germany	19	20 **MWJ/Besser Webinar: Electrically Small Antennas** Sponsored by AWR, CST	21	22	23	24
25 **EMC 2010** **IEEE International Symposium on Electromagnetic Compatibility** Fort Lauderdale, FL	26	27 CST **CST MICROWAVE STUDIO Microwave and Antenna Training** Nottingham, United Kingdom	28	29	30	31

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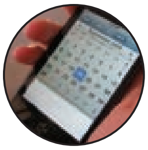

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JULY

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July 11–17, 2010 • Toronto, Ontario, Canada
www.apsursi2010.org

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IEEE International Symposium on Electromagnetic Compatibility
July 25–30, 2010 • Fort Lauderdale, FL
www.emc2010.org

AUGUST

ASQED 2010
ASIA Symposium Quality Electronic Design
August 3–4, 2010 • Penang, Malaysia
www.asqed.com

NIWeek 2010
August 3–5, 2010 • Austin, TX
www.ni.com

10th Mediterranean Microwave Symposium (MMS)
August 25–27, 2010 • Guzelyurt, Turkey
www.mms.ncc.metu.edu.tr

SEPTEMBER

IEEE Great Lakes Technology Symposium
September 16–17, 2010 • Ann Arbor, MI
www.ieeegreatlakes.org

EuMW 2010
European Microwave Week
September 26–October 1, 2010 • Paris, France
www.eumweek.com

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October 3–6, 2010 • Atlanta, GA
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MWP 2010
International Topical Conference on Microwave Photonics
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www.mwp2010.org

AMTA 2010
Antenna Measurement Techniques Association
October 10–15, 2010 • Atlanta, GA
www.amta2010.com

IEEE International Symposium on Phased Array Systems & Technology
October 12–15, 2010 • Waltham, MA
www.array2010.org

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

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October 21–24, 2010 • Cerritos, CA
www.microwaveupdate.org

MILCOM 2010
October 31–November 3, 2010 • San Jose, CA
www.milcom.org

DECEMBER

Asia Pacific Microwave Conference
December 7–10, 2010 • Yokohama, Japan
www.apmc2010.org

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FEBRUARY

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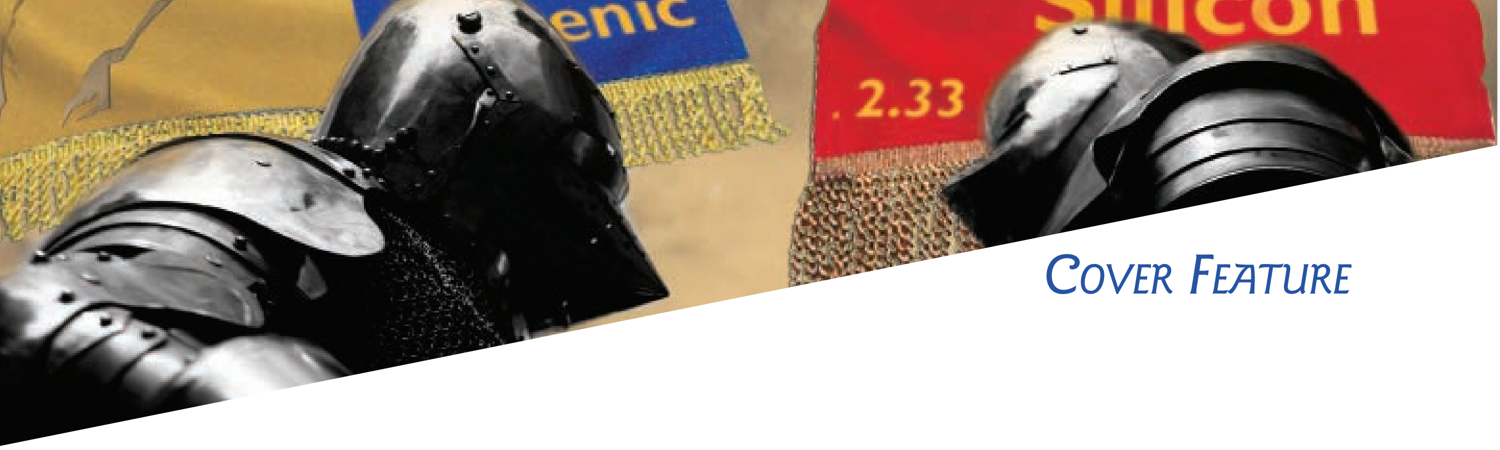

2010 GaAs Foundry Services Outlook

In the 1980s, the running joke was "GaAs is the future and always will be." Up until that time it had shown great promise, but was having a hard time living up to its performance potential and was plagued by high material costs and inconsistent processes. However, due to large investments by the government/military (mostly the DARPA MIMIC programs) in the 1980s and high commercial demand for wireless applications in the 1990s (such as satellite TV and cellular handsets), it has become the mainstay of the RF/microwave industry for the last couple of decades. Many companies built large GaAs fabs in the '80s and '90s, but today most rely either totally or partially on foundries for their supply of chips. This allows for greater flexibility in fast changing markets and many "fabless" companies have leveraged this business model to develop lower fixed cost businesses that have flourished over the last ten years.

SQUEEZE PLAY

Today, GaAs is being squeezed more than ever by competing Si technologies and newer high voltage compound semiconductor materials like GaN and SiC. Recent developments in Si CMOS and BiCMOS processes have achieved cut-off frequencies over 300 GHz,[1] allowing it to compete in many applications where GaAs had mostly dominated. Si chips have a large cost advantage in high volumes and offer superior digital integration opportunities for single chips solutions (BiCMOS). In addition, LDMOS processes have significantly advanced with higher voltage designs that produce robust transistors capable of output power performance as good as GaN and SiC, but at a much lower cost. There is also competition from UltraCMOS™ (Peregrine Semiconductor) for lower power, fast switching applications. They are now expanding the process with several other types of devices to further compete with GaAs. SiGe processes are creating highly integrated single chip solutions at high frequencies such as automotive radar at 24 and 77 GHz and point-to-point radios. There are a large number of RF Si foundries that have high capacities available such as Taiwan Semiconductor (TSMC), Tower/JAZZ Semiconductor, IHP Microelectronics, IBM, austriamicrosystems, etc., so the costs for large volumes are relatively low with available capacity.

As Si technologies mostly squeeze GaAs from the lower frequency and lower power applications side, other compound semiconductors such as GaN and SiC are squeezing GaAs from the high frequency, high power side where it has always excelled. As with GaAs in the 1980s, these other compound semiconduc-

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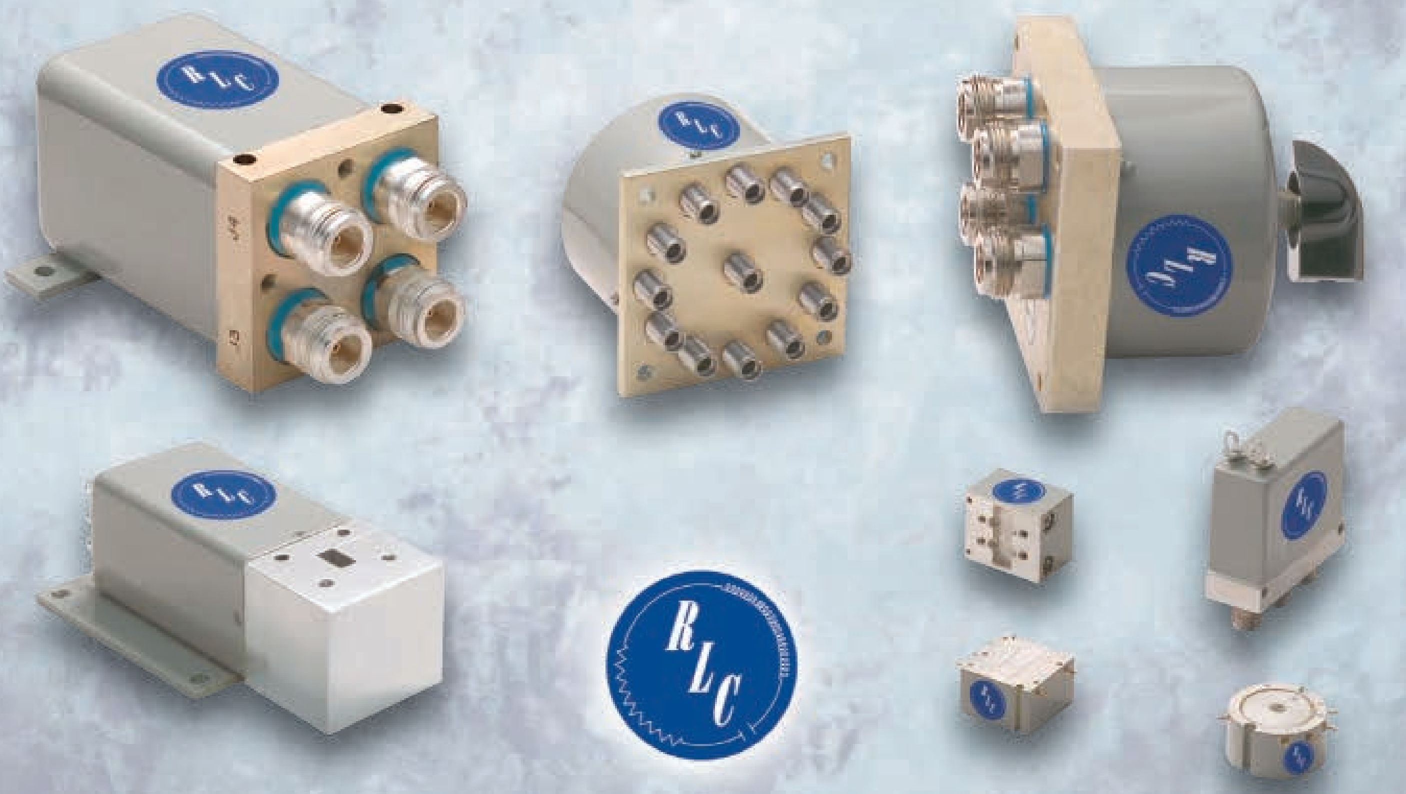

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tor technologies are benefiting from government/military funding and the commercial demand for more efficient "green" technologies. GaN (typically grown on Si or SiC substrates) has a wider band gap (higher breakdown voltages of 100 V or more) and higher gain, which means it has an advantage in high power applications. Although most GaN development is in high power applications, it also shows good low noise properties giving it the ability to produce LNAs that can withstand higher input voltages in the receive chain. This will enable multi-function LNA/switch MMIC devices in addition to high power amplifiers. ***Table 1***[2] shows a comparison of material properties for various semiconductor materials.

TABLE I

COMPARISON OF RF SEMICONDUCTOR MATERIAL PROPERTIES

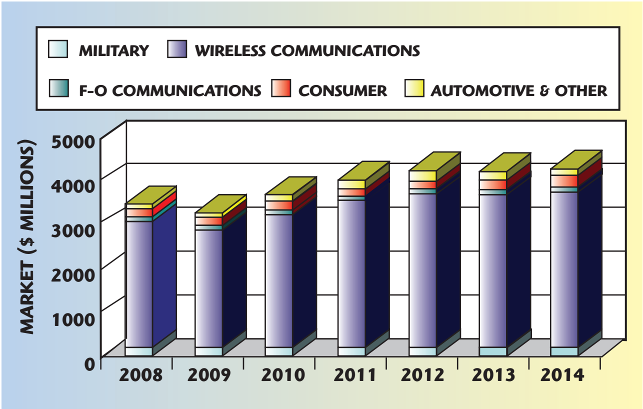
	Si	GaAs	InP	SiGe	SiC	GaN
Lattice constant (Å)	5.4	5.7	5.9	5.5	3.1	3.2
Saturation velocity (cm/S)	1×10^7	0.8×10^7	2.2×10^7	--	2×10^7	2.5×10^7
e- mobility (cm^2/Vs)	1350	8000	10000	3000	900	1500
Eg bandgap (eV)	1.1	1.4	1.3	0.7-1.1	3.3 (4H)	3.4
F_t (GHz) FET	20	150	300	50	20	150
Power density (W/mm)	0.2	0.5	--	0.3	10	>30
Thermal conductivity (W/cmK)	1.5	0.5	--	--	4.9	~2.0

Higher gain GaN devices are starting to make a significant impact in military programs and cellular infrastructure applications; GaN can achieve 5 W/mm or more compared to GaAs, which has about 1 W/mm (some special high voltage GaAs processes can reach about 1.5 W/mm). With all that heat being created from these high power devices, the packaging costs can be relatively high and swing back in favor of GaAs. GaAs also typically has higher linearity than other semiconductor type devices, which can be a big advantage in the newer 3G/4G systems that require high linearity for OFDM. RFMD recently announced the opening of its GaN fabrication facility for foundry business to join others such as TriQuint, United Monolithic Semiconductors (UMS), Eudyna/Fijitsu, Cree and Nitronex. Most GaAs foundries plan to start offering GaN services this year if they have not already announced it.

Another high voltage compound semiconductor material, SiC, has demonstrated impressive high-power devices for lower frequency, pulsed applications from companies like Microsemi. These devices also have much higher breakdown voltages than GaAs and superior thermal conductivity properties. However, the wafer sizes are smaller and are much more expensive than some competing technologies. So far SiC has been competing in the relatively lower frequency ranges for pulsed applications.

COST AND PERFORMANCE

GaAs has fought back on both the cost and performance side of the battle. GaAs foundry wafers cost up to $2500 a wafer versus a Si CMOS wafer of about $1000 and a SiGe wafer of about $2500; however, both Si processes are on larger 8 inch wafers compared to 6 inch GaAs wafers so they yield about twice as many die.[3] Therefore, the chip cost is far less for Si-based processes including the more specialized SiGe processes based on volume.

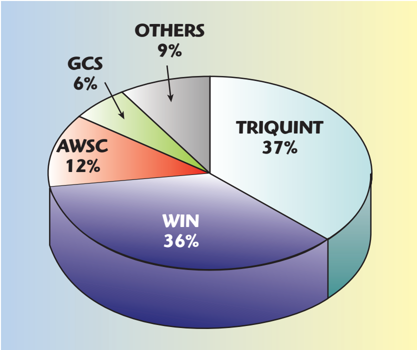


▲ *Fig. 1 Projected GaAs market value by application from 2008 to 2014.*[4]

However, there are two other cost factors that can make GaAs less expensive. First, GaAs mask sets typically cost from about $25 to $50k versus Si-based processes that cost from about $50 to $300k[3] so the initial investment is larger. Second, about 95 percent of RF cellular handset front-end devices are done by Integrated Device Manufacturers (IDM), whose internal costs are far less because they own their own fabs.[3] The internal wafer for IDMs is about the same as a Si CMOS foundry wafer so they are competitive with Si if produced for internal use. Therefore, looking at the total cost, lower to medium volume applications will probably be cheaper on GaAs while high volume applications (tens or millions or more) will be cheaper on Si-based technologies. One possible exception in the market today is millimeter-wave radios/automotive radar applications where SiGe single chip solutions have been custom developed to leverage high levels of integration (single chip radios) and are displacing some GaAs-based solutions. NXP is an example of a company making a significant push to replace GaAs devices with SiGe products as they recently announced they are releasing 50 new products by the end of 2010 for this purpose.

GAAS FOUNDRY MARKET

The GaAs market in 2008 grew 6 percent year-on-year, but really declined in the fourth quarter of that year according to Strategy Analytics. Strategy Analytics then reported the market declined by over 10 percent in 2009. However, the outlook going forward is better as they are projecting the GaAs market to be worth over $4.3 B by 2014 growing with a CAGR of 6 percent. ***Figure 1***[4] shows the GaAs market size for the major application areas with wireless commu-



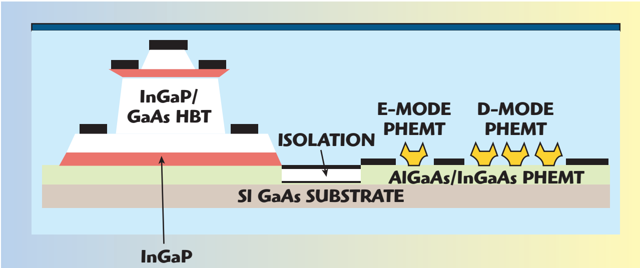
▲ *Fig. 2 GaAs market share by company.*[5]

nications being the primary growth market. The dominant market within wireless communications is for handset applications for front-end modules in the cellular market.

The current total market size data from Strategy Analytics for the GaAs foundry business is about $360 M with TriQuint and WIN Semiconductor neck-in-neck with a market share of a little over a third each (see ***Figure 2***).[5] WIN is the largest pure play GaAs foundry and has rapidly closed the gap with the market leader TriQuint over the past couple of years.

These two market share leaders are followed by Advanced Wireless Semiconductor Co. (AWSC) and Global Communication Semiconductors (GSC). United Monolithic Semiconductor (UMS) and OMMIC are the major European players that tend to concentrate on lower volume applications like defense and aerospace, so they are not major players in the overall market share data. In the 2007 time frame, several pure play GaAs foundries folded, including Knowledge On, Suntek and GCTC. WIN, ASWC and GSC are now the remaining major pure play foundries in the market.

There are many other captive GaAs fabs around the world, some of which do offer specialized foundry services. These include mostly defense companies such as Northrop Grumman, Cobham, Raytheon, BAE, etc., who will offer foundry services for specific large government programs or opportunities that utilize their design expertise and fit into their specific markets. However, they are mostly captive in the use of their fabs and not typically available for most applications. Other large captive commercial GaAs foundries include Skyworks, M/A-COM Technology Solutions, Anadigics, Avago, RFMD and Eudyna/Sumitomo.



▲ *Fig. 3 Cross-section diagram of WIN Semiconductor BiHEMT device structure.*[6]

GaAs devices first evolved from discrete implanted FETs to metal-eptiaxial-semiconductor field-effect transistor (MESFET) technology for integrated circuits (MMICs), but over the last decade, heterojunction bipolar transistors (HBT) have been used for most power amplifiers and pseudo-metamorphic high electron mobility transistors (PHEMT) for low noise and high frequency devices. These device types, in general, outperform MESFET technology, although the material costs are a little higher. Originally, only depletion-mode PHEMTs were available, but now foundries offer E/D PHEMT (enhancement/depletion mode PHEMT) devices, allowing for both types of transistors on a circuit. Logic type devices can be realized using enhancement mode FETs and depletion mode devices are typically used for other functions. This allows more capability on a single chip as digital logic, amplifiers, switches, LNAs, attenuators, mixers, passive devices, etc., can be integrated onto the same MMIC die.

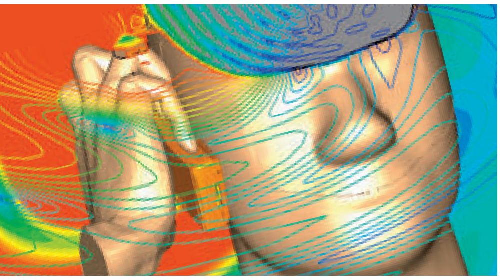
Another device technology available is metamorphic high electron mobility transistor (MHEMT), which is very good for high frequency, low noise applications but are not widely available. These devices have lower breakdown voltages so they are not suitable for power devices. With excellent low noise, high frequency characteristics, they are mostly used in space-based applications and thus serve more niche type, low volume markets.

A significant trend in GaAs foundry processes over the last few years and a logical next step has been to combine both HBT and PHEMT technologies on the same MMIC so that optimal devices of all types can be realized on a single chip. This allows even more integration on a single chip while optimizing the performance of the circuit. These BiHEMT or BiFET processes (analogous to Si BiCMOS) allow HBT-based power amplifiers to be integrated next to PHEMT logic circuitry, switches and LNAs. TriQuint and WIN Semiconductor started releasing these processes in 2007. Taking a different approach than some other manufacturers who grow the

TABLE II

GaAs FOUNDRY PROCESSES OFFERED BY THE MAJOR COMPANIES AROUND THE WORLD

Process	*TriQuint*	*WIN*	*AWSC*	*GCS*	*OMMIC*	*UMS*
InGaP HBT	✓	✓	✓	✓	✓	✓
.5 µm power PHEMT		✓	✓	✓		
.25 µm power PHEMT	✓	✓		✓		✓
.5 µm switch PHEMT	✓	✓	✓	✓		✓
.25 µm switch PHEMT	✓					
.15 µm PHEMT	✓	✓			✓	✓
<.15 µm PHEMT	✓	✓			✓	
.5 µm high linearity HFET	✓			✓		
.25 µm high linearity HFET				✓		
BiHEMT	✓		coming			
MHEMT	✓	✓			✓	
MESFET	✓					
Diodes	✓		✓	✓	✓	✓
Passives	✓		✓	✓		



FET within the emitter or collector structure, TriQuint and WIN both grow the epi layer by MOCVD on semi-insulating GaAs using a stacked layer structure with the InGaP HBT on top of the PHEMT (see ***Figure 3***).[6] In this architecture, the HBT device is processed and then the rest of the remaining HBT material is etched away to expose the PHEMT layers that are then processed. Etch stops are used between layers and the HBT device structures are isolated from the PHEMT devices for optimal performance. This structure is suitable for high-volume, low-cost manufacturing and is a good trade off with manufacturability and performance. Some other manufacturers grow the PHEMT layers within or under the HBT structures, which might simplify the epi structure but degrades the FET performance to some degree. ***Table 2*** shows the various processes offered by the major GaAs foundries as we surveyed the six major players.

TABLE III
DESIGN AND LAYOUT TOOLS SUPPORTED BY THE MAJOR GaAs FOUNDRIES

Tool	TriQuint	WIN	AWSC	GCS	OMMIC	UMS
Agilent ADS	✓	✓	✓	✓	✓	✓
Ansoft Nexxim (design/layout)						✓
AWR Microwave Office	✓	✓		✓	✓	✓
Cadence	✓	✓		✓	✓	
ICED	✓					
Mentor Graphics	✓					

TABLE IV
TRIQUINT AND WIN SEMICONDUCTOR OPTICAL LITHOGRAPHY PROCESSES

	TriQuint TQP13N	TriQuint TQP15N	WiN PP25-1x (Ku-band)	WIN PP25-1x (Ka-band)
Wafer size (mm)	150	150	150	150
Gate length (μm)	0.13	0.15	0.25	0.25
F_t (GHz)	95	75	60	70
IDSS (mA/mm)	100	300	36	480
P1dB (dBm/mm)	25.4	27.5	29	28
Idmax (mA/mm)	500	550	490	630
Gm (S/mm)	700	400	400	540

FOUNDRY SERVICES

Customer service and support are major factors when considering which foundry to work with. Items to consider range from design support to capacity, through-put and prototype turn-around. Most foundries provide various supporting services such as design assistance, modeling, packaging and testing. They have design libraries and models that can be accessed for designing circuits and devices, which can typically be found on their web sites. Most foundries also support several design and layout tools, as shown in ***Table 3***.

We surveyed the major players and found the typical lead times for most GaAs foundries is 6 to 8 weeks with some longer times for more customized or complicated circuits. WIN quoted the shortest lead times of 23 to 48 calendar days. Most major foundries use 6 inch wafer lines for higher volume processes, but many 4 inch lines are still running and make sense for lower volume processes. Typical capacities range from a couple hundred to a couple thousand wafers per month.

Some of the unique features that specific foundries offer include TriQuint's vertical PIN (VPIN) diode, MHEMT, BiHEMT and GaN on SiC processes; WIN Semiconductor's 0.1 μm PHEMT and BiHEMT processes; GCS's low phase noise VCO HBT (-105 to -110 dBc/Hz at 100 KHz offset), high speed HBT (f_t up to 300 GHz) and THz Schottky diode processes; UMS's defense/space qualified processes and Schottky diode process (BES up to 200 GHz); and OMMIC's specialty high frequency processes including commercially available MHEMT processes (2.2 dB NF at 94 GHz LNA MMIC with 18 dB gain).

ONGOING III-V DEVELOPMENTS

As Si has put more cost pressure on GaAs, another significant trend in GaAs foundry processes over the past few years has been the use of optical lithography for higher frequency millimeter-wave processes to greatly reduce wafer processing costs. Typically, small geometries (less than 0.5 microns) are difficult to image using optical lithography because of the diffraction of optical light from dimensions of that size. Instead, e-beam systems are typically used. Unfortunately, e-beam systems are much more expensive and much slower as they typically use direct write systems versus a mask stepper process. There are many processing technologies available today that can avoid the optical imaging resolution issues to form very small geometries. Shorter wavelength stepper systems and specialized photoresists stacks have overcome many of these limits. As an example, TriQuint released its optical millimeter-wave processes in 2008 with processes for 0.25, 0.15 and 0.13 micron geometries on PHEMT wafers; WIN Semiconductor has a couple of 0.25 micron PHEMT processes available (see ***Table 4***).

Another trend is outsourcing GaAs wafer fabrication to realize greater flexibility, higher margins and faster time-to-market. While fabless companies have been doing this for years, IDMs have recently been outsourcing a portion of their business to realize similar flexibility and higher margins for larger volume applications. Companies such as Skyworks, M/A-COM Technology Solutions, Avago, Freescale, Anadigics and others have been doing more of this over the last few years to compete in the up and down semiconductor markets. This is certainly favorable for the foundries as they become more important to a wider base of companies.

The main European foundries, UMS and OMMIC, have been specialty players for the most part, especially in the high performance aerospace markets. They did not benefit from large government funding in the

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Model	Frequency Range (GHz)	Attenuation Range (dB)	Notes
150-11	dc-18.0	0-11/1	
150-75-3	dc-18.0	0-75/5	
150-70	dc-18.0	0-70/10	
150-70-1	dc-18.0	0-70/10	
151-11	dc-4.0	0-11/1	
152-90-3	dc-26.5	0-90/10	
150T-11	dc-18.0	0-11/1	◆
150T-15	dc-18.0	0-15/1	◆
150T-31	dc-18.0	0-31/1	◆
150T-62	dc-18.0	0-62/2	◆
150T-70	dc-18.0	0-70/10	◆
150T-75	dc-18.0	0-75/5	◆
150T-110	dc-18.0	0-110/10	◆
151T-110	dc-4.0	0-110/10	◆
152T-55	dc-26.5	0-55/5	◆
153-70	dc-40	0-70/10	*New*
153-110	dc-40	0-110/10	*New*

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

Notes: ◆ SmartStep® Control Circuitry, X = 75 Ohm Model
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MAJOR GAAS FOUNDRY PLAYERS AT A GLANCE

TriQuint Semiconductor

TriQuint is the world's largest commercial GaAs foundry and is located in Hillsboro, OR, USA. They offer OEMs, fabless semiconductor and wireless startup companies one of the industry's broadest in-house technology portfolio. Their current technology portfolio includes a host of different types of process technologies including GaAs FETs (PHEMT, MHEMT and MESFET), InGaP HBT, BiHEMT and GaN.

WIN Semiconductors

WIN Semiconductors was founded in 1999 as the first pure-play 6-inch GaAs foundry and has an advanced GaAs wafer fab in recognition of the growing demand for low cost manufacturing of high speed and high quality GaAs MMICs and RFICs. They provide dedicated foundry services to design houses as well as IDM partners. WIN supplies HBT and PHEMT MMIC fabrication services to worldwide IC manufacturers. They are based in Tao Yuan Shien, Taiwan, ROC.

Advanced Wireless Semiconductor Co. (AWSC)

Advanced Wireless Semiconductor Co. is a GaAs HBT and PHEMT pure-play foundry service company. They utilize cost-effective mainstream GaAs manufacturing process technology and optimal process equipment, device layout and material structures for both wireless and optoelectronic communication applications. They were established in 1998 and are located at Tainan Science-Based Industrial Park of Taiwan, ROC.

Global Communications Semiconductors (GCS)

Global Communications Semiconductors is a compound semiconductor foundry service provider for wireless telecommunication, high-speed networking, optoelectronics and automotive industries. Their baseline processes include GaAs-based HBT and PHEMT technologies, which meet most requirements for wireless, high speed optics and millimeter-wave applications. They are headquartered in Torrance, CA, USA.

OMMIC

OMMIC, formerly known as Philips Microwave Limeil, was formed in 2000 with the mission to focus on III-V activities. This change has enabled OMMIC to fully develop activities in innovative III-V ICs and epitaxial material. OMMIC is developing new techniques for epitaxial wafer production, advanced PHEMT and MHEMT technologies as well as innovative circuits for 40 Gb/s and new generation wireless standards. They are located in Limeil-Brévannes Cedex, France.

United Monolithic Semiconductors (UMS)

United Monolithic Semiconductors designs, produces and markets RF and millimeter-wave components and solutions for telecom infrastructure, space, defense/security, automotive and ISM applications. The company's strategy is to position itself as a "one-stop" supplier, offering a broad range of standard and custom designed MMICs, along with an open foundry service. They have production facilities, at Ulm in Germany, and Orsay in France.

1980s and '90s like most US-based foundries, so they never seemed to expand beyond their regional aerospace and defense market needs. But they are now starting to expand internationally. UMS has opened a design center in Boston, MA, and a sales office in Shanghai, China, in an effort to expand its global reach. OMMIC has traditionally excelled at high frequency, low noise applications, but is becoming more commercially aware of its markets and more efficient in its technology development efforts to compete globally.

Going forward many GaAs foundries have immediate plans to begin offering GaN devices this year if they are not already providing them. TriQuint and RFMD are major players in the GaN market along with several others who specialize in this area. Most foundries see the millimeter-wave and high linearity applications as a growth area and are developing GaAs processes optimized for these opportunities. They are also expanding their services by working with design companies to develop design kits and developing advanced services or processes such as wafer bumping, chip scale packaging, multi-project wafers and Known Good Die (KGD). KGD come from a wafer that is 100 percent tested and the reject die are marked and/or removed so only fully tested, good die are delivered to the customer.

THE BATTLE HEATS UP

Si technologies are steadily improving as they increase their operating frequencies and levels of integration. They are starting to displace GaAs in some targeted millimeter-wave applications such as automotive radar and threatening to encroach upon the mainstream handset market. New

(Continued on page 112)

A 2.4 GHz Low Power, Short-range Transceiver

The ADF7242 is a low power, short-range transceiver designed for operation in the global 2.4 GHz ISM band. It complies with the IEEE 802.15.4-2006 2.4 GHz PHY requirements with a fixed net data rate of 250 kbps and DSSS-OQPSK modulation. Additionally with GFSK/FSK modulation, the ADF7242 supports a wide range of data rates, and is therefore equally suitable for proprietary applications. The agile frequency synthesizer of the ADF7242, together with short turnaround times, facilitates the implementation of FHSS transmission systems.

The ADF7242 has been designed with emphasis on flexibility, robustness, ease of use and low current consumption. The receive path is based on a zero-IF architecture enabling high blocking and selectivity performance. The transmit path is based on a versatile direct closed-loop VCO modulation scheme to allow the device to work with a variety of modulation schemes and data rates with a very low modulation error rate. The ADF7242 features an excellent performance versus power consumption metric, making it especially suitable for battery-powered systems.

The ADF7242 features a flexible dual-port RF interface with support for switched antenna diversity (see ***Figure 1***). An integrated biasing circuit is also provided to significantly simplify the interface to external PAs. Its applications can include the areas of smart metering, industrial control, home and building automation, health care and consumer electronics.

DUAL-MODE FUNCTIONALITY

The fact that the ADF7242 supports both IEEE 802.15.4 and GFSK/FSK modes allows a user to design a network that can incorporate both a standardized communications protocol and a proprietary link using one transceiver. For example, in a smart metering application the ADF7242 enables communications with standard ZigBee sensors in the home while meter information could be relayed in the neighborhood area network using a proprietary link.

RF PERFORMANCE

Receiver

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Model	Bands	Step Size	BW (GHz)	Typical Phase Noise 10	100	1K	10K	100K	1M	Output Frequency	Output Power (dBm, Min.)
BTE	L - Ku	1 kHz	2.2	-73	-80	-96	-96	-97	-123	12.72 GHz	13
MFS	L - K	1 kHz	2	-60	-75	-90	-95	-95	-120	5.3 GHz	13
CFS	L - K	1 Hz	2	-62	-75	-85	-89	-97	-110	14.84 GHz	13
Ku3LS	X - Ku	1 kHz	2.2	-62	-70	-75	-85	-97	-115	12.50 GHz	13
C3LS	C	1 kHz	1.1	-63	-88	-90	-100	-100	-115	5.50 GHz	13
UWB	S - K	1 kHz	Multioctave	-60	-71	-80	-90	-96	-105	12 GHz	13
MOS	VHF - K	1 kHz	Multioctave	-55	-65	-75	-85	-90	-100	20 GHz	13
SLS	L - Ku	125 kHz	1	-70	-80	-86	-88	-105	-115	3.3 GHz	13
SLFS	VHF - Ku	100 kHz	2	-70	-75	-80	-90	-115	-125	5 GHz	13
LFTS	VHF - Ku	100 Hz	1	-78	-88	-98	-98	-110	-130	350 MHz	13
VFS	L - Ku	>25 MHz	1.5	-60	-80	-110	-115	-115	-130	12.5 GHz	13

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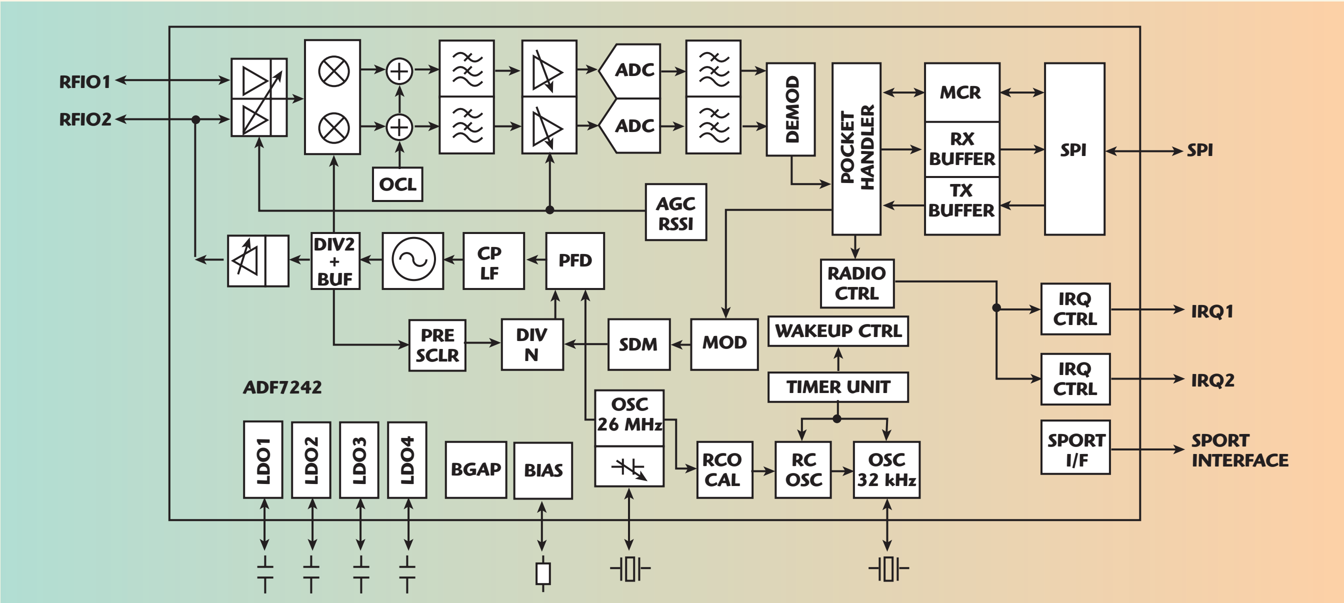
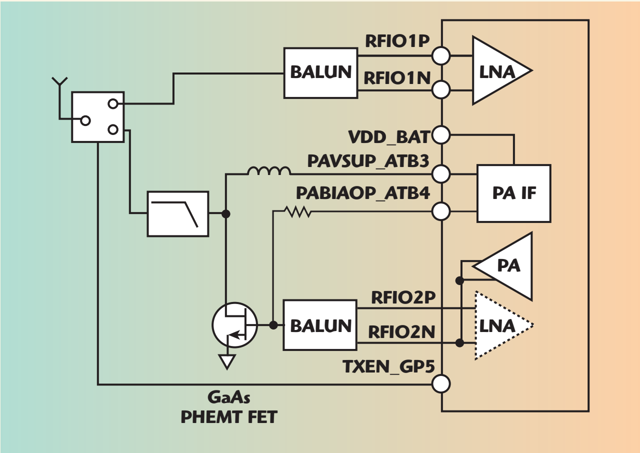


▲ *Fig. 1 ADF7242 functional block diagram.*



▲ *Fig. 2 Typical external PA applications circuit.*

of being able to operate globally. However, this advantage means that it can be a busier/noisier environment. Thus, for robust and efficient operation, resilience to interferers is particularly important in this band. The value of good sensitivity and low current will be constrained if the reception is not successful, necessitating retransmissions in this real world environment. The zero IF architecture of the ADF7242 facilitates its robust performance in the presence of interferers. It does not suffer from the inherent finite image channel rejection of a low IF architecture. In IEEE 802.15.4 mode, for example, the ADF7242 can successfully receive in the presence of another IEEE 802.15.4 signal in either an adjacent channel, which is 48 dB higher or an IEEE 802.15.4 signal, which is two channels away and is 62 dB higher. With the signal level at -92 dBm reception is still successful when a CW interferer at 5 MHz offset from band edge is as high as -26 dBm.

Transmit

The transmitter has programmable output power from -20 to +4 dBm with good stability over supply and temperature. The transmitter incorporates a PA ramping controller, which minimizes spectral splatter generated by the transmitter. Upon entering the Tx state, the ramping controller automatically ramps the output power of the PA from the minimum output power to the specified nominal value. The ramp rate is user programmable. Particular emphasis has been placed on the versatility of the transmitter to support the IEEE802.15.4 standard as well as FSK or GFSK modulation schemes with data rates ranging from 2 Mbps down to 50 kbps. The transmitter typically achieves a 3 percent EVM in the IEEE802.15.4 mode and 8° RMS phase error in 2 Mbps GFSK mode at 3 dBm output power.

RF PORT INTERFACE FEATURES

External PA Interface

For applications where higher output power is desirable, the ADF7242 offers an integrated biasing block for the external PA circuits. It is especially suitable for external PA circuits based on a single GaAs MESFET and a wide range of integrated PA modules. The key elements are a switch between pin VDD_BAT and pin PAVSUP_ATB3, a 5-bit DAC and a bias servo loop, all of which are controlled by control logic. This interface is enabled either under direct control of the MCU or automatically while the ADF7242 is in the Tx state.

Using this internal switch allows the supply to an external circuit to be switched on or off, which is useful for circuits that have no dedicated power down pin and/or have a high power-down current. In addition, the PABIOP_ATB4 pin can act as a programmable current source or sink.

When the PA circuit is based on a single external FET, the bias servo can be used to stabilize its output power by controlling the gate bias voltage of the external FET such that the current through the supply switch is equal to a reference current. The reference current for bias servo is generated by the current DAC (see ***Figure 2***).

DUAL RF PORT: CONFIGURATIONS/ ANTENNA DIVERSITY

The ADF7242 is equipped with two fully differential RF ports. Port 1 is capable of receiving; Port 2 is capable of receiving or transmitting. Only one of the two RF ports will be active at any one time. The availability of two RF ports facilitates the use of switched

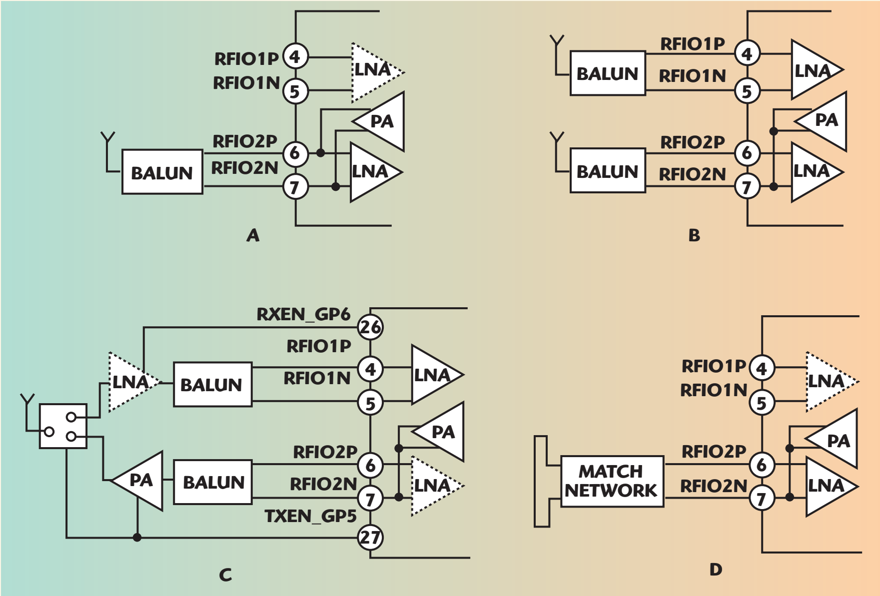


Fig. 3 RF interface configuration options (A: Single antenna; B: Antenna diversity; C: External LNA/PA; D: Dipole antenna).

antenna diversity. For receive antenna diversity, the link margin is maximized by selecting the optimum antenna based on the RSSI level of the desired signal received with each antenna. As an additional parameter, the measured link quality can be used. Suitable algorithms for the selection of the optimum antenna depend on the particulars of the underlying communication system. In a static communication system, it is often sufficient to select the optimum antenna once during setup.

The dual RF ports also simplify the application circuit if the ADF7242 is connected to an external LNA and/or PA. Connecting to an external PA and/or LNA is possible with a single external Rx/Tx switch, reducing the cost and loss associated with an additional switch. In addition to the external PA support described, the ADF7242 provides two signals to automatically enable an external LNA and/or a PA while in Rx or Tx state, respectively.

Figure 3 shows some of the different possible RF PORT configurations. In configuration A, a single antenna is connected to RF Port 2. In configuration B, a dual-antenna configuration is suitable for switched antenna diversity. In configuration C, the PA is configured to transmit on RF Port 2. RF Port 1 is configured as the receive input. Configuration D is similar to configuration A, except that a dipole antenna is used. In this case, a balun is not required.

EASE OF USE/FLEXIBILITY IN DATA PROCESSING

In FSK/GFSK a sync word of up to 24 bits can be programmed and optionally be used to activate the SPORT interface on sync word detection in receive mode. In IEEE 802.15.4-2006 mode a total of 256 bytes of TX_BUFFER and RX_BUFFER are provided to decouple the over-the-air data rate from the MCU processing speed. The integrated automatic packet handling includes the insertion of preamble, SFD and FCS in transmit and SFD detection and FCS checking in receive mode. Allowing additional flexibility, an alternative to the standard IEEE 802.15.4-2006 SFD byte can optionally be selected by the user and used by the ADF7242 packet handling processes. Additionally, a firmware download is available to control timing critical activities in IEEE 802.15.4-2006 mode. This includes address filtering, auto acknowledge and CSMA-CA.

In conclusion, the ADF7242 provides a flexible and robust solution for the 2.4 GHz ISM band market, incorporating dual-mode operation, excellent RF performance and a range of features to facilitate ease of use.

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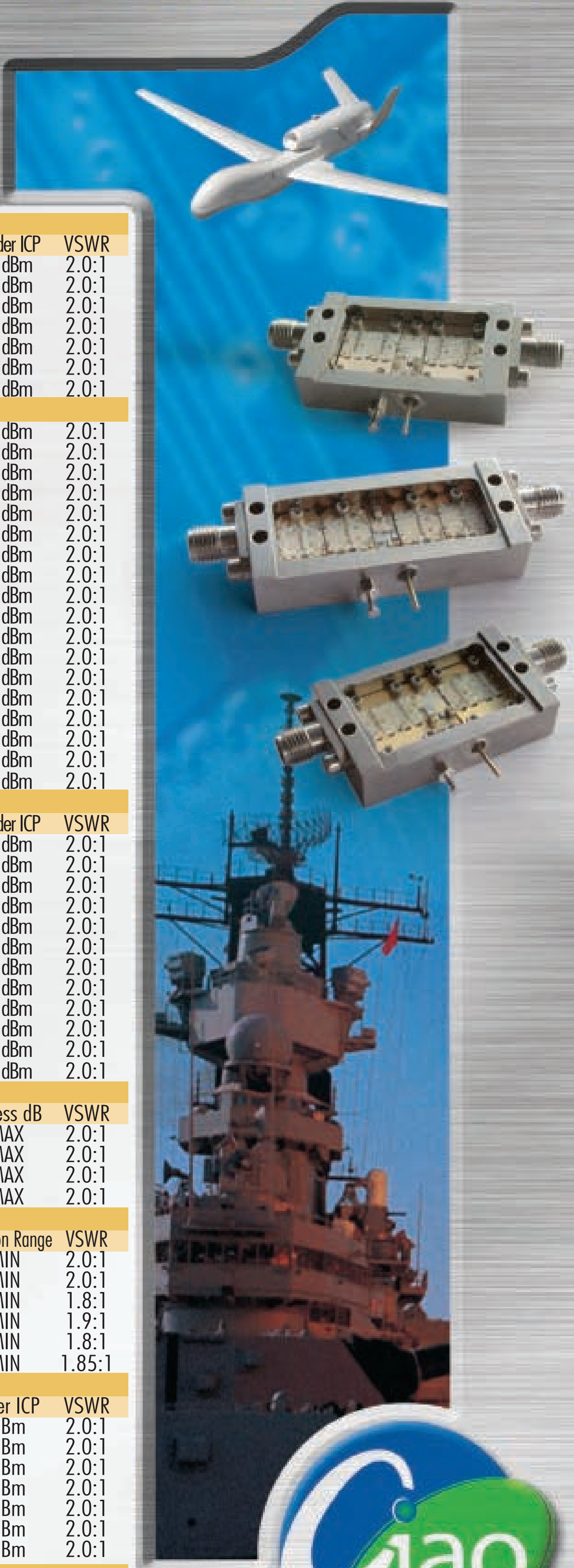

OCTAVE BAND LOW NOISE AMPLIFIERS

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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Defense News

Dan Massé, Associate Technical Editor

AEGIS Upgrades Drive Advanced Electronic Market Demand

Global naval forces rely on radar to defend and augment ship offensive capability, the most prevalent of which is the Aegis Combat System. The Strategy Analytics Advanced Defense Systems (ADS) service report, "Electronic Component Demand Scenarios for the Aegis Combat System," predicts that the annual market for electronics will grow at an overall CAAGR (compound annual average growth rate) of 5 percent through 2020, with upgrades to existing platforms becoming an increasingly prevalent portion of this market.

The Aegis Combat System's increasingly sophisticated mission, which now includes Ballistic Missile Defense and in-shore protection, is creating opportunities for advanced electronic components. The annual market for electronics will show steady growth, increasing from $590 M in 2009 to $677 M in 2020. The market itself is largely US-centric with a handful of companies involved, including Lockheed Martin, Northrop Grumman and Raytheon.

...the annual market for electronics will grow at an overall CAAGR of 5 percent through 2020...

"Integrating all of the Aegis Combat System functions together creates opportunities for a wide variety of electronics and technologies," noted Asif Anwar at Strategy Analytics. "Increasingly sophisticated mission requirements are driving innovation, which is leading to increased use of phased array radars, commercial off-the-shelf (COTS) components and computing power."

Lockheed Martin GPS III Team in Critical Design Review Phase

The Lockheed Martin team developing the US Air Force's next-generation Global Positioning System (GPS) satellite, known as GPS III, continues to maintain schedule performance and meet or exceed key milestones in the Critical Design Review (CDR) phase of the program. To date, the team has successfully executed 26 of 65 GPS III CDRs, most recently completing individual CDRs for the satellite's power regulation unit, batteries and space vehicle antenna assemblies. Preparations were made to conduct the TT&C, ACS and L2, L3 and L5 transmitter assembly CDRs. By the end of April, the team had completed over 50 percent of the planned CDRs and is well on its path to conduct the overall space vehicle CDR in August, two months ahead of the planned schedule. These rigorous CDR events demonstrate comprehensive designs and embody the core GPS III program focus on strong systems engineering and program management fundamentals. GPS III will improve position, navigation and timing services, and provide advanced anti-jam capabilities yielding superior system security, accuracy and reliability.

To date, the team has successfully executed 26 of 65 GPS III CDRs...

The new generation GPS IIIA satellites will deliver significant improvements over current GPS space vehicles, including a new international civil signal (L1C), and increased M-Code anti-jam power with full earth coverage for military users. Lockheed Martin, Newtown, PA, along with teammates ITT of Clifton, NJ, and General Dynamics of Gilbert, AZ, is working under a $3 B Development and Production contract awarded by the Global Positioning Systems Wing of the US Air Force Space and Missile Systems Center, Los Angeles, CA, which includes production of up to 12 GPS IIIA satellites. The team is on track to launch the first GPS IIIA satellite in 2014.

The GPS constellation provides critical situational awareness and precision weapon guidance for the military and supports a wide range of civil, scientific and commercial functions—from air traffic control to the Internet—with precision location and timing information. Air Force Space Command's 2nd Space Operations Squadron (2SOPS), based at Schriever Air Force Base, CO, manages and operates the GPS constellation for both civil and military users.

Raytheon-Boeing Team Fires First Joint Air-to-Ground Missile

Raytheon Co. and The Boeing Co. fired the first Joint Air-to-Ground Missile during a test funded by the two companies. The weapon, fired from a ground-based rotary-wing launcher, performed a series of preprogrammed maneuvers and flew to a predesignated location, validating the flight control software and Brimstone airframe. The mission met all primary test objectives.

"The Raytheon-Boeing JAGM is on track to demonstrate our low-risk entry into the engineering manufacturing development (EMD) phase of the program," said Bob Francois, Raytheon Vice President of Advanced Missiles and Unmanned Systems. "The missile uses existing technologies to provide the warfighter a cost-effective, low-risk and highly capable solution for destroying a wide range of stationary and moving targets in all weather conditions."

The Raytheon-Boeing JAGM features proven components from other Raytheon and Boeing programs including the Raytheon GBU-53/B Small Diameter Bomb II and Boeing Brimstone. "We had a successful flight of the control test vehicle and anticipate achieving additional milestones with a successful series of guided test vehicle missile firings as a culmination of our technology demonstration

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The weapon... performed a series of preprogrammed maneuvers and flew to a predesignated location...

phase," said Carl Avila, Director of Boeing Advanced Weapons and Missile Systems. "Our system-solution approach to the JAGM program will carry forward into EMD, setting the stage for success. Boeing's extensive experience integrating weapons on the F/A-18 E/F Super Hornet and AH-64D Apache Longbow combined with Raytheon's proficiency in seeker design and integration make our JAGM the lowest-risk and lowest total-cost solution."

Harris Corp. Receives Order for High-frequency Radio Systems

Harris Corp., an international communications and information technology company, has received a $139 M order to provide additional Falcon II® AN/VRC-104 high-frequency (HF) tactical radio systems for the US Department of Defense (DoD) Joint Mine Resistant Ambush Protected (MRAP) Vehicle Program. The radio systems will be installed in new standard-size MRAP vehicles and MRAP All-Terrain Vehicles (M-ATV).

"The DoD's Joint MRAP Program has standardized on our AN/VRC-104 vehicular system, which includes the AN/PRC-150(C) HF radio, for long-range communication requirements," said Steve Marschilok, President, US Department of Defense business, Harris RF Communications. "This software-defined radio system will provide beyond-line-of-sight communications in the rugged and mountainous terrain of Afghanistan. We're continuing to provide our US and international defense customers the broadest portfolio of field-proven, future-focused communications technologies that meet mission needs today and tomorrow."

The AN/VRC-104 system is a vehicular transceiver/amplifier that includes the AN/PRC-150(C), a Type-1 certified HF radio. In addition to the AN/VRC-104 and AN/PRC-150(C), Harris radios systems in a range of configurations have been installed in MRAP vehicles across the DoD's fleet. Harris RF Communications is a supplier of secure radio communications and embedded high-grade encryption solutions for military, government and commercial organizations. The company's Falcon family of software-defined tactical radio systems encompasses manpack, handheld and vehicular applications. Falcon III is the next generation of radios supporting the US military's Joint Tactical Radio System (JTRS) requirements, as well as network-centric operations worldwide.


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GSA Reports Global March of Mobile Broadband

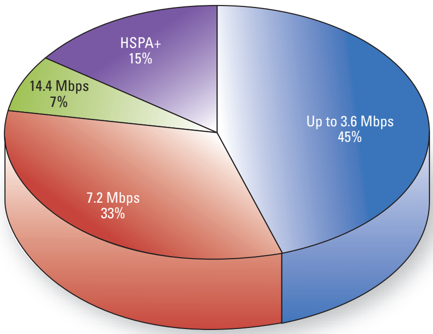
The Global mobile Suppliers Association (GSA) has released a new set of reports—*3G/WCDMA-HSPA Launches Worldwide, HSPA Operator Commitments, Global HSPA+ Network Commitments and Deployments, HSPA Devices Survey* and *Evolution to LTE*—that confirm the march of mobile broadband into the global mainstream.

The facts and figures show that the path to mobile broadband began with 3G/WCDMA, which is now commercially available on 347 networks in 144 countries. Its first evolution, High Speed Packet Access (HSPA), has now been deployed and commercially launched on 341 networks. There are now almost 1,000 models of HSPA-enabled phones on the market, with smartphones being the key growth segment.

For the uplink, the number of HSUPA devices has expanded by 77 percent since October 2009 with 609 products now launched and the commercial launch of 100 HSUPA networks in 53 countries. Further improvements in data speed, capacity and performance come with Evolved HSPA (HSPA+). Fifty-two HSPA+ systems are now in commercial service in 32 countries and 103 operators in 51 countries having committed to HSPA+ network deployments.

The reports maintain that LTE is the main direction for the industry. There are now 64 firm LTE network commitments in 31 countries, with a further 24 technology trials underway around the globe. GSA anticipates that the number of commercial LTE networks will increase steadily to reach 22 networks launched by the end of 2010.

HSPA Peak Downlink Speeds



Source: Global mobile Suppliers Association (GSA), www.gsacom.com

Mobile Broadband Infrastructure: BuNGee Project Bounces into Action

Cobham Antenna Systems, Microwave Antennas has been awarded a contract to participate in a consortium on a new initiative named Beyond Next Generation (BuNGee) aimed at achieving a tenfold increase in mobile broadband infrastructure capacity. The €4.7 M initiative, which is planned to continue through June 2012, is funded largely by the European Commission and will draw upon collaboration among the consortium members comprising European service providers, technology equipment vendors, universities and research organisations.

...the BuNGee consortium's objective will be to increase the overall mobile network infrastructure capacity...

Organised under the Seventh Framework Programme for Research and Technological Development (FP7), the BuNGee consortium's objective will be to increase the overall mobile network infrastructure capacity density to beyond what is promised by current technologies, targeting the challenging goal of 1 Gigabit per second per square kilometre. The project will identify network deployment strategies especially suited for dense urban environments where the demand for wireless broadband access is highest.

To achieve its stated objectives, the BuNGee project will target the following breakthroughs: unprecedented joint design of access and backhaul over licensed and license-exempt spectrum; unconventional below-rooftop backbone solutions exploiting natural radio isolations; beyond next-generation networked and distributed MIMO and interference techniques; autonomous architectures capitalising on very aggressive spatial and spectral reuse; and a protocol suite facilitating autonomous ultra-high capacity deployment.

The success of this project is critically dependent upon achieving the correct antenna beam characteristics to support high density communications networks. Cobham Antenna Systems, Microwave Antennas will be responsible for the design of appropriate individual radiating elements that will be optimized by EM simulation, the development of arrays of these structures, and the provision of a beam forming network that will control the various antenna beam shapes. Antennas will then be provided for field trials.

Centre for Energy-efficient Telecommunications Established in Australia

Alcatel-Lucent's research arm, Bell Labs, the University of Melbourne and the Victorian State Government are partnering to establish a AU$10 M research centre that will be devoted to innovation in energy-efficient networks and technologies. Bell Labs and the University of Melbourne will share governance of the Centre for Energy-Efficient Telecommunications (CEET), which will be based at the university. It will have a staff of researchers and technology experts that will build to a team of 22 over the next three years.

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The centre will conduct research on a broad range of telecommunications network infrastructure elements and will focus on how those elements can be made more energy efficient. In achieving its goals, CEET will draw on Bell Labs' decades of achieving breakthrough innovations and its extensive experience in managing collaborative research projects as well as on the University of Melbourne's world-class research in telecommunications network infrastructure.

The centre will conduct research on a broad range of telecommunications network infrastructure elements...

Both the University of Melbourne and Bell Labs are members of the GreenTouch™ initiative, a global, industry-wide consortium formed to achieve a dramatic improvement in energy efficiency by driving a radical redesign of communications networks. Accordingly, the research activities undertaken by the Centre will be used to further the GreenTouch initiative and its objectives.

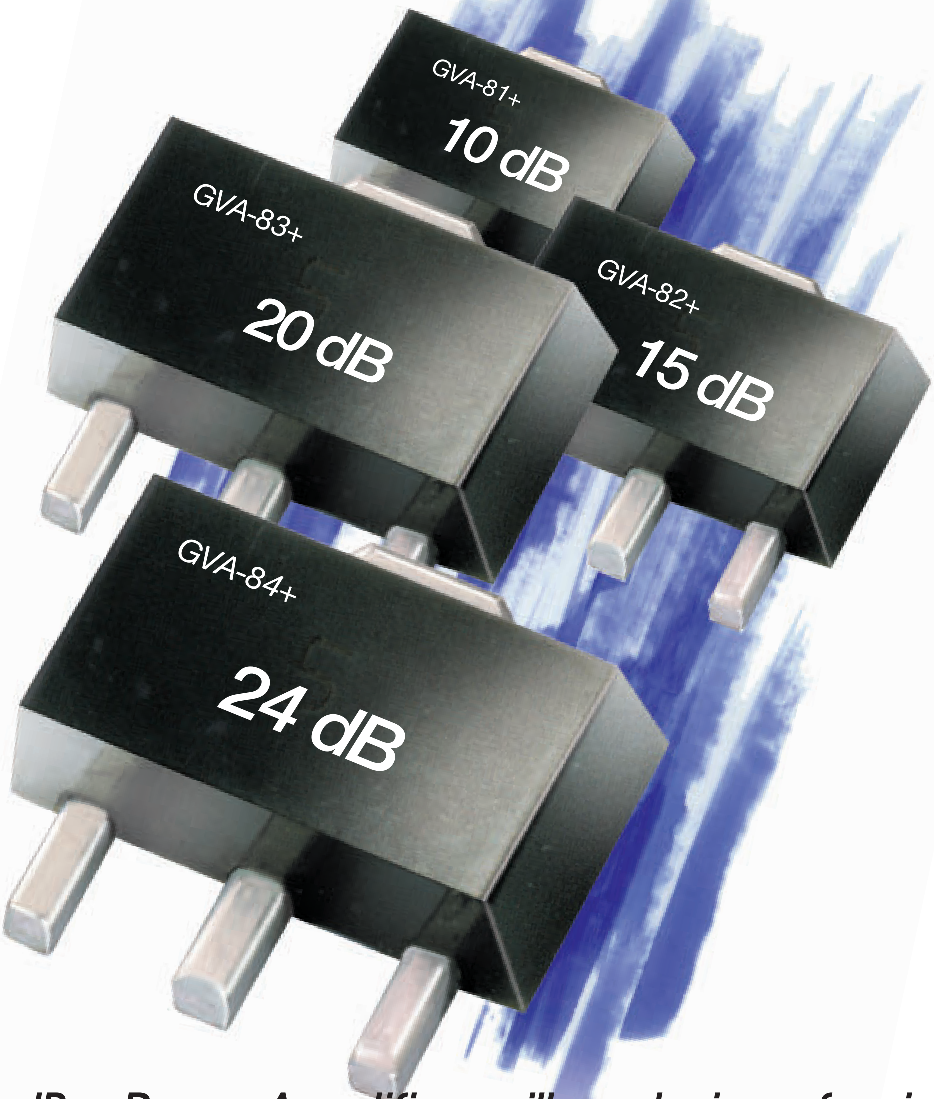
AESA Radar Centre of Excellence for Brazil

SELEX Galileo has concluded an agreement with ATMOS, a subsidiary of ATECH, to establish them as the Brazilian AESA Radar Centre of Excellence and Airborne Radar Systems House. The agreement is in accordance with the Brazilian Defence Strategy's intention to strengthen the country's national defence industrial capability.

This range of surveillance radars is being offered to meet a wide range of major Brazilian Air Force requirements...

The agreement focuses on the individual target programmes, such as the Raven ES-05 AESA for Gripen Next Generation, and details the development, production, training and support activities to be carried out by ATMOS. The agreement also covers all radars in the SELEX Galileo portfolio, including the Seaspray 5000E and 7000E AESA surveillance radars and the Gabbiano T20 mechanically scanned (M-Scan) surveillance radar system.

This range of surveillance radars is being offered to meet a wide range of major Brazilian Air Force requirements including maritime patrol aircraft and helicopter operations. The collaboration will provide ATMOS with in depth training on radar systems, development activities in the Raven ES-05 AESA, including full participation in the final testing and flight trials, plus the skills necessary to test and fully support the radar in Brazil. In the longer term joint development of advanced radar sub-systems will take place to ensure the future needs of the Força Aérea Brasileira (Brazilian Air Force) are fully met.



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*US patent 6,943,629 *Low frequency determined by coupling cap.*

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COMMERCIAL MARKET

Dan Massé, Associate Technical Editor

3G Handset Sales Eclipse 2G Market

"Despite ash clouds over Europe, handset shipments globally for 1Q-2010 powered ahead to 303 million, up 19 percent Year-on-Year," says Jake Saunders, VP for Forecasting at ABI Research. "This bodes well for 2010 as a whole: shipments could well reach 1.3 billion. It is also notable that 3G handset shipments eclipsed 2G handset shipments." Strongest handset shipment growth was seen in the Middle East and Africa (20 percent YoY) followed by the Americas, particularly the US (11 percent). Europe, on the other hand, is languishing with single-digit growth.

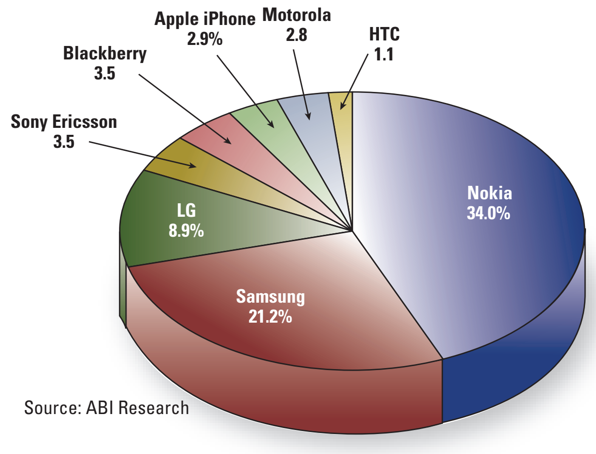
Nokia's market-share stood at 34 percent. New smartphones such as the N8 are helping the manufacturer to shore up its handset portfolio, as its loss of traction in the smartphone sector hit sales hard. In response, revamped efforts with Symbian ^3 and ^4 are intended to help Nokia regain momentum. Nokia is counting on smartphones expanding into the mid-tier and low tier segments where it believes it has strength.

Samsung had a strong quarter, securing 21 percent. Over the past year, Samsung has been cultivating deeper relationships with US and European carriers, which helped the firm grow its shipments 40.2 percent YoY.

LG's market-share, 8.9 percent, has suffered from a weak smartphone portfolio in the North American market. LG has been traditionally strong in the enhanced phone sector, and has been giving a number of its older enhanced phones a smartphone twist. For example, its Chocolate phone has gone wide-screen. Shipments grew 20 percent YoY.

Motorola is benefiting from its initial success (2.8 percent) with the Droid and is keen to back it up with new products such as the Quench, but the market is overtaking it. Motorola is hoping the strong social networking theme to its smartphone line-up will help it to curry favor with the youth and prosumer market.

Handset Vendor Market Share
World Market: 1Q 2010



UMS USA Inc. Celebrates One Year of Exercise

United Monolithic Semiconductors (UMS), a European leader in microwave and millimeter-wave MMIC solutions, is celebrating the first year of operation of its new design and customer support center in the United States. Located in Lowell, MA, United Monolithic Semiconductors USA Inc. increases UMS's presence to better serve its expanding customer base in North America.

The new office fully supports sales and application engineering inquiries. It actively contributes to the expansion of UMS's product offering with components operating from DC to 100 GHz and dedicated to US market sectors such as telecommunication infrastructures, SATCOM, automotive, defense & space, instrumentation and industrial sensors.

Cellular and Mobile Broadband PC Modem Market Up 55 Percent

Cellular and mobile broadband PC modem shipments grew more than 55 percent in 2009. In 2008, a total of 46.4 million such modems (including USB models, PC Card modems and wireless routers) shipped; in 2009, that figure grew to more than 72 million, according to the latest market data released by ABI Research.

"The USB modem continues to flourish," says Senior Analyst Jeff Orr. "They remain amazingly popular. 2009 was actually a good year considering we were in a recession; there was somewhat surprising year-over-year growth in both shipments and revenue. And at the end of 2009 there was a surge of consumer adoption. Business adoption was less robust." USB modems' popularity can be attributed to their low cost, flexibility and portability, as well as to subsidies frequently offered by network operators.

Raytheon Installs Frost Protection System in Canadian Vineyard

A Canadian horticulture research center has contracted with Raytheon Co. to install a prototype microwave frost protection system at its Ontario vineyard. Tempwave™ is a Raytheon-developed system that uses low-level microwave radiant heat to prevent frost damage to crops. Microwave energy is transmitted from towers located in an orchard or vineyard changing the energy balance that slows cooling to prevent freeze damage.

"The agreement leverages Raytheon's expertise in radio frequency applications with the Canadian research center's mandate to introduce innovative horticulture technologies," said Lee Silvestre, Vice President for Mission Innovation at Raytheon In-

...a Raytheon-developed system that uses low-level microwave radiant heat to prevent frost damage to crops.

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tegrated Defense Systems. Mission Innovation is charged with exploring and applying Raytheon technical expertise to address global challenges outside Raytheon's traditional core business interests in defense, homeland security and other government markets. The Vineland Research and Innovation Centre in Ontario, Canada, is a center for horticultural research and innovation whose charter includes commercializing and delivering new technologies to market.

"This new prototype technology will help ensure Ontario vineyards and orchards are protected when temperatures fall below freezing and jeopardize tender fruit and grape production," said Jim Brandle, the Center's Chief Executive. "Our partnership with Raytheon is a new chapter in Vineland's on-going research to protect Canada's food supply."

Latest Trends in Mobile Handset Design

Global mobile handset shipments totaled approximately 1.15 billion in 2009, with enhanced phones and smartphones capturing approximately 81 percent of all handset shipments, according to the latest data from ABI Research. According to Industry Analyst Celia Bo, "In recent years the major technology and application trends in handset design have focused on 3G (and beyond) capabilities including web surfing, social networking, multimedia, connectivity, better cameras, VoIP, pico projectors and more."

Current State of the Art:

- **3.5G Models:** The 3.5G handset category is the fastest-growing segment among all the models announced by vendors. Fifty-six percent of handset models in 2009 were 3.5G-ready devices, while the number of 2G and 2.5G models dropped in comparison.
- **GPS Handsets:** The Global Positioning System has secured a solid position in the automotive segment and is gaining traction in mobile phones, becoming a hot wireless connectivity application for smart phone designers and manufacturers. The penetration rate in new models reached 48 percent in 2009 compared to 29 percent in 2008.
- **Form Factors:** In 2009, the bar form factor led the market, accounting for 51 percent of announced handset models, followed by slider handsets at 27 percent. After a long decline, clamshell handset models picked up 19 percent market share among announced models.
- **Operating Systems:** Microsoft Windows Mobile still has the highest adoption rate among operating systems of newly launched models, with Symbian taking second place.
- **Handset Chipsets:** The chipset is at the heart of a handset; it integrates multiple function blocks and aligns them to different operating system platforms. While Qualcomm's Snapdragon, TI's OMAP, Intel's Atom and Nvidia's Tegra are driving the markets for 3G and 3.5G technology, the development of 4th Generation LTE and WiMAX chipsets is primarily led by Altair Semiconductor, Wavesat and Comsys Mobile, among others.


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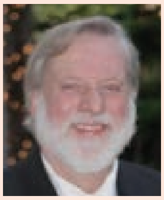
Around the Circuit

Jennifer DiMarco, Staff Editor

INDUSTRY NEWS



Pamtech founder, **George F. Grund III**, passed away on April 23rd. Grund was the founder of Pamtech (Passive Microwave Technology) in March 1976. The company, located in Camarillo, CA, designs and manufactures high performance ferrite products such as circulators and isolators. Pamtech is privately owned with an annual revenue of \$10 to \$20 M, employing a staff of approximately 10 to 19. Grund started Pamtech as a spin off of E&M Labs of Westlake, CA after TRAK of Tampa, FL bought that company in 1975.

Tektronix Inc., a supplier of test, measurement and monitoring products and solutions, completed the acquisition of **SyntheSys Research Inc.** The details of the transaction were not disclosed.

Symmetricom® Inc. announced the company will collaborate with **Alcatel-Lucent** on solutions that use Symmetricom's IEEE 1588 Precision Time Protocol (PTP) synchronization technology. This technology is used by service providers migrating to Ethernet transport for mobile backhaul and opting for IEEE 1588-2008 as the Node-B timing solution. Synchronization of base stations is a critical component in ensuring quality of service in Ethernet-based networks.

Electronic Design Automation (EDA) industry organizations, **Accellera** and **The SPIRIT Consortium**, announced that the organizations have completed their merger (revealed in June of last year). The new organization takes on the Accellera name and will continue to develop electronic design language-based and Intellectual Property (IP) standards of benefit to the electronics industry. The new organization is aligned on the path to create formal standards through the IEEE, and currently has eight standardization subcommittees operating. These standards include: SystemRDL (Register Description Language), IPtagging, Interface Technical Committee (ITC), Open Verification Library (OVL), Unified Coverage Interoperability (UCI), Verilog Analog/Mixed Signal (AMS), Verification IP (VIP) and IP-XACT.

Nitronex and **Modelithics** have released the first state-of-the-art nonlinear model for Nitronex's high power gallium nitride (GaN) NPT1012 device. The model combines heating effects, static and dynamic bias characteristics with large-signal performance to deliver accuracy unlike other GaN HEMT device models. The collaborative model predicts performance of the NPT1012 in broadband application circuits specifically targeting the military communications, electronic warfare and radar markets.

Anritsu Corp. announced it is the first test equipment vendor in the world to achieve GCF-approved test case validations for both LTE (Long Term Evolution) RF and protocol conformance testing. LTE is the next-generation wireless communications service supporting 100 Mbps downlink and 50 Mbps uplink data communications, which is 5 to 10 times faster than current 3G services.

Mini-Circuits, Brooklyn, NY, was recognized by **Rockwell Collins** as its top supplier for 2010 when it was presented with the President's Award by Jeff Moore, Senior Vice President of Operations, during the company's Annual Supplier Conference. For 27 years, the Rockwell Collins President's Award has served as an acknowledgment of significant contributions made over the past year based upon quality, delivery, total cost of ownership, lead time and customer service. Mini-Circuits also was named the Crystal Products Commodity Supplier of the Year.

AVX Corp. received the Capacitor Supplier of the Year 2010 award from Rockwell Collins for the third consecutive year. The award was presented to AVX by Jeff Moore, Senior Vice President of Operations at Rockwell Collins, at its Annual Supplier Conference. The Capacitor Supplier of the Year 2010 award acknowledges significant contributions made during the year by suppliers, and is based upon quality, delivery, total cost of ownership, lead-time and customer service.

ZTE Corp. recently honored **Andrew Solutions**, the CommScope Inc. division that is a leader in wireless communication systems and products, with its 2009 Best Partner award, a distinction Andrew has now won for the fourth consecutive year. ZTE, a Chinese telecom equipment provider, granted Andrew the award based on the company's superior performance in designing, supplying and delivering innovative products and solutions for wireless networks, especially base station antenna systems.

Aeroflex/Metelics announced that the company has received JANS certification for the company's diode line by the Defense Supply Center Columbus (DSCC). The product families covered by the JANS certification include: switching diodes and rectifiers; Zener and temperature compensating diodes; current regulators; and Schottky rectifiers.

CONTRACTS

The US Army Communications-Electronics Life Cycle Management Command recently awarded **SRCTec** a contract valued at \$94,386,209 for urgently required Counter Remote Control Improvised Explosive Device Electronic Warfare, or CREW Duke V2 systems.

Comtech Telecommunications Corp. announced that its Santa Clara, California-based subsidiary, **Comtech**

Xicom Technology Inc., and its Tempe, Arizona-based subsidiary, **Comtech EF Data Corp.**, received satellite communications equipment orders totaling $12.1 M from a major government prime contractor. The orders are for follow-on procurements of high-power tri-band amplifiers, high-power Ka-band amplifiers and satellite earth station modems for transportable USAF satellite terminals, and will be utilized to expand an existing military network.

TiaLinx Inc. announced it has received a Phase II award from the Defense Advanced Research Project Agency's (DARPA) Microsystems Technology Office. The SBIR Phase II award includes delivery of an advanced V-band high-bandwidth communication link and a high-precision radar system. The integrated system-on-chip is considered a key element within the entire dual function system to both implement precision object detection, and serve as a wireless link to transfer large data files.

Cobham's Mission Equipment strategic business unit has been awarded further production contracts by **The Boeing Co.** to supply more than 500 BRU-61/A carriage systems for the Small Diameter Bomb (SDB) program. The BRU-61/A is a pneumatic multi-store system designed for carriage and release of Boeing's SDB weapon system, which has been in service since 2006 on the Boeing F-15E Strike Eagle. To date, Cobham has supplied more than 900 carriages in support of worldwide operations. The BRU-61/A is manufactured at Cobham's facility in Orchard Park, NY.

LeCroy Corp. announced that it has received a contract award from the US Navy to supply digital oscilloscopes to the US Navy's Supply Systems Command. The contract has a Best Estimated Quantity (BEQ) of up to 200 WaveRunner oscilloscopes per year for five years. LeCroy's WaveRunner 64Xi-A-N oscilloscopes passed stringent technical requirements as part of a competitive bid to qualify for US Navy acceptance.

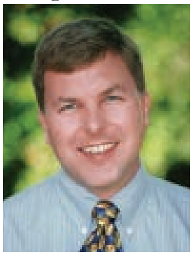
Camstar Systems Inc. announced that **REMEC Broadband Wireless**, a manufacturer and EMS provider of broadband wireless devices, components and subsystems, including transceivers and microwave radio ODUs, has selected Camstar's ElectronicsSuite™, configured for the electronics industry on the Camstar Enterprise Platform, to support its manufacturing, quality and customer satisfaction goals.

Aeroflex announced that **Silicon Laboratories** has selected Arendar® 2009 Suite from **VI Technology**, an Aeroflex company. Arendar 2009 Suite is an enterprise software solution that utilizes a modular architecture, integrated security, comprehensive API and web accessibility to shorten test cycles and speed time-to-market.

PERSONNEL

AWR Corp. announced that Chief Executive Officer **Dane Collins** has been elected to the Electronic Design Automation Consortium (EDAC) board of directors. The EDA Consortium is an international association of more than

100 companies that develop EDA tools and services for the design of communications, computer, and aerospace systems, medical and industrial equipment, and consumer electronics. Collins possesses a broad perspective, spanning job functions from integrated circuit designer and EDA tool developer to corporate executive, as well as company environments from small start-ups like EEsof, High Level Design Systems and AWR, to large commercial and military corporations such as Cadence Design Systems and General Dynamics.



▲ *Dane Collins*

Auriga Microwave announced the creation of a Department of Defense (DoD) Industry Advisory Board and the appointment of four advisors. Appointed to Auriga's Advisory Board are: **General (ret) Tom Hobbins**, USAF retired as Commander of US Air Force in Europe (USAFE); **Brigadier General (ret) John Meincke**, USAF retired from the US Air Force as director of command, control, communications and computer systems (J6) at the US Central Command; **Rear Admiral (ret) George Wagner** retired from the Navy as Commander of Space and Naval Warfare Systems Command (SPAWAR); and **Anthony M. Valletta** has spent 40 years in the C3/C4ISR and IT business area. He is presently an independent consultant, assisting companies in the DoD space.

RF Monolithics Inc. announced that with the continued strengthening and maturing of the M2M market, additional emphasis and resources will be directed towards it. Additionally, the company has appointed **Farlin A. Halsey** as Senior Vice President of Marketing and M2M Business.

Millennium Microwave Corp. is pleased to announce that **John Devlin** has joined the company as General Manager. Devlin brings over 30 years experience in the microwave industry, in engineering, management and sales. Millennium designs and manufactures integrated subassemblies, switched filter banks, solid state switches and switch matrices covering frequency ranges from DC to 26.5 GHz.

▲ *John Devlin*

NDK (Nihon Dempa Kogyo Co. Ltd.) announced the addition of **Jason Glavy** as Sales Executive responsible for the Southern California region. He will be supporting NDK's sales representatives, CK Associates, and their offices in Los Angeles, Orange County, San Diego, CA and Arizona. Among his key tasks will be the launch of NDK's new QPL oscillators and their COTS products for Hi-Rel/Demanding Applications into the defense and aerospace industries. He will

▲ *Jason Glavy*

also support NDK's traditional OEMs and work with the chip set designers in the area of reference designs.

REP APPOINTMENTS

Molex has become a licensed second source for **Radiall** SMP-MAX board-to-board coaxial connectors and as such will manufacture and market the connectors. The SMP-MAX connector line offers cost-effective large misalignment tolerance, making it simpler and more reliable to make connections even in blind-mate applications. The connectors address the demanding wireless telecom applications required for the new generation of infrastructure compact equipment such as base stations or handheld devices.

Eclipse Microwave Inc. announced the appointment of **Steward Technology** as its Arizona and Northern California sales representative. Based in Tempe, AZ and San Jose, CA, Steward Technology is also a supplier of precision microwave connectors, microwave diodes, filters, microwave chip resistors, chip capacitors and terminations, and discrete semiconductor products. Contact Steward at (408) 568-9159 or visit the company's website at www.stechrep.com.

SemiProbe has appointed **Inseto** as its representative for the UK, Ireland and Scandinavia. Inseto provides advanced manufacturing equipment, assembly materials and related consumable products for electronic production, including semiconductor, micro and nanoelectronic assembly, as well as products for general industrial manufacturing.

Endwave Corp. has announced the hiring of a collection of new sales representatives as part of a global marketing effort to promote the MMIC product line introduced last September. **Trionic** will cover the territories of New York, New Jersey and Pennsylvania, and can be reached either by phone or e-mail (516-466-2300, info@trionic.com). **Youngewirth & Olenick** will represent Endwave in Southern California, Arizona and New Mexico (contactus@yando.com, www.yando.com). **Mid-Atlantic Microwave** is a representative of the RF and microwave components in the Maryland, Washington, DC, and Virginia territories, and can be reached by phone or e-mail, or by visiting their website (301-421-0266, mamsinc@verizon.net, www.mamsinc.net). **Costar**, a Silicon Valley-based technology sales company, will represent Endwave in Northern California (401-946-9339, dlikens@costar-rep.com), **Innovative Marketing & Sales** will cover Arkansas, Texas, Louisiana and Oklahoma (972-462-1281, imstexas@earthlink.net), and **Matrix Sales Inc.** will cover sales in the New England states (978-459-4000, matrix@matrixsalesinc.com).

Richardson Electronics Ltd., whose new website features the latest products from top manufacturers for the most important RF/wireless and power conversion applications, announced it has signed a global distribution agreement with longtime engineering partner **LS Research** to distribute its line of innovative embedded solutions products.

New NanoSecond Switch Technology

GaAs MESFET-based switches have been a mainstay of the celluar telephony marketplace for more than two decades. These switches have and continue to deliver high performance over the entire cellular spectrum. Additionally, they are capable of very broadband performance; able to handle moderate power levels; and accomplish this at low voltages with essentially no current draw. This makes them ideal for hand-held, battery-powered applications. Until recently, one key limitation of this switch technology lies in the fact that, while moderately fast, 10 to 90 percent switching speeds in the 50 nanoseconds range were achieved, an extremely long 90 to 98 percent settling/gate lag times on the order of several hundred microseconds were routinely observed. Previously, while these very long delays in the completion of the on/off characteristic switch response have not been a factor in the overall performance of many systems, most new high frequency applications cannot tolerate these extremely long 2 to 98 percent switching times.

The fundamental problem of long switch settling times can be understood at the basic device level by understanding how charge moves and is stored within the MESFET structure. The RF switching time is dominated by the charge in the gated channel region, as well as the ungated recessed regions adjacent to the gate between both the source and drain ohmic contacts. The device turn-on time is the time required to move charge from the source through the channel region to the drain after the application of the control signal. The turn-on time is a function of the delay associated with filling the channel region with charge. This includes both the channel charge associated with the gate capacitance and the surface trap charge in the ungated recess regions. The turn-off time is dependent on the reverse of this process, with full turn-off not being complete until all charge is removed from the channel and recess regions.

The majority of the charge is associated with the channel charge in the depletion region directly under the gate. This charge can be moved into and out of the gate region relatively quickly by applying the proper polarity bias on

Timothy Boles and
Andrew Freeston
M/A-COM Technology Solutions, Lowell, MA

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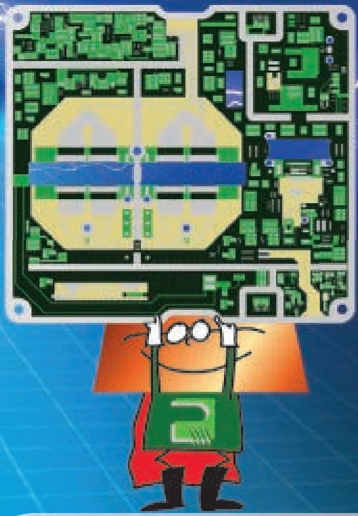

When amplifier designers asked, Rogers listened and developed RO4360™ high-frequency laminates. These thermoset materials feature a powerful balance of high performance, low cost and ease of processing in a laminate with a dielectric constant of 6.15.

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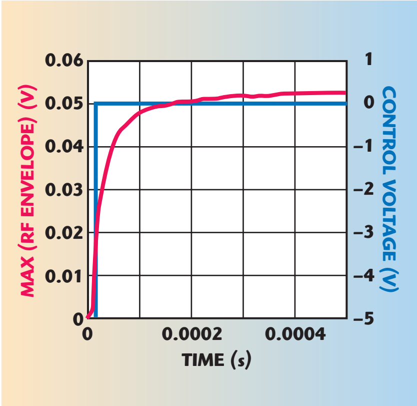
USA - AZ, tel. +1 480-961-1382 • EUROPE - BELGIUM, tel. +32 9 235 3611 • www.rogerscorp.com the gate terminal. On the other hand, the charge in the ungated recessed regions between the gate and the source and drain contacts is tied up in the semiconductor/passivating nitride surface states and interface traps. This trapped charge is relatively insensitive to applied bias and can only be charged or discharged through an RC circuit formed by the Schottky diode gate capacitance and the R_{dson} series resistance of the FET.

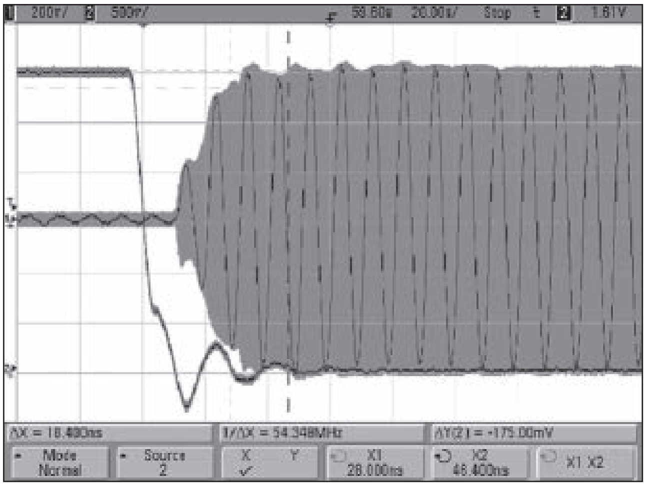
In order to address these issues with the long RF switching times associated with the long times due to gate lag dominated change of state, a number of patent pending modifications were made to the existing PHEMT process and device structure. First, the number of surface states and interface traps were reduced at the ungated GaAs surface via a combination of cleaning techniques and the deposition of a passivating dielectric. Second, the formation of the Schottky diode gate was modified to both reduce gate resistance with no additional gate capacitance in order to minimize the RC charging time associated with device turn on and turn off. Lastly, a proprietary III-V layer was added to the PHEMT structure to further reduce the channel resistance and enable enhanced movement of charge through the device especially from the ungated recess region. This process optimization for low gate lag not only resulted in a dramatic improvement in the 90 to 98 percent switch settling time, but also exhibited reduction in the 10 to 90 percent switching speed.

Figures 1 and ***2*** present measured gate lag data taken on standard and optimized process/structure PHEMT switches. In Figure 1, it can be seen that a gate lag delay of 274 microseconds was obtained as the switch transitioned from a 90 to a 98 percent level of the RF envelope. With the new PHEMT structure, the data in Figure 2 shows a total gate lag delay at the same 90 to 98 percent level of the RF envelope of only 18.4 nanoseconds. This is an improvement of almost a factor of 15,000 times. In addition, measurements of the 10 to 90 percent RF levels on this FET structure resulted in a switching speed of only seven nanoseconds as compared to a typical 50 nanoseconds on standard PHEMT switches. Combining these two improvements, a total switching speed for a 2 to 98 percent transition of 25 nanoseconds was obtained.

On an absolute level, while the above improvements in the switch settling time and in the overall switching speed are very significant, a comparison relative to similar GaAs PHEMT switches and other semiconductor technologies, which is presented in ***Table 1***, are very revealing. This table was compiled by a combination of data sheet information and direct measurement at M/A-COM Technology Solutions of the settling time and



▲ *Fig. 1 Standard PHEMT switch process—90 to 98% RF gate lag time = 247 μs.*



▲ *Fig. 2 Optimized PHEMT switch process—90 to 98% RF gate lag time = 18.4 ns.*

TABLE I
SWITCH TECHNOLOGY COMPARISON

Switch Technology		M/A-COM Tech New Nanosec PHEMT	M/A-COM Tech Std PHEMT	M/A-COM Tech Fast Switch PHEMT	Industry PHEMT	Industry SOS1	Industry SOS2	Industry RF CMOS	Industry SOI
Parameter	Units								
Settling Time (2%-98%)	ns	18.4	284,000	109	<2000*	78	1650	30.4	23.4
Switching Speed (10%-90%)	ns	14	15	30	--	55	350	28.2	15.4
Insertion Loss	dB	0.6	0.75	0.95	1.0	0.6	1.8	1.2	2.5
Isolation	dB	23	26	62	19	24.5	40	22.5	30
$P_{-0.1dB}$	dBm	28.5	26	20	38.5	13#	33#	13	16

*Based on Datasheet Information; #$P_{-1.0dB}$

the overall switching speed of specific switches that were felt to be representative of different industry technologies and were purchased through commercially available distribution channels.

If only the GaAs PHEMT switch processes are considered, the settling time for the new nanosecond switch process is truly in a class by itself. When compared to industry standard processes, the new low gate lag switch structure has a settling time that is measured in nanoseconds and compares to the standard processes settling times measured in microseconds or hundreds of microseconds. If the previous "Fast Switch" is used for comparison, the gate lag time of approximately 100 nanoseconds, while much better than standard PHEMT switches, still does not measure up when compared to the new nanosecond PHEMT structure.

Extending the comparison into silicon-based RF switch technologies, Table 1 lists the same switch parameters that were used to characterize all of the GaAs PHEMT devices for Silicon-on-Sapphire (SOS) technology. SOS was pioneered as a technological replacement for standard silicon CMOS by RCA in the early 1970s. The advantages of SOS over standard CMOS included a significant reduction in size, much lower access time, and higher frequency operation when applied to timing circuitry, DRAM memory, and CMOS-based microprocessors. While RCA only exists today as a brand name, other companies have picked up the SOS technology baton and significantly advanced the performance by application of shorter gate lengths, and tighter, more dense design rules, resulting in a true RF capability combined with CMOS logic.

Referencing Table 1, when the new nanosecond GaAs PHEMT technology is compared to two SOS high frequency switches, the settling time is significantly worse for either SOS switch with absolute times for gate lag ranging from tens of nanoseconds to as high as several microseconds. In addition, the standard switching speed to a 90 percent level exhibits similar proportional delays when compared to the new nanosecond PHEMT switch structure. The basic switch parameters shown in Table 1 indicate that the insertion loss of the SOS is generally higher, the isolation comparable, and the typical linearity, $P_{-0.1dB}$, is significantly worse when measured against the nanosecond GaAs PHEMT technology. In fact, the standard high frequency switch parametric of $P_{-0.1dB}$ for linearity is not even specified, but the much less capable parameter of $P_{-0.1dB}$ is employed.

The last two silicon RF technologies that were compared to the nanosecond PHEMT technology are RF CMOS and Silicon-on-Insulator (SOI), FET-based switches from two different suppliers. Commercially available high frequency switches in both RF CMOS and SOI technologies have settling times and overall switching speeds that are certainly comparable to the new nanosecond PHEMT switches; however, these silicon RF switches suffer from generally higher insertion loss and severely degraded $P_{-0.1dB}$ linearity. This demonstrates that the new patent pending nanosecond GaAs PHEMT switch process/structure is in a class by itself when it comes to overall RF and microwave performance. ■

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A COMPARISON STUDY OF HIGH-FREQUENCY CHARACTERISTICS FOR BALL AND RIBBON BONDING

In many microwave applications above 10 GHz, ribbon wire bonding is usually used because of its high frequency and high power characteristics. In general, ribbon bonding with a rectangular-shaped wire will provide lower impedance and inductance at higher frequency than a round wire. However, these results were not reached under a fair comparison for ribbon and round wires. In this article, two objective comparisons for these two wires were compared under the same wire cross-section and surface area. Therefore, three types of bonding wires were measured up to 20 GHz individually to analyze their high-frequency characteristics of self-inductance, insertion loss (IL) and self-resonant frequency (f_{SR}) with the same cross-section or surface area conditions. Based on the measurements, two wires with the same surface area provide very similar characteristics due to the skin effect. It clearly demonstrates that the surface area of bonding wire determines the current carrying ability instead of the cross-section area, and dominates the high-frequency performance of the wire.

Wire bonding is the most common interconnect method for providing the interconnection between an integrated circuit (IC) and a printed circuit board (PCB), IC-to-IC, or PCB-to-PCB. The two main wire-bonding technologies are ball bonding and wedge bonding. Although ball bonding is faster and much more popular, wedge bonding offers advantages that are well suited for optic-electronic and power devices, where reliability and performance outweighs bonding speed. However, ribbon bonding is a form of wedge bonding where flat ribbon wire is used instead of round wire. Ribbon bonding first came into use in the defense electronics sector, where it was the first interconnection level of choice for GaAs MMICs in millimeter-wave radar. Compared with the round wire, the ribbon wire bonding results in higher reliability because of the larger cross-section at the heel of the bond. There is also less cratering with a ribbon wire because the bond force and ultrasonic are distributed over a larger area.[1] In the past few years, several published papers[2-4] have compared the mechanical properties for ball and ribbon bonding, but very few papers discussed their electrical performance.

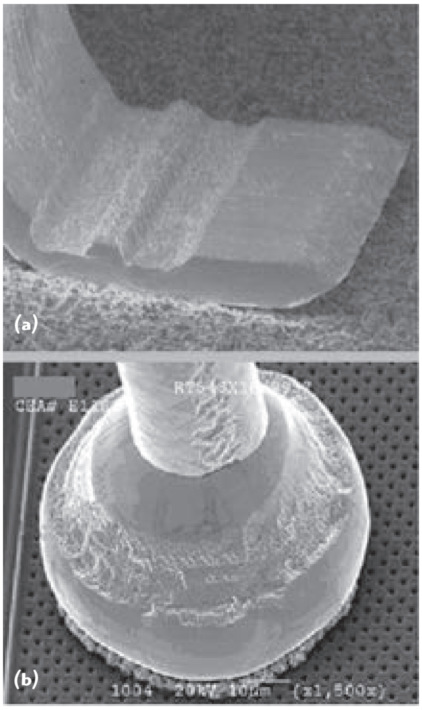
CHIEN-CHENG WEI, CHIN-TA FAN, TA-HSIANG CHIANG, MING-KUEN CHIU AND SHAO-PIN RU
Tong Hsing Electronic Industries Ltd. Taipei Hsien, Taiwan

In this article the electrical characteristics of ball and ribbon bonding (round and ribbon wires, shown in ***Figure 1***) were compared, such as wire self-inductance, self-resonant frequency (f_{SR}) and insertion loss (IL). In order to objectively compare these parameters, three types of wires were adopted to satisfy the same comparison conditions: 0.5 × 2 mils ribbon wire, 2 mils round wire and 0.8 mils round wire. These wires, made of the same material (gold), loop height and wirelength, were measured up to 20 GHz, to obtain their electrical properties for further comparison.

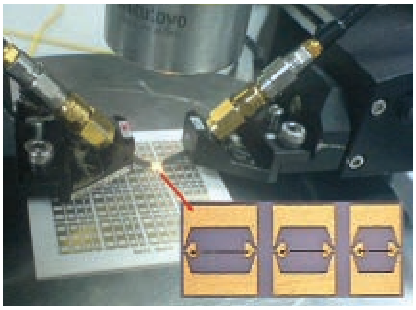
TEST METHOD

To carry out the high-frequency measurements for round and ribbon wires, all wires were bonded on the designed test board individually and measured from DC to 20 GHz, using an Agilent E8364A network analyzer and G-S-G RF probes. These designed test patterns were fabricated on high-resistive Al_2O_3 substrate. The spacings between the first and second bond pads were chosen as 75, 60, 45 and 25 mils, for different wire length, as shown in ***Figure 2***. Thus, through these measurements, each bonding wire can be characterized for a comprehensive high-frequency comparison.

Based on the different wire shape of round and ribbon wires, however, two comparison conditions were set according to the wire cross-section and surface area. For round wire, the cross-section area can be defined as ϖr^2 due to its circular shape; r is the radius of round wire. On the other hand, the rectangular-shaped ribbon wire has a cross-section area of W × L, where W and L are the wire cross-section width and thickness.[5-6] There-



▲ *Fig. 1 Two types of wire bonding technologies: (a) ribbon bonding and (b) ball bonding.*



▲ *Fig. 2 High frequency test system.*

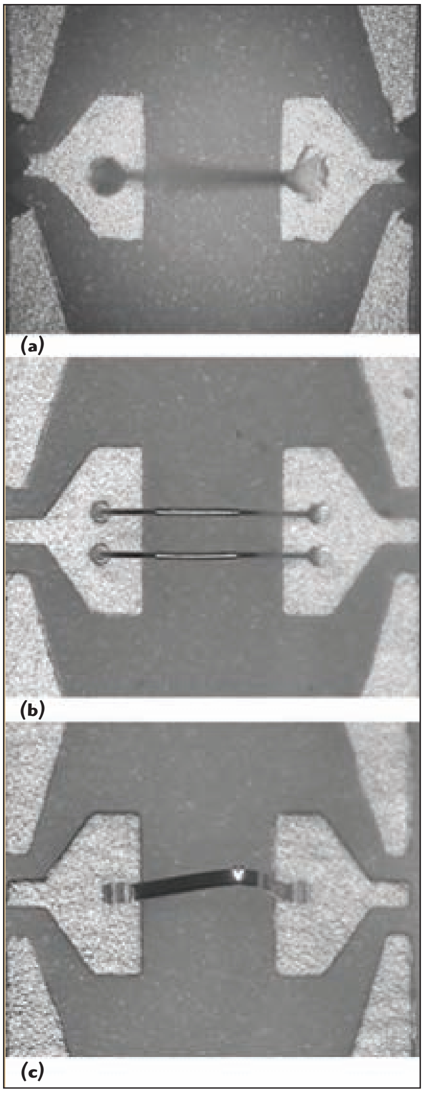
fore, under the same wire length, two 0.8 mil round wires and a single 0.5 × 2 mil ribbon wire have the same cross-section area of approximately 1 mil^2. A 2 mils round wire and a 0.5 × 2 mils ribbon wire have almost the same surface area. A total of three types of bonding wires were selected to see the performance difference at high-frequency region, as shown in ***Figure 3***: ball bonding with a 2 mils round wire (a), ball bonding with two 0.8 mil round wire (b) and 0.5 × 2 mils ribbon bonding (c).

MEASUREMENT COMPARISONS

For characterizing the bonding wire, probe testing was used to diminish most extra parasitic effects from the test fixture. The network analyzer measured each wire individually to acquire their high-frequency characteristics on wiring inductance, f_{SR}, and IL from S- and Z-parameters. However, even though probe testing is used, all measurements still include not only the wire characteristics but also the external parasitics from the test pattern, such as bond-pad inductance and resistance, bond-pad to bond-pad coupling capacitance, and capacitance to ground, etc. Here, however, these parameters were not removed since all measurements and comparisons were accomplished under the same test patterns and method. More accurate data for bonding wire can be achieved by using a de-embedding procedure.

BALL BONDING WITH ROUND WIRE

At first, ball bonding with 2 mils round wires was systematically tested and compared for different wire lengths (75, 60, 45 and 25 mils) and loop height (10, 15 and 20 mils). ***Fig-***



▲ *Fig. 3 Three types of bonding wires.*

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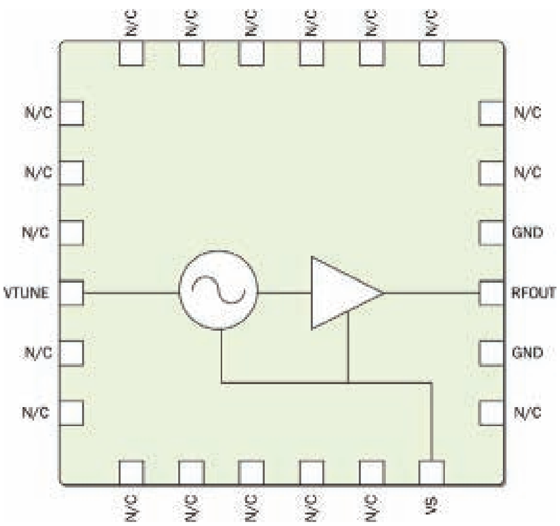
RFVC-1801	5000	10000	3.0	72.0	96.0	18	6	5 V at 55 mA
RFVC-1802	4000	8000	3.5	74.0	99.0	16	4	5 V at 55 mA
RFVC-1803	6000	9000	3.5	73.0	97.0	22	—	5 V at 52 mA



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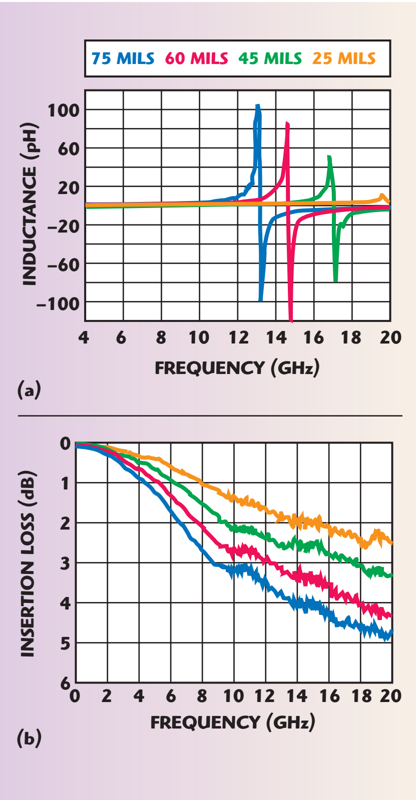
ure 4 shows the measured inductance and insertion loss values for these different wire lengths. From these measurements, it clearly shows that the longer wire will induce a larger inductance and the values will increase slowly with increased frequency. The 10 mils height wires, with 60 and 25 mils lengths, provide approximately 1.29 and 2.98 nH at 10 GHz before de-embedding, respectively. However, since the wire inductance and the parasitic capacitance from the test pattern resonate at a specific frequency, the inductance becomes a capacitance above the measured frequency f_{SR}. The 25 mils long wire has an f_{SR} greater than 20 GHz, which is approximately 7 GHz higher than for a 75 mils wire length. Undoubtedly, these values depend on the design of the test pattern. A designed test pattern with lower (higher) parasitic capacitance increases (decreases) the wire inductance value and its f_{SR}. For a simple comparison, these data can be objectively compared to other round or ribbon wires, but may not be too accurate for other cases.

Meanwhile, the wire length also affects the insertion loss directly. The measured insertion loss of the long wire shows an insertion loss 2 dB higher than that of the short wire at 20 GHz. It clearly indicates that the wiring length must be as short as possible when the operating frequency goes up above 10 GHz. The higher insertion loss is due to the impedance mismatch. In order to further compare the ball bonding and wedge bonding for the same cross-section area wires, two wires with 60 and 25 mils length were measured for comparison. From the measured results displayed in ***Figure 5***, it is shown that two wires using ball and wedge bonding with the same cross-section have almost the same frequency response up to 20 GHz. It clearly points out that the bonding type does not affect the high-frequency performance dramatically. However, the wiring shape is the most important factor dominating the wiring characteristics.



▲ *Fig. 4 Inductance (a) and insertion loss (b) measured for 2 mils ball bonding wires of different lengths.*

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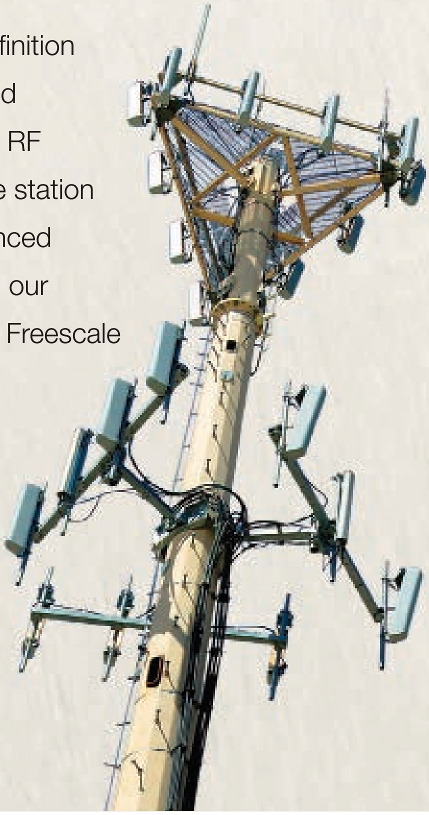

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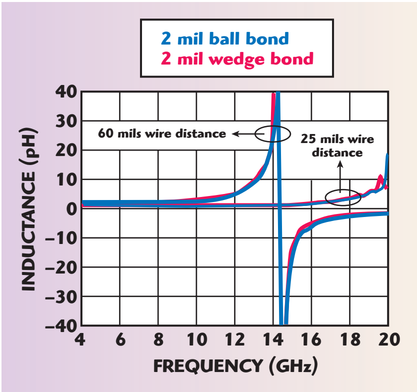
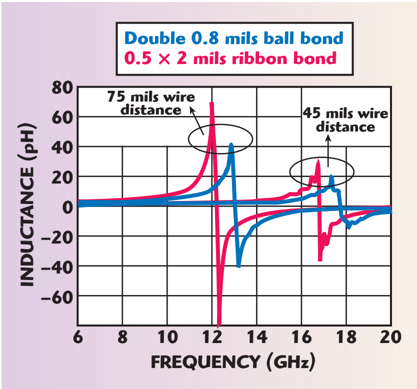
BALL BONDING VS. RIBBON BONDING (SAME WIRE CROSS-SECTION AREA)

Measurements were taken to compare the high-frequency performance between ball and ribbon bonding of wires of the same cross-section area. Therefore, a single 0.5 × 2 mils ribbon wire and double 0.8 mils round wires were measured with a spacing of 5 mils between the double round wires. ***Figure 6*** shows the measurements for these wires with length of 75 and 45 mils. Under the same cross-section area of 1 mil^2, ball bonding wires achieve lower inductance value and higher f_{SR} than ribbon wire. For 75 mils wire length, the inductance values are 7.1 nH for ribbon wire and 5.0 nH for round wires; these values are 2.7 and 3.3 nH for 45 mils wire length, respectively. The lower inductance for round wires is due to the two round wires bonded in parallel, which provide a larger current flow area; therefore, the inductance values were decreased even though they have the same cross-section area as the ribbon wire. In addition, once the spacing between two round wires was increased from 5 to 10 mils, the inductance values will be reduced to 3.7 and 2.5 nH for wire lengths of 75 and 45 mils. This is because the wider spacing between the two wires generates a lower mutual inductance than the narrow spacing. However, a single 0.8 mils round wire does provide the largest inductance and the lowest f_{SR} compared to the other wires, due to the smallest conductor area and significantly high-frequency parasitic effects. All the measured inductances and insertion losses are shown in ***Figure 7***.

The insertion losses of all wires shown, round and ribbon wires, are measured with the same wire length (60 mils). Under the same cross-section area, three types of bonding wires, 0.5 × 2 mils ribbon wire, double 0.8 mils round wire, with 5 and 10



▲ *Fig. 5 Measured inductance for ball and wedge bondings of the same 2 mils round wire.*



▲ *Fig. 6 Measured inductance for ribbon and wedge bonding of wires of the same cross-section area.*

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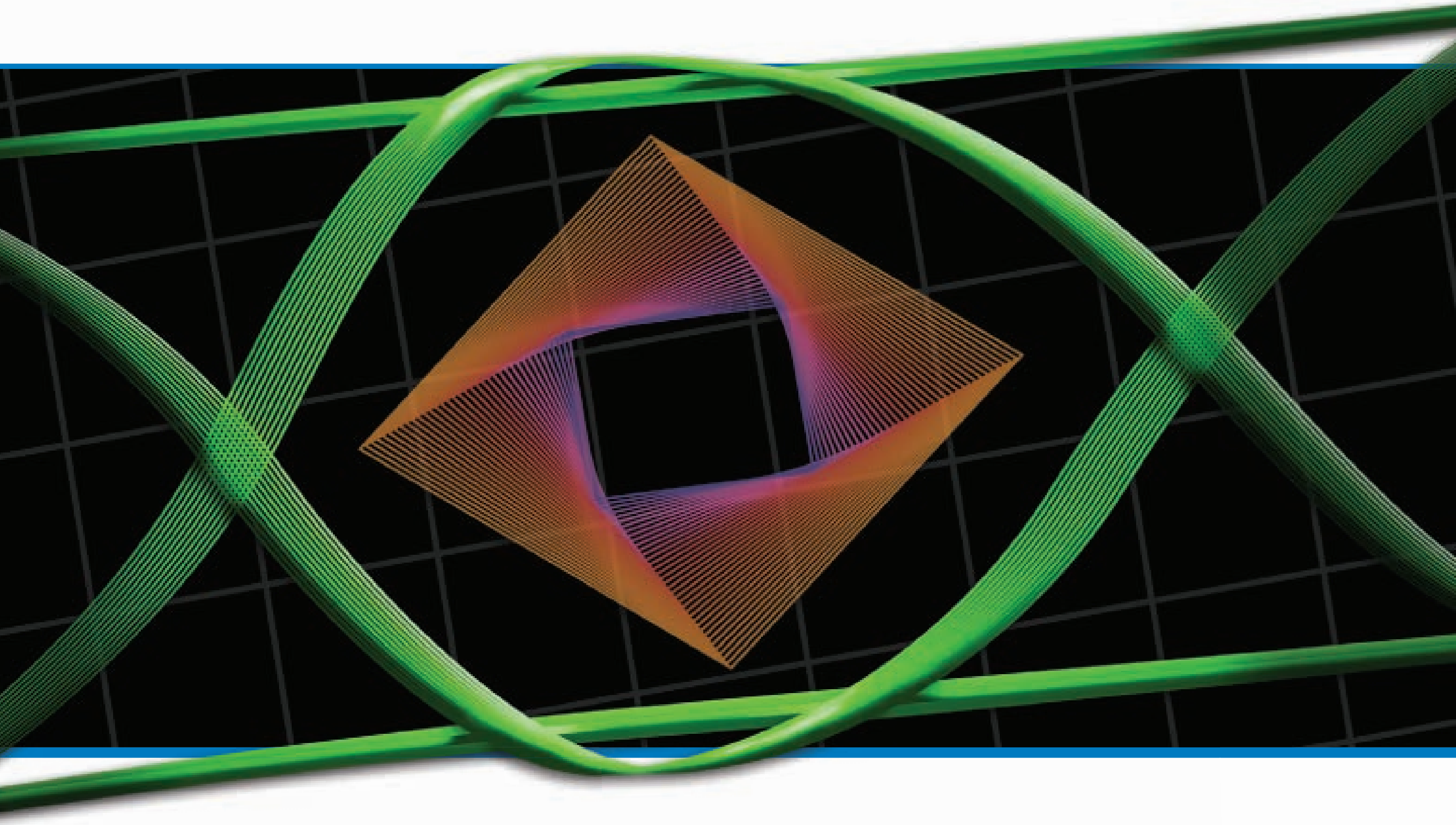

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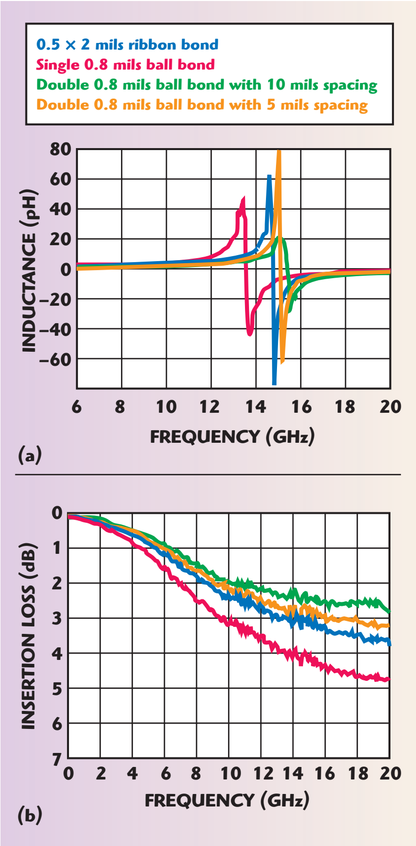
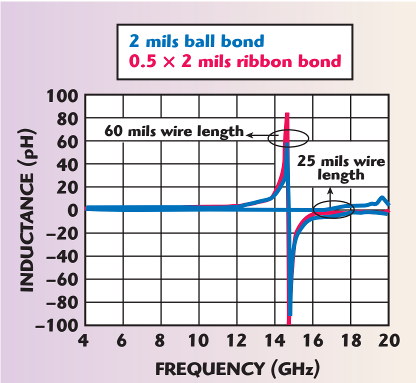
mils separation, have almost the same ILs below 2 GHz. However, these values increase with frequency, as well as the loss difference among them. The lowest insertion loss was achieved by using double round wires with 10 mils spacing, because of their smallest wire inductance. The insertion loss of this double round wire is approximately 2 dB lower than that of single round wire at 20 GHz.

BALL BONDING VS. RIBBON BONDING (WIRE SURFACE AREA)

Measurements were performed to compare both round and ribbon wires with the same surface area, 0.5 × 2 mils ribbon wire with 2 mils round wire. The measured inductance results are shown in ***Figure 8***. In this comparison, it is shown that the two wires have similar high-frequency characteristics from low frequency to 20 GHz, since the main influence is the "skin effect". However, for a DC current (zero frequency) applied to the wire, the electron flow is uniform throughout the wire. However, when a high-frequency signal is carried, the electron flow moves toward the wire surface. Therefore, due to the skin effect for the bonding wires, the same cross-section round wire has much higher current carrying capability than ribbon wire, and achieves small-



▲ *Fig. 7 Measured inductance (a) and insertion loss (b) for ribbon and ball bonding with different wiring conditions.*



▲ *Fig. 8 Measured inductance for ribbon and ball bonding of wires of the same surface area.*


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TABLE I

MEASURED INDUCTANCE, INSERTION LOSS AND F_{SR} FOR DIFFERENT WIRES

	Single 0.8 mil round wire	Double 0.8 mil round wire (S=10 mils)	Double 0.8 mil round wire (S=5 mils)	Single 2 mils round wire	0.5 × 2 mils ribbon wire
Inductance @ 10 GHz (nH)	4.238	2.509	2.769	2.98	3.077
Insertion loss @ 10 GHz (dB)	3.24	2.06	2.29	2.47	2.5
Self-resonant frequency (GHz)	15.3	13.4	14.6	14.82	14.8

er effective inductance and less signal loss. It also illustrates that the surface area of the conductor determines the current carrying ability instead of the cross-section area. To achieve the same surface area, a round wire needs more cross-section area than a ribbon wire. Moreover, this article demonstrates that the main factor dominating the wire high-frequency characteristics is the surface area of a bonding wire. Finally, all measured inductances and f_{SR} results for three types of bonding wires are summarized in ***Table 1***.

CONCLUSION

A comparison study of the high-frequency performance of ball and ribbon bonding was presented in this article. Different wire types, 0.5 × 2 ribbon wire, 0.8 and 2 mils round wires, were systematically measured up to 20 GHz, under two different conditions: same wire cross-section area and same surface area. The wiring self-inductance, f_{SR} and IL parameters were measured. The experimental results show that the high-frequency performance for round and ribbon wires are almost identical when they have the same surface area, due to the "skin effect", and that these characteristics are quite different when the two wires have the same cross-section area. It points out that the surface area of a bonding wire mainly determines the current carrying ability, rather than the cross-section area, and dominates the electrical performance at high frequencies. This data can be very useful for RF designers when selecting the suitable bonding types for their applications. ■

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DESIGN OF A MICROSTRIP OPEN LOOP RESONATOR BPF WITH WIDE STOPBAND FOR WLAN

A new microstrip open loop resonator bandpass filter (BPF) for wireless local area networks (WLAN) with a wide stopband response is presented in this article. The BPF consists of a pair of λ/2 open loop resonators and two additional resonators operating at the center frequency of 2.44 GHz. The novel resonator consisting of asymmetrical spurlines and quarter-wavelength open-circuited stubs are used at the input and output (I/O) feed lines to improve the stopband characteristics. The current distribution is demonstrated and analyzed. For the out of band spurious response suppression, its stopband attenuation loss is better than 20 dB from 2.6 to 10 GHz, and its insertion loss is as low as 1.05 dB. Good agreement is achieved between simulated and measured results.

RF and microwave microstrip BPFs with high selectivity, low insertion loss, suppression of spurious sideband and wide stopband are widely used in recent wireless communication systems.[1] In 2002, the IEEE extended the 802.11b standard in the 2.4 to 2.4835 GHz frequency range; the fast development of WLAN communications has also made high performance essential for RF BPFs.[2] However, many microstrip planar BPFs have spurious resonant frequencies, which may be close to the operating frequencies, with severe influence on the system.[3] Although quarter-wavelength resonator filters have their first spurious passband at $3f_0$, where f_0 is the center frequency, they require short circuit connections with via holes, which creates a parasitic effect difficult to cancel.[4] BPFs using low temperature co-fired ceramic and stepped impedance resonators are able to control the spurious responses, but they can only be implemented in certain filtering configurations with high insertion loss.[5,6] The open loop resonator filter has a pair of attenuation poles at finite frequencies, making it a viable intermediate between the Chebyshev and elliptic-function filters.[7,8] Defected ground structures (DGS) have been applied to improve the spurious response of the microstrip open loop resonator BPF; it also results in some problems such as high insertion loss and electromagnetic compatibility interference.[9]

In this article, a 0° feed open loop resonator WLAN BPF is presented, using a spurline and quarter-wavelength open-circuited stubs to improve the out of band response. The use of the spurline and quarter-wavelength open-circuited stubs realizes a wide range of spurious response suppression without changing the

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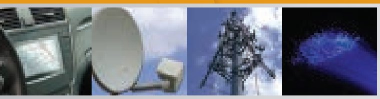

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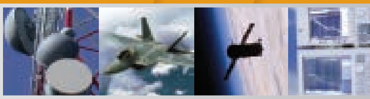

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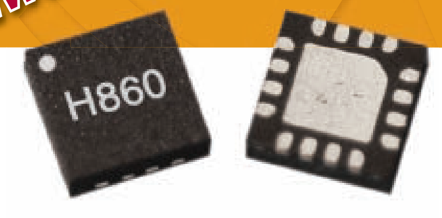

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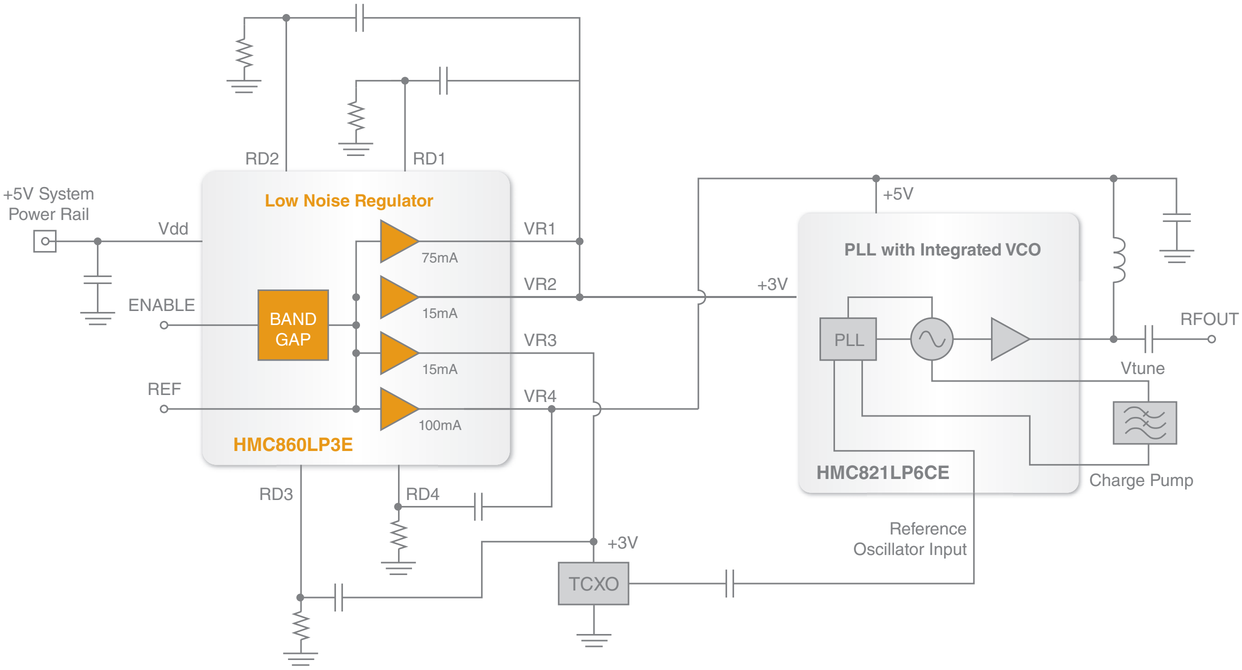

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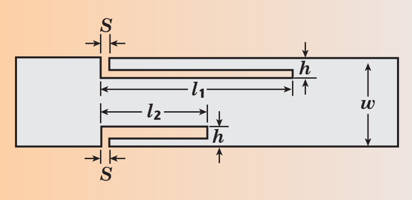
passband performance. By modifying the dimensions of spurline and quarter-wavelength open-circuited stubs, different stopband frequencies are obtained. The proposed 0° feed open loop resonator BPF shows stopband attenuation losses better than 20 dB from 2.6 to 10 GHz and insertion loss as low as 1.05 dB. This BPF is characterized by two attenuation poles, low insertion loss and high out of band rejection.

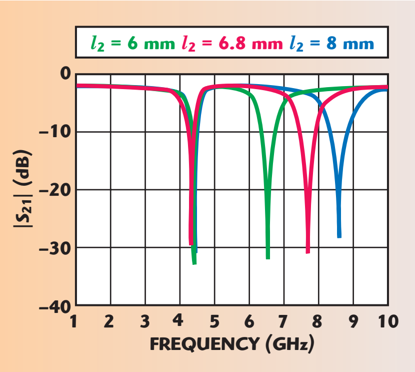
SPURLINE AND QUARTER-WAVELENGTH OPEN-CIRCUITED RESONATORS

Figure 1 shows the configuration of conventional asymmetric spurlines, which are etched on the microstrip transmission line.[10,11] This is different from the DGS, which is located on the ground side. The spurline is etched as an inverted "L" shape slot on the microstrip transmission line. Generally, the spurline dimension parameters include slot width s, slot length l and slot height h, where the slot gap provides a capacitive effect while the narrow microstrip line exhibits an inductive effect.[12,13]

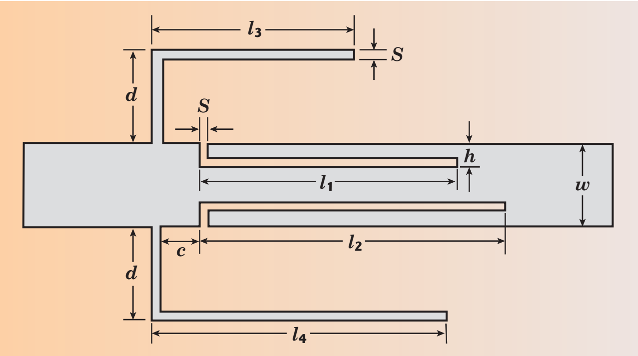
The spurlines are etched on a microstrip line with a width of w = 2.73 mm, which corresponds to a 50 Ω characteristic impedance. The substrate has a relative dielectric constant of 2.65 and a thickness of 1 mm for simulation. The transmission characteristics of the spurlines are simulated using the electromagnetic simulator IE3D. ***Figure 2*** shows the transmission characteristics of the asymmetric spurlines for various l_2. The other dimensions include: s = 0.2 mm, l_1 = 12 mm, h = 0.6 mm and w = 2.73 mm. When l_2 is increased from 6 to 8 mm, the resonant frequency shifts to a lower range, from 8.56 to 6.52 GHz. It is also found that the resonant frequency caused by l_1 changes slightly at 4.3 GHz. It is concluded that the asymmetrical spurlines provide obvious dual-band gap characteristics, with two resonant frequencies, and the resonant frequencies can be controlled by adjusting the length of l_1 and l_2.



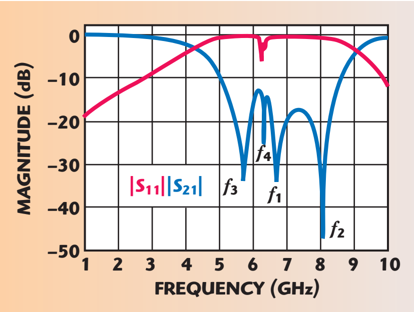
▲ *Fig. 1 Configuration of conventional asymmetric spurlines.*



▲ *Fig. 2 Frequency response of the conventional asymmetric spurlines.*



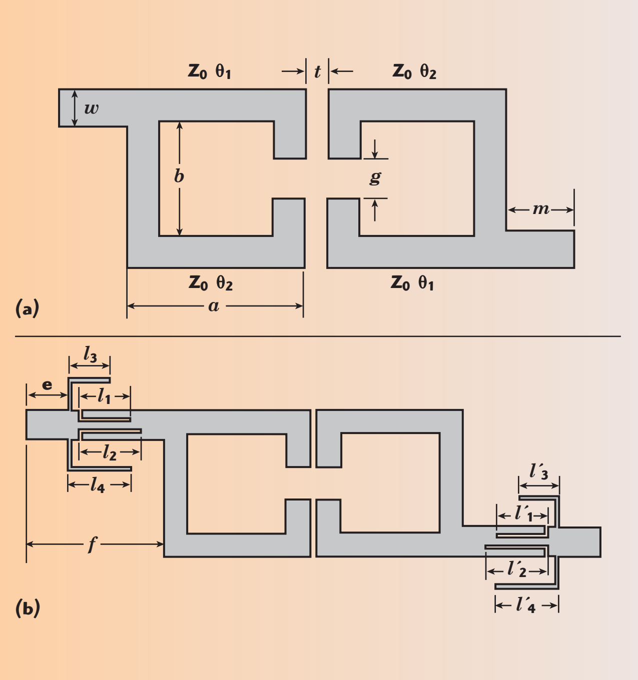
▲ *Fig. 3 The proposed resonator.*



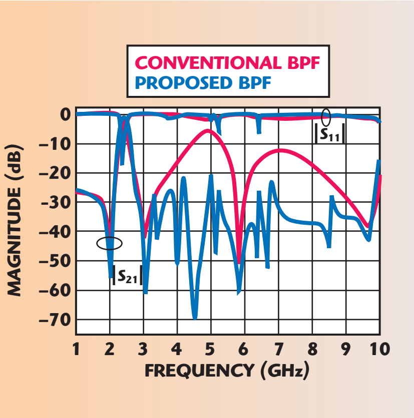
▲ *Fig. 4 Stopband characteristics of the proposed resonator.*

Figure 3 shows the layout of the proposed resonator, which consists of the asymmetric spurlines and two quarter-wavelength open-circuited stubs using a folded shape for compact size. As is known, a quarter-wavelength open-circuited stub has a bandstop property at a finite frequency range, similar to a single spurline. The proposed resonator structure

can generate a wide stopband with four attenuation poles by modifying the dimension parameters l_i, for i = 1, 2, 3, 4. As shown in ***Figure 4***, the resonator has a wide stopband from 5.13 to 8.25 GHz with a return loss lower than 13 dB and has little effect at the low frequency range. The dimensions include: d = 3 mm, s = 0.2 mm, c = 1 mm, h = 1 mm, w = 2.73 mm, l_1 = 8 mm, l_2 = 7 mm, l_3 = 5.8 mm and l_4 = 4 mm. The attenuation poles are generated by the quarter-wavelength open-circuited stubs and spurlines. For the resonator, the resonant frequencies f_1 = 6.65 GHz, f_2 = 8.03 GHz, f_3 = 5.81 GHz and f_4 = 6.38 GHz are corresponding to l_1, l_2, l_3 and l_4. It demonstrates that the proposed resonator could be effectively applied for out of band suppression by controlling the dimensions l_1, according to different spurious responses.



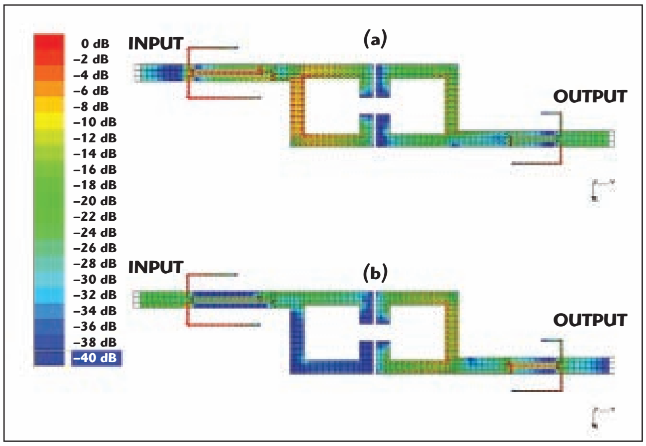
▲ *Fig. 5 Layout of a conventional BPF (a) and of the proposed BPF with spurlines and stubs at the I/O feed lines (b).*



▲ *Fig. 6 Full-wave simulated performance of the conventional BPF and the proposed BPF.*

OPEN-LOOP RESONATOR BANDPASS FILTER

Figure 5 shows the layout of a conventional open-loop resonator filter, which is made up of two square open loop λ/2 resonators with a 0° feed structure. The electric coupling between resonators is used to design the filter with a pair of attenuation poles for sharp skirt. For the 0° feed folded open loop λ/2 BPF, which has a 0° difference between the electric delays of the upper and lower paths, and where θ_1 and θ_2 are the electrical lengths of the upper and lower path, the transmission matrix of the two paths can be expressed as



▲ *Fig. 7 Simulated current distribution of the BPF at the resonant frequency with different input phase: (a) θ = 0° and (b) θ = 90°.*

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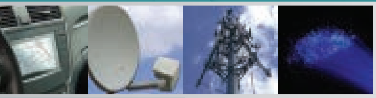

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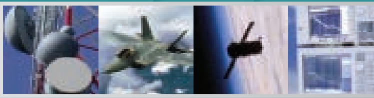

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$$\begin{bmatrix} A_l & B_l \\ C_l & D_l \end{bmatrix} = \begin{bmatrix} \cos(\theta_1+\theta_2)+\dfrac{Y_0\cos\theta_1\cos\theta_2}{\omega C_m} & jZ_0\sin(\theta_1+\theta_2)-j\dfrac{\cos\theta_1\cos\theta_2}{\omega C_m} \\ jY_0\sin(\theta_1+\theta_2)+j\dfrac{Y_0^{\,2}\sin\theta_1\sin\theta_2}{\omega C_m} & \cos(\theta_1+\theta_2)+\dfrac{Y_0\sin\theta_1\sin\theta_2}{\omega C_m} \end{bmatrix} \quad (2)$$

where $Y_0=1/Z_0$, and C_m is the coupling capacitance between the upper and the lower path. According to circuit theory, the transmission matrix of the whole circuit can be written as

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} \dfrac{A_uB_l+A_lB_u}{B_u+B_l} & \dfrac{B_uB_l}{B_u+B_l} \\ \dfrac{\left[A_uB_l+A_lB_u\right]\left[B_uD_l+B_lD_u\right]-(B_u+B_l)2}{(B_u+B_l)B_uB_l} & \dfrac{B_uD_l+B_lD_u}{B_u+B_l} \end{bmatrix} \quad (3)$$

From Equations 1 and 2, it is found that $A_u + A_l = D_u + D_l$, $B_u = B_l$ and $C_u = C_l$. The transmission matrix can be simplified as

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} \dfrac{A_u+A_l}{2} & \dfrac{B_u}{2} \\ \dfrac{(A_u+A_l)^2-4}{2B_u} & \dfrac{A_u+A_l}{2} \end{bmatrix} \quad (4)$$

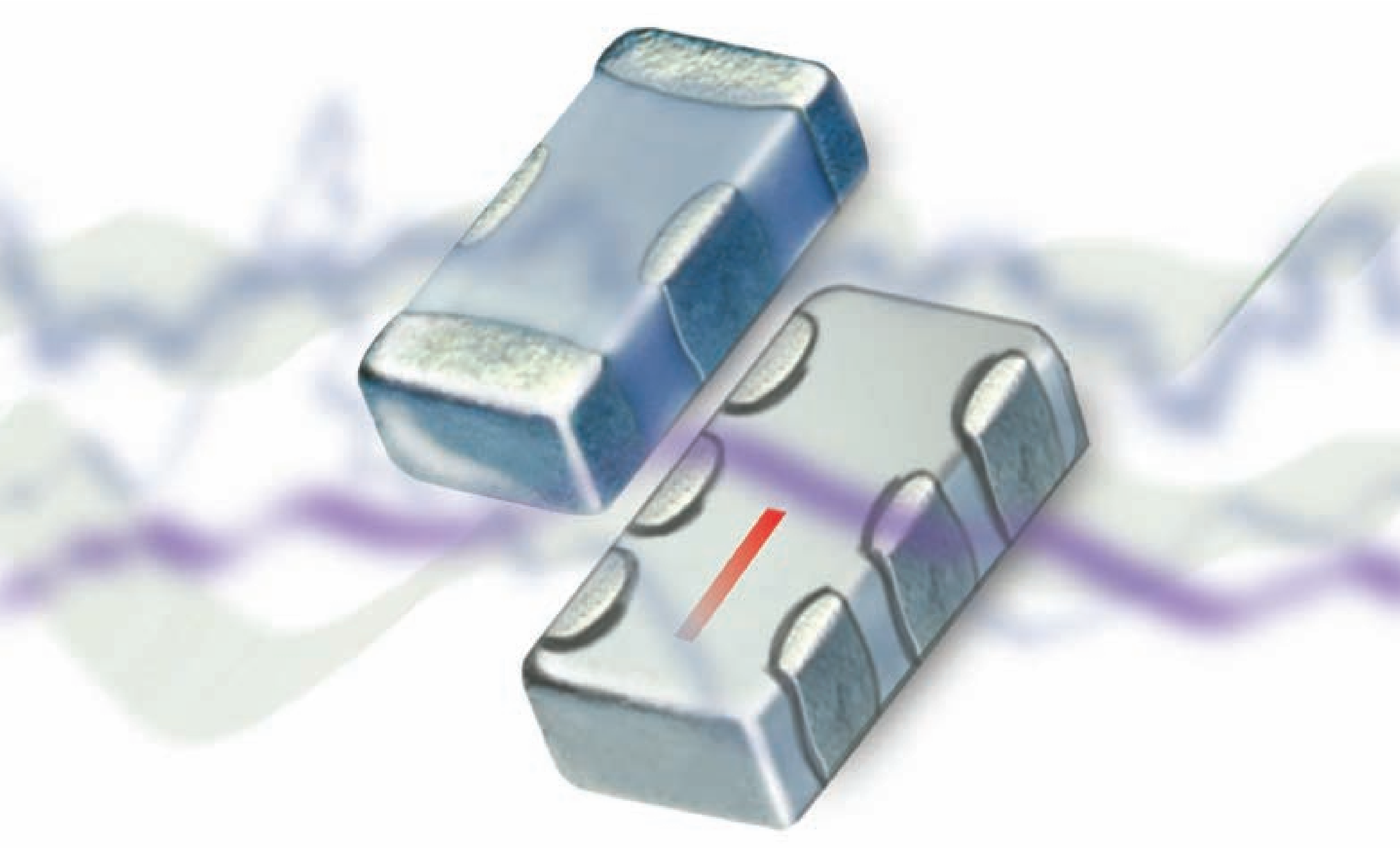
The transmission coefficient is

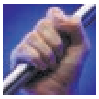
$$S_{21}\ \frac{4B_uZ_l}{B_u^{\,2}+2(A_u+A_l)B_uZ_L+\left[(A_u+A_l)^2-4\right]Z_L^{\,2}} \quad (5)$$

where Z_l is the system impedance. If $S_{21} = 0$, there are attenuation poles existing. This means that the sufficient and necessary conditions for the existence of the poles are the denominator of S_{21} not equal to zero and $B_u = 0$. It is found that

$$\tan\theta_1+\tan\theta_2=\frac{1}{Z_0\omega C_m} \quad (6)$$

Because C_m is usually very small, $1/Z_0\omega C_m$ is considered large enough at certain low frequency range. Generally, it is considered that $\theta_1 \neq \theta_2$ for the external qualify factor. Equation 4 can be simplified as





$$\tan\theta_1 \approx 1/Z_0\omega C_m \quad (7)$$

or

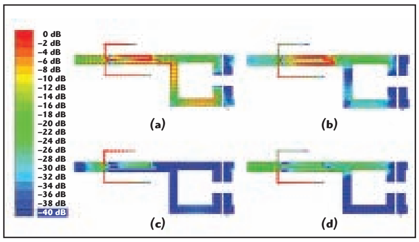
$$\tan\theta_2 \approx 1/Z_0\omega C_m \quad (8)$$

That is to say the attenuation poles occur when the electrical length of the upper and lower path satisfies $\theta_1 \approx \pi/2$ or $\theta_2 \approx \pi/2$. ***Figure 6*** shows the comparison of the frequency responses of the conventional 0° feed folded open loop BPF and the proposed one. The dimensions used include: a = 14 mm, b = 9.5 mm, w = 2.76 mm, m = 15 mm, g = 3 mm, t = 0.6 mm, e = 8 mm, f = 25.7 mm, c = 1 mm, s = 0.2 mm, d = 3.mm, h = 1 mm, l_1 = 11 mm, l_2 = 13.3 mm, l_3 = 8.5 mm, l_4 = 12.5 mm, l'_1 = 7.8 mm, l'_2 = 7.6 mm, l'_3 = 3.5 mm, l'_4 = 8.5 mm, θ_1 = 66.3° and θ_2 = 113.7°. Both filters have the center frequency of 2.44 GHz. The conventional BPF has two spurious passbands at approximately 4.89 and 7.32 GHz. The two resonators at the I/O feed lines are applied for the lower and higher out of band suppression, respectively. The resonator at the input feed line with the longer length of l_i corresponds to the lower range; the other at the output feed lines with shorter length of l'_i corresponds to the higher range. The proposed filter achieves better spurious response suppression below -21 dB. The out of band property is effectively improved by using two harmonic suppression resonators, with their stopband characteristics easily controlled.

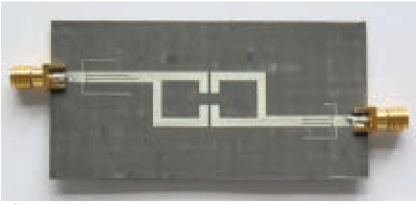
Simulated current distributions of the BPF at resonant frequency are depicted in ***Figure 7***, with different input phase θ. As shown in the figure, the input port of the filter is driven by the current (θ = 0°) while the output port is terminated to 50 Ω microstrip line. High current density distributions (red area) are mainly concentrated at the area where it is distorted by the spurlines. It is similar when the filter is driven by current (θ = 90°). ***Figure 8*** shows the simulated current distributions of the proposed resonator at four frequencies at the input feed line, for (a) l_1 = 11 mm, f_1 = , (b) l_2 = 13.3 mm, f_2 = 4.05 GHz, (c) l_3 = 8.5 mm, f_3 = 5.17 GHz, (d) l_4 = 12.5 mm and f_4 = 3.34 GHz. As mentioned above, the proposed resonator at the input feed line generates a wide stopband with four poles corresponding to asymmetric spurlines and two quarter-wavelength open-circuited stubs. It is clear that a different resonant frequency corresponds to a different stub length or spurline length. The two resonators at the I/O feed lines with their resonant frequencies are shown in ***Table 1.***

EXPERIMENTS AND MEASUREMENT

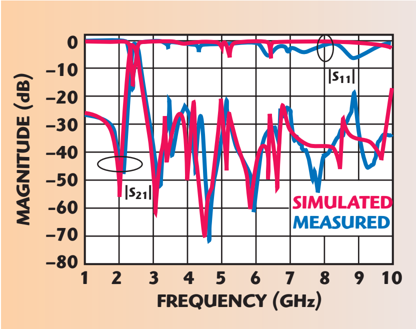
Figure 9 shows the proposed BPF, which consists of two folded open-loop λ/2 resonators with spurlines



▲ *Fig. 8 Simulated current distribution of the proposed resonator at four frequencies at the input feed line.*



▲ *Fig. 9 Photograph of the fabricated open loop BPF with spurlines and stubs.*



▲ *Fig. 10 Comparison between measured and simulated results.*

TABLE I

LENGTH OF RESONATORS AND THEIR RESONANT FREQUENCIES

Length (L_i)	Resonant Frequency	Length (l'_i)	Resonant Frequency
l_1=11 mm	4.39 GHz	l'_1=7.8 mm	6.42 GHz
l_2=13.3 mm	4.05 GHz	l'_2=7.6 mm	6.51 GHz
l_3=8.5 mm	5.17 GHz	l'_3=3.5 mm	8.45 GHz
l_4=12.5 mm	3.34 GHz	l'_4=8.5 mm	5.17 GHz

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

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and quarter-wavelength open-circuited stubs at the feed lines for harmonics suppression. It is fabricated on a Teflon substrate, which has a relative dielectric constant of 2.65 and a thickness of 1 mm. The measurements are carried out on Agilent Vector Network Analyzer N5230A. The simulated and measured results are shown together in ***Figure 10***. The center frequency of the BPF is 2.44 GHz and its 3 dB bandwidth covers 112 MHz. The filter has a wide stopband with attenuation of 20 dB up to 10 GHz, using two additional harmonics suppression resonators. Its insertion loss is as low as 1.05 dB. It is obvious that the measured results are in good agreement with the simulation.

CONCLUSION

A novel open-loop BPF with a wide stopband for WLAN is presented in this article. Its spurious responses are effectively suppressed by adding two resonators, which are composed of asymmetrical spurlines and quarter-wavelength open-circuited stubs. Employing the harmonics suppression resonators, its stopband is controllable by adjusting the dimension parameters of two resonators. The BPF has an out of band attenuation better than 20 dB from 2.6 to 10 GHz. The measurement results have shown good agreement with the simulated results. It is believed that this newly proposed BPF can be used in WLAN systems. ■

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AN OVERLOOKED CLASS OF N-WAY POWER DIVIDERS COMBINING RESISTIVE AND REACTIVE DIVIDERS

An overlooked class of in-phase, equal power split, N-way power dividers combines resistive and reactive dividers. This "partial resistive divider" (PRD) has a series input transformer similar to reactive dividers and series resistors at the output ports similar to resistive dividers. In appropriate circumstances, it has significant advantages over not only the resistive and reactive dividers, but also over Wilkinson dividers. Design equations and theoretical and measured performance values are presented.

The "partial resistive divider" (PRD) is often overlooked when selecting a power divider circuit. This article compares its attributes with those of resistive, reactive and Wilkinson divider circuits. ***Figure 1*** shows the basic resistive, reactive, partial resistive divider (PRD) and Wilkinson divider circuits. There are 1 through N equal output branches.

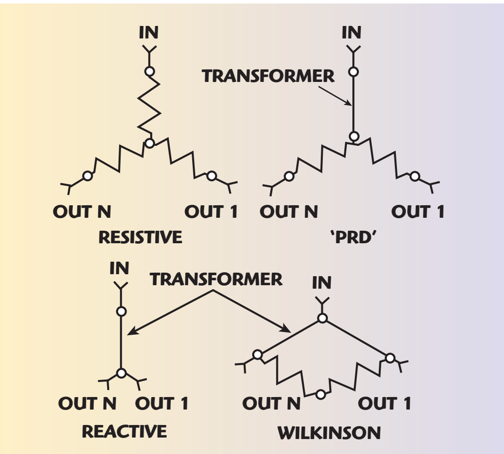


Fig. 1 Families of equal power dividers.

PROS AND CONS OF THE APPROACHES

Resistive dividers offer minimum size and a perfect match without transformers. The tradeoffs are a path loss twice the split loss, isolation only twice the split loss, a low (1 to 100 mw) input power limit, and only an equal power split.

The PRD match is limited only by the input transformer, which has an impedance ratio of approximately half the number of outputs. The path loss is less than 3 dB more than the split loss. Isolation is twice the path loss and up to 6 dB better than the resistive and reactive divider isolation. The input power handling is more than twice that of the resistive divider, but less than the reactive and Wilkinson circuits. As with the resistive divider, it is limited to equal power divisions.

HARRY CHAPELL
Retired Professional Engineer

The reactive divider input power is limited only by the transmission lines; the output power split can be unequal. Its input match is limited only by the input transformer, but that has an impedance transformation twice that of the PRD. Its output VSWR is almost twice the number of outputs. Also, a failure at one of the output loads can short out all the outputs.

The Wilkinson input match has the same impedance transformation as the reactive divider. The input power can be large, but will be limited if the output loads are not perfect. The output powers can be unequal. The output match and isolation can be very good. Wide bandwidth with multiple outputs or unequal output powers is very difficult in an individual unit. Cascading units to obtain multiple outputs adds to path losses and match problems.

RESISTIVE, PRD AND REACTIVE DIVIDER DESIGN AND PERFORMANCE

The values in *Table 1* assume perfect transformers and resistors. The input and output impedances are assumed to be equal (Zo). The values obtained from Table 1 can be used to design a PRD for any number of outputs. *Figure 2* shows the path losses and isolation for the three different power dividers. A narrow band and a wide band application are described below.

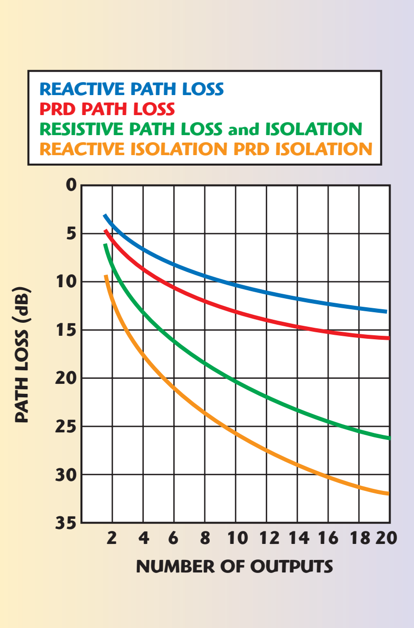
TABLE I

N-WAY DIVIDER PARAMETERS

Type	Resistive	PRD	Reactive
Path Loss (dB)	-20Log(N)	-10Log(2N-1)	-10Log(N)
Isolation (dB)	-20Log(N)	-20Log(2N-1)	-20Log(N)
Output VSWR	1.0	1.0	2N-1
Transformer Z ratio	1.0	$N^2/(2N-1)$	N
Series R (ohm)	Zo(N-1)/(N+1)	Zo(N-1)/N	None

NARROW BAND 22-WAY L-BAND PRD

This unit was prototyped for possible use in Iridium communications satellites. The path loss (27 dB) of a resistive divider would be excessive. The high output VSWR (43:1) of a reactive divider ruled it out. (Adding circulators to a reactive divider would add complexity and weight.) A cascaded Wilkinson divider would be much more complex. A single-stage, 22-way



▲ *Fig. 2 Path loss and isolation values for different power dividers.*

▲ *Fig. 3 Photograph of a 22-way PRD.*

TABLE II
22-WAY POWER DIVIDER PERFORMANCE

Parameter	Frequency GHz	Measured	Theory
Input VSWR	1.7	1.08	1.0
Output VSWR	0.1 to 4	1.18 max	1.04
Path loss (dB)	1.7	16.8 max	16.3
Unbalance (dB)	1.7	0.2 max	0
Isolation (dB)	1.7	31 to 33	32.7
Isolation (dB)	0.1 to 4	28 min	--

TABLE III
SPECIFICATIONS FOR A BROADBAND 8-WAY PRD

Parameter	Specification		Units
Frequency	475-7700	7700-8050	MHz
Input VSWR	1.8:1	1.8:1	Max
Output VSWR	2:1	2:1	Max
Path Loss	13.5	14.0	dB Max
Ripple	1.4	2.2	dB Max
Unbalance	1.4	1.6	dB Max
Isolation	18	18	dB Min

Wilkinson divider would not be practical. Cascaded unequal power split Wilkinson dividers would be complex, large and lossy.

The PRD unit is pictured in ***Figure 3***. This unit uses an axial quarter wavelength coaxial input transformer. The prototype body size was determined by the minimum clearances required between the SMA output connectors. In the final system configuration, with direct soldered output pins, the diameter would be much smaller. The as-built test results are summarized in ***Table 2***. Note the broadband isolation and output VSWR. Although it met expectations, the unit was not used in production because the customer changed the requirement to an unequal output power split. This is one of the limitations of the simple PRD approach. All output powers are equal and in-phase.

BROADBAND (475 TO 8050 MHZ) 8-WAY PRD

This unit is an 8-way partial resistor divider, which covers the frequency range from 475 to 8050 MHz. Resistor dividers were a real possibility, but would have had an unacceptably high (approximately 20 dB, including circuit loss) path loss.

A reactive divider would have a longer transformer and high output VSWR (15:1). Three stages of cascaded 2-way Wilkinson dividers would be larger with high path loss. This unit

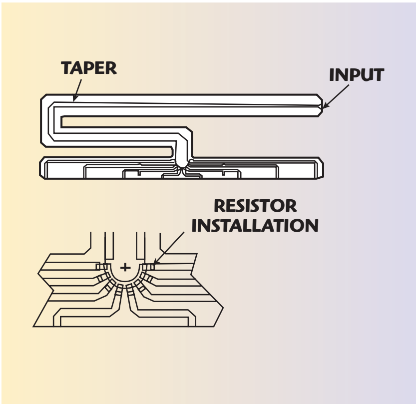


Fig. 4 Eight-way PRD.

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IN-PHASE N-WAY DIVIDER SELECTION

1. Select a reactive divider when:
- High (2N-1) output VSWR and inferior (-20Log(N)dB) isolation are acceptable
- Arbitrary power division, or minimum (-10Log(N)dB) path loss (or high power handling is required)

2. Select a resistive divider when:
- Reactive divider VSWR is unacceptable
- Higher (-20Log(N)dB) path loss and inferior (-20Log(N)dB) isolation are acceptable
- Ultra broad bandwidth (from DC) or minimum size is required

3. Select a partial resistive divider when:
- Reactive and resistive dividers will not meet requirements
- Moderate (-10Log(2N-1)dB) path loss and (-20Log(2N-1)dB) isolation are acceptable

4. Select cascaded Wilkinson dividers when:
- Need more isolation or less path loss than resistive and PRD dividers provide; or need an unequal power division
- Need more isolation or lower VSWR than reactive dividers provide
- Bandwidth can be met without losing path loss advantage (~3 dB) over PRD

shows both the PRD design capability and some of its shortcomings. The input transformer is a 3/8 wavelength at 475 MHz Klopfenstein microstrip tapered line. The taper includes two mitered 90 degree bends. A copper alloy block on top of the microstrip at the split point spreads the resistor heat over a larger area.

Although unrelated to the divider design, the blind mate OSP connector design may be of interest. The "shells" are machined into the body, thus eliminating another build up of true position error, which separate shells would introduce. ***Figure 4*** shows the resistor's installation in the 8-way PRD.

The unit performance shows the effect of finite element size and circuit losses. The insertion loss increases up to 2.2 dB with frequency. The longer path length to end ports introduces up to 1.6 dB output amplitude unbalance at high frequencies. The isolation rolls off to 18 to 19 dB at 8050 MHz (compared to 23 dB theoretical isolation with ideal elements). The production specifications are shown in ***Table 3***.

CONCLUSION

The design of partial resistor dividers is straightforward using available equations. They can use either lumped element or distributed element input transformers. Measured results show that the partial resistor divider is a useful in-phase, equal power split, design approach. ■

Harry F. Chapell *received his BS degree in Physics from Worcester Polytechnic Institute in 1954. From 1954 to 1955 he was a member of the technical staff at Bell Telephone Laboratories. He developed high power crossed field oscillators and amplifiers at Raytheon Power Division from 1955 to 1963. He advanced to Vice President of Research and Development at Sage Laboratories while developing passive microwave devices over the period from 1963 until his retirement in 1996.*

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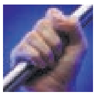

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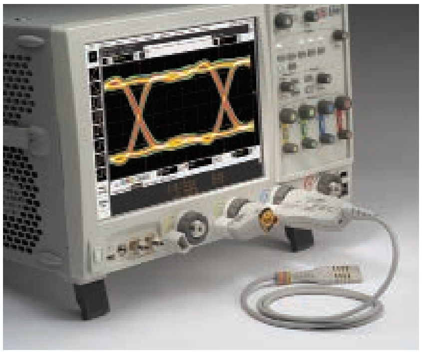

▲ *Fig. 1 The industry's first 30 GHz probing system.*

The Infiniium 90000 X-Series is the first Agilent equipment to take advantage of a new transistor technology developed internally by Agilent using Indium Phosphide (InP) double hetero-junction bipolar transistor (DHBT) technology. The InP technology extends the capabilities of well established InGaP/GaAs HBT IC technology, enabling oscilloscope performance up to 32 GHz without sacrificing the reliability and manufacturability associated with GaAs bipolar devices. The InP-based process provides cut-off frequency to 200 GHz. While InP is rarely mass produced as it is difficult to achieve excellent economies of scale, it is ideal for test and measurement equipment, which need thousands of chips as opposed to millions.

In addition to the InP-based process, the company achieved the unprecedented performance using proprietary advanced thick film microcircuit processes and design techniques, known internally as Quick Film 3D Microcircuits. Unlike traditional thick film dielectrics, the Quick Film dielectrics are characterized by very good broadband electrical properties that are stable through microwave frequencies. These microcircuits are used to package the 90000 X-Series and InfiniiMax III InP chipsets and optimize their outstanding pulse fidelity, low jitter and flat broadband response. Using the quick film technology, Agilent has developed its new multi chip module (MCM). This

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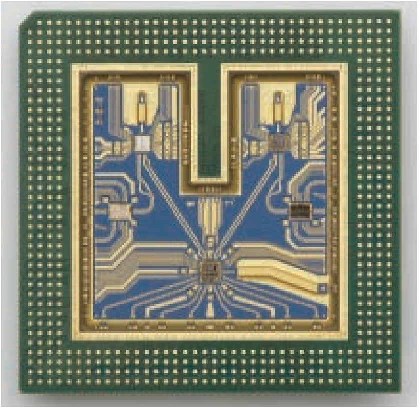

▲ *Fig. 2 Front-end module for Infiniium 90000 X-Series.*

MCM houses five newly developed InP-based chips (see ***Figure 2***) including a new pre-amplifier (rated to the full 32 GHz) and the fastest edge trigger at > 20 GHz. A "lid" is then placed on the MCM to shield the circuit and ensure high signal integrity.

Comparing the 90000 X-Series oscilloscope with its predecessor, the 90000A Series oscilloscope, the 90000 X-Series features significantly lower noise, ½ the jitter measurement floor, and two and ½ times the true analog bandwidth. The 90000 X-Series features a pre-amplifier bandwidth of 32 GHz, resulting in true analog bandwidth performance to the full 32 GHz. This compares to other products that only achieve 16 GHz of pre-amplifier performance, meaning the 90000 X-Series has double the analog performance, avoiding techniques such as digital signal processing (DSP) boosting or frequency interleaving to achieve > 16 GHz bandwidth. While these techniques allow for higher bandwidth, they cause tradeoffs that designers may not want. DSP boosting causes nearly a doubling of oscilloscope noise density. Frequency interleaving can cause significant harmonic distortion and increasing of noise density over the analog hardware performance. The 90000 X-Series, with its true analog bandwidth to 32 GHz, results in significantly less noise and none of the tradeoffs associated with other technologies used to increase bandwitdth.

In addition to the low noise, the 90000 X-Series has a sample clock jitter that is less than 150 fs, which combined with its low noise floor, means a jitter measurement floor (the actual jitter measured) of less than 150 fs. In comparing similar bandwidths from other comparable oscilloscopes, this is as much as 1/10th the jitter measurement floor.

In addition to being targeted at fast serial busses, the 90000 X-Series is also targeted at satellite and radar communications. The bandwidth allows one to directly digitize signals in the L-, S-, C-, X-, Ku-, Ka-, K- and low Q-band. This means the ability to directly digitize signals from 1 to 32 GHz, avoiding the need to down convert and add unnecessary noise. The 90000 X-Series will also come standard with "tune and zoom" software, allowing for locking on a carrier frequency and re-sampling the interesting content around the frequency of interest. This provides industry leading speed on its FFTs. The low noise down, which can be tuned to 7 mV/div in hardware and 1 mV/div through software expansion, provides details on signals at high frequencies that previously would be buried in oscilloscope noise. The 90000 X-Series can also be combined with Agilent's 89600 Vector Signal Analyzer software, making it possible to easily look at constellation diagrams and diagnose complex modulation. The 90000 X-Series provides segmented memory, which is ideal for radar applications, enabling it to only capture the needed signal at a very fast capture rate. In segmented mode, the 90000 X-Series can provide up to 4 Gpts of deep memory. Finally, the 90000 X-Series provides higher effective bits at higher frequencies (currently > 6 effective bits at > 15 GHz) than any other real time oscilloscope.

The 90000 X-Series is the fastest real time oscilloscope available today. Its world class hardware makes it possible to see details that are buried in other oscilloscope's noise. The scope is ideal for many technologies including high speed serial busses, high end physics, satellite and radar communications. The performance reduces oscilloscope noise caused by tradeoffs found in other oscilloscopes.

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NOVEL GAN TECHNOLOGY ENHANCES S-BAND RADAR PERFORMANCE

The current trend in the growing S-band market demands wider bandwidths, higher power levels and wider pulses, which are best served with a new technology to satisfy these advanced requirements. AlGaN/GaN HEMT on silicon substrate technology is a viable alternative to traditional technologies for high power transistors used in pulsed applications because of the lower thermal stress of pulsed operation compared to CW. The IGN2731M25 from Integra Technologies Inc. is the first in a series of devices designed for RF, pulsed power for S-band radar applications using GaN on a silicon substrate.

▲ *Fig. 1 IGN2731M25 produces over 25 W from 2.7 to 3.1 GHz (32 V, 300 μs and 10% duty cycle).*

The IGN2731M25 utilizes a 6 mm GaN HEMT chip on silicon substrate and is housed in an industry standard single-ended package (see ***Figure 1***). The device has 50 μm gate-gate spacing and 100 μm gate finger length. Source pads are outside of the active area and connected to each source metal region by a dielectric overlay, i.e. no air bridge technology has been used. The semiconductor chips are 4 mils thick after wafer thinning, resulting in excellent thermal performance.

RF characterization of the IGN2731M25 device was conducted with approximately 5 mA/mm of forward bias current and 32 V of drain bias. The device was characterized with pulsed input signal conditions with a 300 μs pulse width and 10 percent duty cycle. The device electrical characterization of the AlGaN/GaN HEMT is shown in ***Figure 2***. The power drive-up curve shows output power performance exceeding 4 W/mm across the frequency band of operation between 2.7 and 3.1 GHz while exhibiting more than 50 percent efficiency in this range.

The input return loss performance across power level and over frequency is shown in ***Figure 3***. An input matching network has been implemented using a silicon MOSCAP and the inductance of the bond wires under the lid of the package. The device also has good isolation and is very stable with a 3:1 VSWR on the load.

Output power droop is a critical measurement parameter for system level performance. ***Figure***

INTEGRA TECHNOLOGIES INC.
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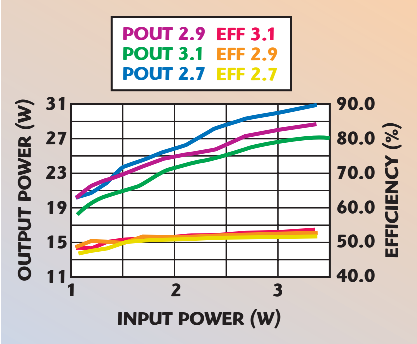
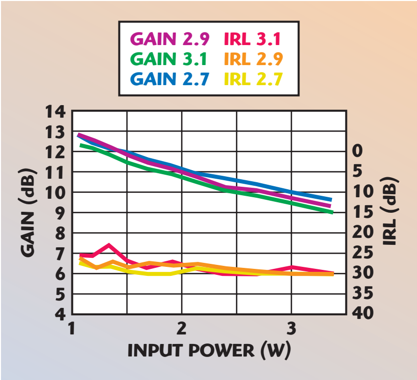
4 demonstrates the power droop from 2.7 to 3.1 GHz, which exhibits almost no droop, i.e. less than 0.25 dB even when the devices are saturated. Since power droop is typically attributed to heating, the demonstrated droop performance is another testament to the thermal performance of the GaN on silicon device geometry design.

Existing GaN on silicon technology operates at 28 V, whereas GaN on SiC is available at both 28 and 50 V. Clearly 50 V operation with its higher power density capability is a much desired feature in the high power S-band radar market. The GaN HEMT technology processed on silicon versus the more expensive substrate material is attractive both from a current cost basis standpoint and the possibility of manufacturing on larger wafers.

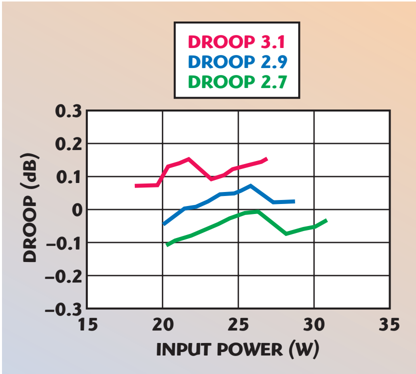
GaN on silicon technology for operation at 28 V is already standard; however, a robust AlGaN/GaN HEMT technology for operation at 50 V has not yet reached the market. The GaN HEMT process flow described earlier has been modified to include a major feature that improves RF performance in the S-band region: A gate connected field plate to improve breakdown and, therefore, operation at higher voltage. Although 50 V GaN on SiC solutions for S-band are available in the marketplace from several vendors, this device is the first GaN silicon technology operating at 50 V. This enhancement can be accomplished by using a dielectrically defined gate resulting in breakdowns well above 100 V and allowing 50 V operation. The higher operating voltage accounts for higher performance, as seen in **Figure 5,** where at a fixed input power of 3 W the device



▲ *Fig. 2 Output power and efficiency vs. input power for IGN2731M25.*

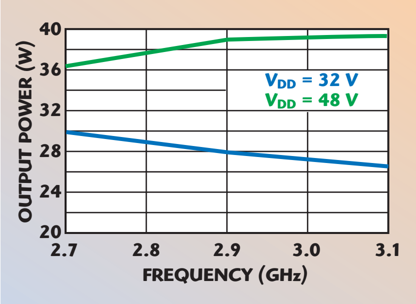


▲ *Fig. 3 Gain and input return loss vs. input power for IGN2731M25.*



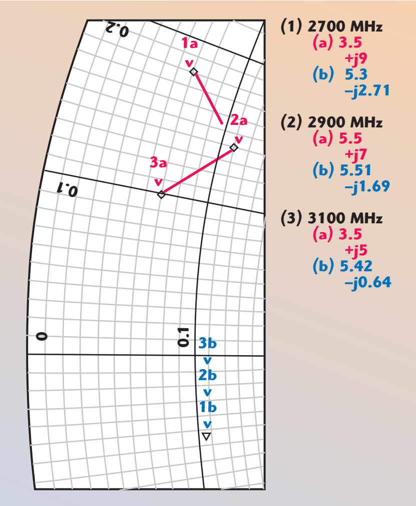
▲ *Fig. 4 Power droop vs. output power for IGN2731M25.*

produces another 30 percent more power across the operating frequency band. ***Table 1*** demonstrates how the gain parameter improves by more than 1 dB and gain flatness is negligible measuring 0.1 dB over 400 MHz from 2.7 to 3.1 GHz.



▲ *Fig. 5 Output power vs. frequency at V_{DD} = 32 and 48 V for IGN2731M25.*

GaN HEMT technology has excellent power density and thus small parasitic die capacitance resulting in higher impedances for the designer to work with. The single stage input match results in more than 3 ohms of real impedance while the unmatched output stage has 5 ohms of real impedance, which contributes to the improved bandwidth response of the transistor (see ***Figure 6***). The higher impedance facilitates the matching networks at the PCB level in a 50 ohm system.



▲ *Fig. 6 Impedance vs. frequency for IGN2731M25.*

TABLE I

GAIN FLATNESS OVER FREQUENCY AT VARIOUS VOLTAGE BIAS CONDITIONS FOR IGN2731M25

	Frequency		
VDD(V)	**2.7**	**2.9**	**3.1**
32	12.8 dB	12.8 dB	12.3 dB
48	13.7 dB	13.8 dB	13.7 dB

Although this first generation technology demonstrates high performance, the GaN roadmap includes future designs with shorter gate lengths resulting in better frequency response and improved gain. The next generation targets 0.5 µm gate length, which is expected to have performance suitable for C-band applications.

The advantages of GaN technology serving several pulsed applications with small, high impedance, and reliable products addressing the radar and avionic bands are clear. As market demand grows and requires a new technology with higher voltages and broader bandwidths, additional RF power transistors will be developed that will continue to reduce system size, weight and cost leading to a host of new applications that can be served.

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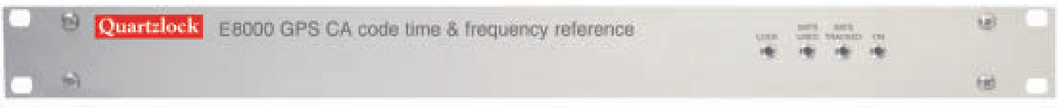

The Quartzlock E8000 represents a breakthrough in low cost, 1U rack-mount, traceable, calibration-free 'off air' frequency and time standards. It is a GPS controlled frequency and timing source, with both 10 MHz frequency output and 1 PPS timing mark synchronized to GPS time. Features include a holdover function on both the timing (1 PPS) and the frequency output. The module may be configured with a variety of controlled oscillators, from low cost OCXOs to rubidium standards, with the short-term stability (Allan variance) and holdover performance being a function of the controlled oscillator. The 10 MHz output phase noise specification is -110 dBc/Hz at 1 Hz offset.

GPS RECEIVER

A key component of the E8000 is a special GPS receiver module, which has enhanced performance for timing applications. This is significant as the choice of GPS receiver is vital in the design of a GPS controlled frequency/ time standard. All GPS receivers make a calculation of GPS time every update interval, often one second. However, methods of using this information, and communicating it to the outside world, vary.

The GPS receiver chosen for the E8000 has a programmable frequency output. This is a square wave generated from an NCO (a simple version of a DDS without the DAC) clocked from the internal 120 MHz clock. Every occasion that the time solution is calculated, the phase of the NCO is adjusted so that the frequency output is accurate. This frequency output means that a phase lock loop can be used to lock the controlled oscillator to GPS time.

TIME SOLUTION ACCURACY

A further consideration in the choice of GPS receiver is the accuracy of the time solution. A conventional navigation receiver will have a typical variation in its timing calculation of 0.5

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to 2 µs RMS. This is a random variation caused by noise and ionospheric effects. There will also be a systematic longer term (minutes to hours) variation due to the satellite constellation continuously changing.

A navigation receiver needs at least four satellites to calculate a 3D position and time. More satellites will add redundancy, and will thus reduce errors in the position and time calculation. A special timing receiver assumes that the receiver is stationary; therefore, the position does not change. The pseudo range measurement from each satellite is only used to calculate the time, giving greater redundancy and less jitter.

If the position is not correct, then the 1 PPS time output will have a systematic error. In order to avoid this, a timing receiver will have a self-survey mode where the position is calculated and averaged continuously for several minutes. After the self-survey is complete, the receiver switches into position hold mode.

A timing receiver operating in position hold mode will have an RMS jitter on the GPS time calculation of between 5 and 50 ns RMS. The GPS receiver chosen for Quartzlock designs, including the E8000, has a measured RMS jitter on the outputs of about 7 ns.

HOLDOVER MODE

A GPS receiver used for timing applications will often have a built in monitor of the likely timing accuracy. The algorithm used was developed by Motorola, and is called the Time-Receiver Autonomous Integrity Monitoring (TRAIM) algorithm. If the predicted error in the time calculation increases above a threshold, default 300 ns, the GPS receiver will go into holdover mode. In this mode the 1 PPS output time is held, and the frequency output is locked at its current frequency. The GPS receiver will also set its digital output to indicate that the receiver is in holdover. The microcontroller can then freeze the tuning voltage of the controlled oscillator, putting this into holdover mode.

The drawback with this simple design is that the GPS receiver uses a low quality internal TCXO for its internal clock. When the GPS receiver goes into holdover, it freezes the output time of the 1 PPS. However, as the 1 PPS is timed internally from the TCXO, it will drift and will not give very good holdover performance. What is required is a 1 PPS time pulse that is timed from the controlled oscillator. In this way the holdover performance of the 1 PPS will be identical to that of the controlled oscillator.

If the controlled oscillator is a rubidium standard (E8010), then the holdover performance will be 1 µs a day. The solution is to use the GPS receiver in external clock mode. If this is done when the GPS receiver goes into holdover, the 1 PPS timing will come from the controlled oscillator.

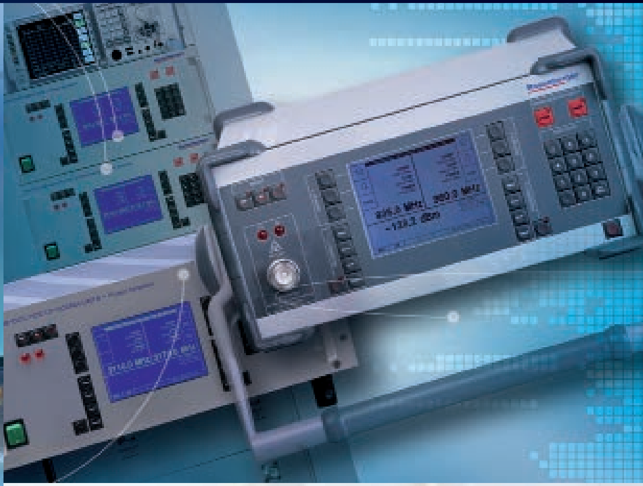
LOCKING CIRCUIT

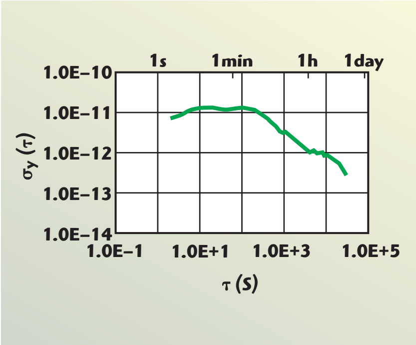
The hardware and software used to lock the controlled oscillator to GPS time is a classic PLL implemented digitally using a microcontroller. The frequency output from the GPS receiver is set to 2.5 MHz. This is then compared with divided outputs, also at 2.5 MHz, from the controlled oscillator using a quadrature phase detector. The microcontroller then samples the outputs from the phase detectors and implements the PLL.

This PLL is slightly unusual in that the controlled oscillator has an effect on both inputs of the phase detector. On one input the controlled oscillator is divided down to 2.5 MHz and is applied directly to the phase detector. On the other input the 2.5 MHz comes from the GPS receiver, which is clocked from the controlled oscillator multiplied to 20 MHz. The effect of the GPS lock may be considered as a variable divider, which sets the frequency output to 2.5 MHz regardless of the frequency of the controlled oscillator.

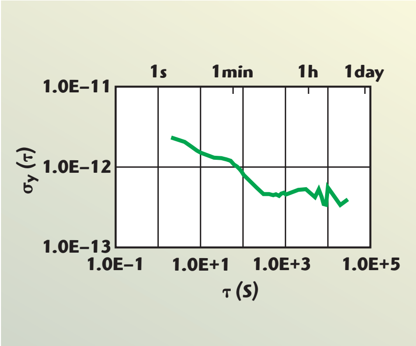
However, there will be regular phase adjustments. These occur because the binary NCO in the GPS receiver cannot divide by the exact decimal divider required to generate 2.5 from 120 MHz (the GPS receiver internal clock). These regular phase adjustments are filtered out by the narrow bandwidth of the digital PLL.

A further effect is that the response of the GPS receiver to a change in frequency of its clock is not instantaneous. There is a delay between a shift in clock frequency and the restoration of the frequency output to its nomi-





▲ *Fig. 1 E8000 with high quality OCXO, reference passive H maser.*



▲ *Fig. 2 E8000 with rubidium, reference passive H maser.*

nal value. The effect of this delay is to add a further time constant to the PLL loop filter. This unavoidable extra filter means that PLL bandwidths cannot be too wide without loop instability developing.

SWITCH-ON SEQUENCE

For the E8000, the time from switch-on to the frequency standard becoming useable is a function of many things. These include the GPS receiver cold start, self-survey time, reference oscillator warm-up, and PLL locking and stabilization time. Sometimes a switch-on will follow a change in position of the receiver, but more often the position will remain unchanged. In spite of this, for design and user simplicity, it is assumed that the receiver has moved after every switch-on. Thus, the GPS receiver will carry out its self-survey after every switch-on. This takes about 15 minutes.

Most controlled oscillators are very far from their final frequency during warm-up. An OCXO may be 10 ppm in error, and a rubidium will sweep its OCXO during warm-up in order to find the atomic resonance. The GPS receiver will not operate properly if its external clock is not stable to within 1 ppm. For this reason the GPS receiver is held in reset until the controlled oscillator has warmed up.

At this point the PLL is activated and starts locking. As the tuning voltage for the controlled oscillator is stored in EEPROM from the last time the PLL was in lock, the frequency error at the phase detector should be very small. However, there may be an initial phase error of up to 2π radians. This applies when the phase/frequency detector is in use, which it is during initial locking. Correction of the initial phase error can only be made by offsetting the frequency of the controlled oscillator. This is quite normal for any PLL. In order to minimize the phase pull in time the PLL bandwidth is set to a maximum during locking.

MEASURED PERFORMANCE

The E8000 has been tested with a variety of controlled oscillators. For all the tests the GPS antenna was on a flat roof with an unobstructed view of the sky. The Allan variances (AVAR) can be seen in ***Figures 1*** (OCXO) and ***2*** (rubidium). With a rubidium oscillator, the measured Allan variance was below 1×10^{-12} at averaging times longer than 100 seconds, with a floor of about 4×10^{-13}. With a high quality OCXO the Allan variance was about 1×10^{-11} between two seconds and 100 seconds, and fell to less than 1×10^{-2} at 10,000 seconds.

CONCLUSION

The E8000 now has a standard performance level of -110 dBc/Hz at 1 Hz offset for phase noise and a short-term stability of 8×10^{-13}/s. Optional -115 dBc/Hz at 1 Hz offset and AVAR of 6×10^{-13}/s are also available. This performance and choice in a low cost GPS time and frequency reference is a major breakthrough. The E8000 has full NTP server plus separate RS232 for GPS View/WinOncore 12.

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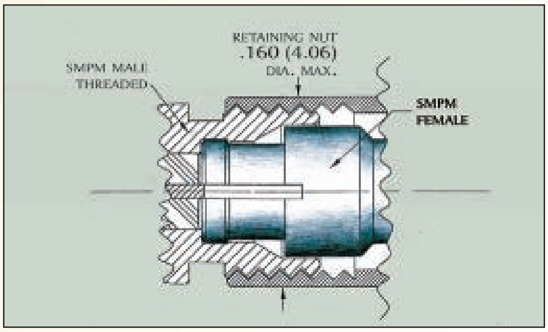

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(Continued from page 28)

market entries, such as Javelin Semiconductor, Black Sand Technologies and RFaxis, are preparing for battle with replacement parts to GaAs front-end modules and will probably see some Si solutions start to challenge the GaAs dominance in this market. Most of the designs from these players include single chip Si solutions for applications such as handset front-ends, WiFi, Bluetooth and ZigBee. For the high volume handset front-end market today, however, GaAs is still the preferred technology and offers the best performance, proven reliability and fastest time to market. The emerging Wireless HD technologies for using short-range millimeter-wave technologies (typically 60 GHz) are single chip Si technologies as their range is limited so power levels are adequate from Si solutions (SiBeam and several of the large consumer electronics companies are involved in this technology). In addition, the millimeter-wave automotive radar systems are migrating to highly integrated SiGe solutions to meet the cost constraints to bring this technology into mainstream cars (Autoliv—formerly M/A-COM, Infineon, etc.).

GaN is being inserted into future high power military radar and communications systems so it will displace GaAs to some extent in those applications, but the design cycles are long and it will take a while for this to take effect. Although most of the GaN work is being done on power devices, expect to see some GaN LNA/switch MMICs being designed to take advantage of its low noise advantages and high breakdown voltages so limiters could be eliminated improving overall performance in the receive chain. GaN is just starting to prove its worth in cellular infrastructure applications, but will also have to fight with Si LDMOS for high power solutions.

The integration technologies of GaAs have improved with the recent BiHEMT processes to enable higher performance single die solutions for applications such as Wi-Fi and bias circuitry in handsets, so GaAs is not standing still. GaAs foundries are also reducing costs with optical lithography for smaller dimensions and continued cost efficiencies. With expected CAGR growth of 6 percent over the next five years, the GaAs market still has some legs in it and should for the next several years as it battles Si and GaN with both hands. Over this time period, however, Si and GaN technologies will take away noticeable market share in select markets such as short-range millimeter-wave and high power military applications. ■

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Hittite Launches Two Low Cost, Highly Flexible RMS Power Detectors

Hittite Microwave has launched two new low cost, highly flexible RMS power detectors for RF power measurement/control in Cellular/3G, LTE/WiMAX/4G, broadband, test equipment and military applications between DC and 5.8 GHz. Ideal for the measurement of complex modulated waveforms with large, dynamically changing crest factors, the HMC1010LP4E RMS Power Detector provides 60 dB of dynamic range, a nominal logarithmic slope of 37 mV/dB and a nominal intercept of -68 dBm. The HMC1010LP4E exhibits superior detection accuracy of ±1 dB compared with any RMS detector in the market for a price point of only $1.99 at 10,000 piece volumes. It exhibits less than 0.1 dB modulation error at 900, 1900 and 2200 MHz.

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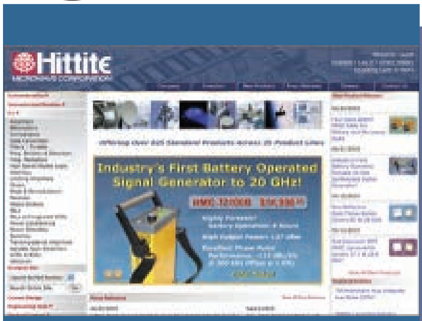

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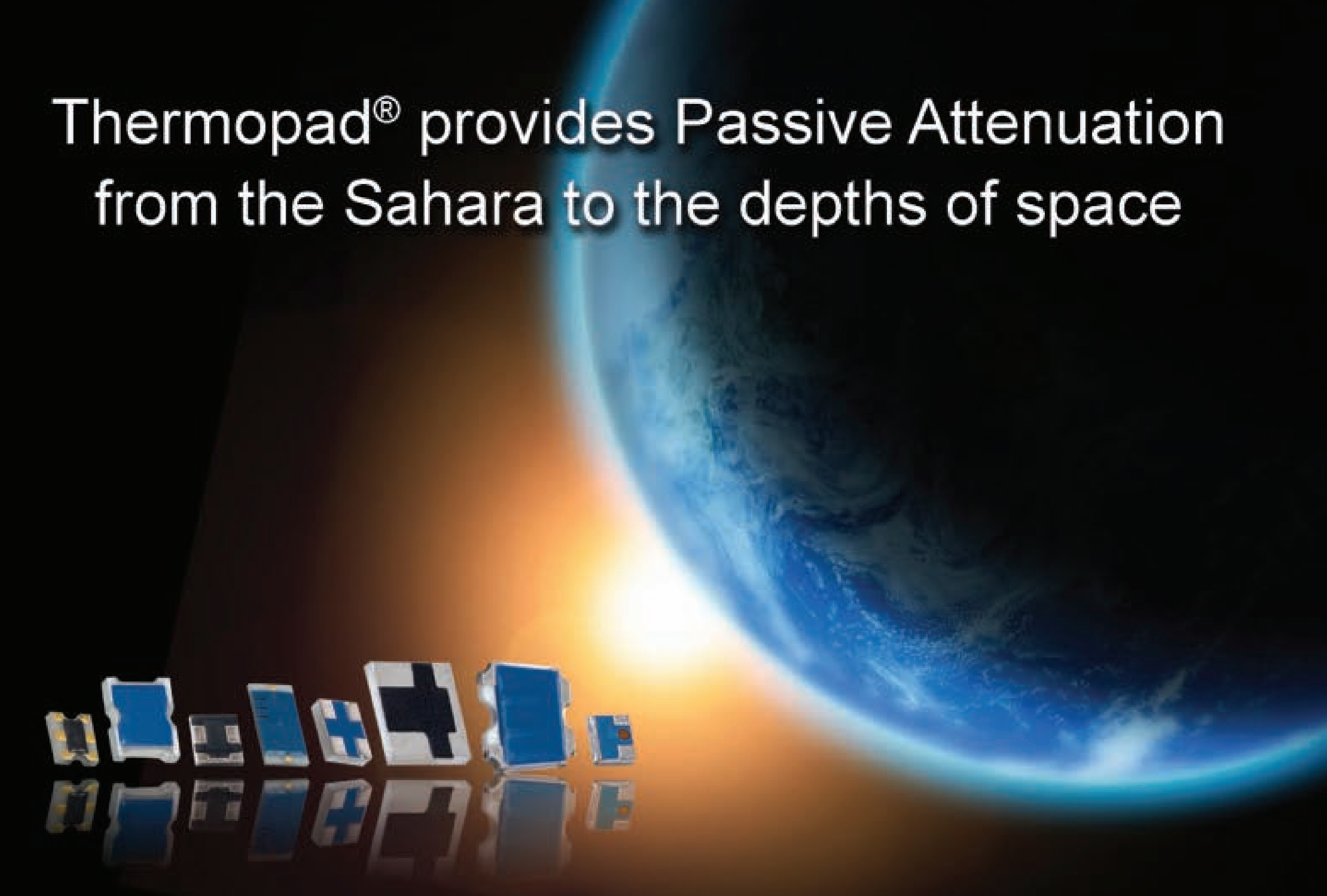
TECOM Industries Inc., part of Smiths Interconnect, is a leader in innovative design and manufacturing of high performance antennas and antenna systems for aerospace, defense and commercial wireless applications. TECOM's antenna systems meet challenging RF requirements in telemetry, electronic warfare and broadband communications. As a key partner to customers, the TECOM team is adept at development and production of high volume antenna systems with excellent quality, reliability and on-time delivery.

TECOM Industries Inc.,
375 Conejo Ridge Avenue,
Thousand Oaks, CA 91361

www.tecom-ind.com



We are the Global Leader in Temperature Variable and Fixed Attenuation from DC to 50 GHz

- Solves temperature compensation problems with a passive device
- SMT components in all frequency ranges up through Q band
- A workhorse in telecommunication applications for 15 years
- 35 years of space heritage
- Wire-bondable and coax versions available
- Nominal attenuation from 1 to 10dB, power up to 2 watts

EMC Technology

8851 SW Old Kansas Avenue, Stuart, FL 34997 USA
Phone: 772-286-9300 or 800-544-5594
www.emct.com

Visit http://mwj.hotims.com/28490-25 or use RS# 25 at www.mwjournal.com/info

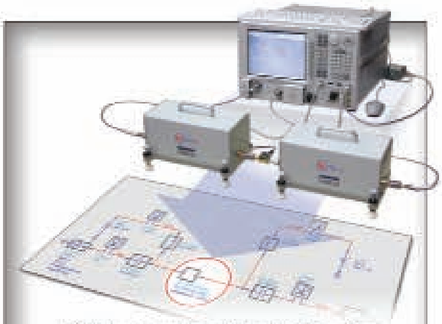
You Have Load Pull Needs – We Have You Covered!

Maury Microwave Has the Most Complete Selection of Load Pull Solutions

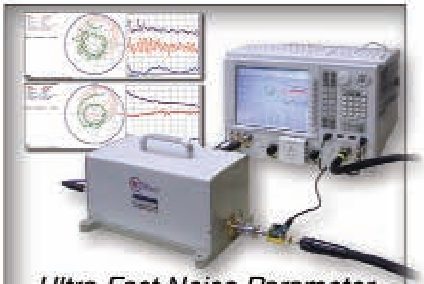
MAURY's Mixed-Signal Active Load Pull Allows Wideband Modulated Impedance Control for Base Station PAs

Active and Hybrid Load Pull Using PNA-X Simplifies Harmonic Tuning with Gamma = 1

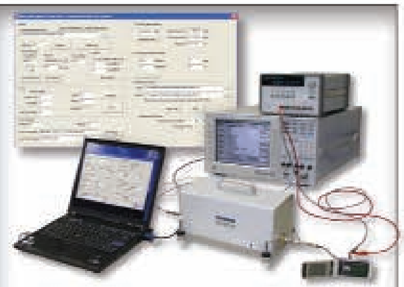
Pulsed-Bias Pulsed-RF Harmonic Load Pull for GaN and Wide Band-Gap Devices



X-Parameter Modeling for First-Pass Advanced Amplifier Design at over 200W!



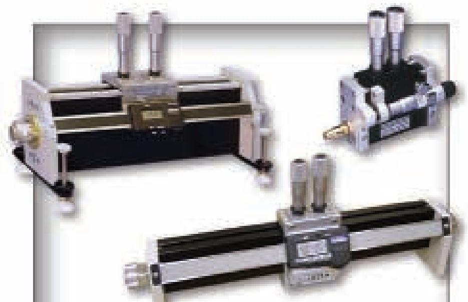
Ultra-Fast Noise Parameter Method Gives More Accurate Results in Less Than 1/100th the Time to 110 GHz!



Stability and Conformance Testing of Mobile Phones for GSM, CDMA, WCDMA...

Advanced Integration of On-Wafer Load Pull and Noise Parameters to 110 GHz

USB and TCP-IP Tuners for Do-It-Yourself Programing Using DLL or Direct ASCII Commands



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Agilent Technologies
Solutions Partner

Visit http://mwj.hotims.com/28490-49 or use RS# 49 at www.mwjournal.com/info

GaAs MMIC Devices

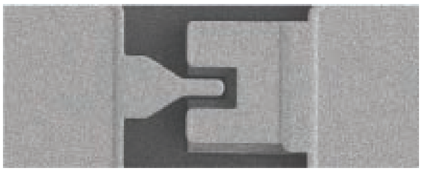
VENDORVIEW

Freescale Semiconductor entered the GaAs MMIC marketplace with the introduction of four new devices designed and optimized specifically for high performance in macro base stations, repeaters and femtocells employed in wireless networks. The devices address low-noise amplifiers and transmit power amplifiers, two elements of wireless infrastructure equipment for which extremely high RF performance is critical. The devices are also designed for low power consumption, resulting in optimized energy efficiency and long-term reliability.

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

RS No. 215

THz Schottky Barrier Diode Foundry Process



The planar Schottky diode process features cut-off frequency (fco) > 1 THz with an ideality factor of 1.1. The low diode turn-on voltage (< 500 mv) allows mixer operation with a LO power below 10 dBm and a conversion loss of 6.5 dB at W-band. GCS's process can be integrated with other passive components, such as MIM caps, spiral inductors, thin film resistors and transmission lines to realize diplexers and filters monolithically. The monolithic integration eliminates unwanted parasitic elements from wire bond, which is highly undesirable at mmW frequencies. For microwave frequency transceiver components, this THz diode is ideal for low conversion loss mixers, with options to be monolithically integrated with HBT circuits (LO and linear PA) and HEMT circuits (LNA, switch and PA).

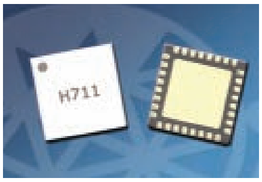
Global Communications Semiconductor,
Torrance, CA (310) 530-7274,
www.gcsincorp.com.

RS No. 216

Sub-harmonic SMT MMIC Upconverter

VENDORVIEW

The HMC711LC5 is a GaAs MMIC Sub-harmonic upconverter that delivers a small-signal conversion gain of 15 dB and wide IF bandwidth of DC to 3.5 GHz. The HMC711LC5 utilizes a double-balanced mixer that is driven by an active ×2 multiplier and followed by a high linearity amplifier. This compact upconverter accepts LO input frequencies from 9.5 to 13.6 GHz, and LO power levels as low as 0 dBm, allowing it to be driven directly from a synthesizer output. The HMC711LC5 also exhibits +28 dBm output IP3 and +17 dBm output P1dB, and operates from a single +5 V supply. This high linearity converter is a much smaller alternative to hybrid style sub-harmonic upconverter assemblies and eliminates the need for wire bonding by allowing the use of surface-mount manufacturing techniques.

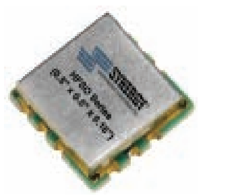


Hittite Microwave Corp.,
Chelmsford, MA (978) 250-3343,
www.hittite.com.

RS No. 217

High Frequency References

VENDORVIEW



The product is available as free running VCOs and phase locked sources with other frequencies possible from 300 to 2500 MHz. Model HFSO1000-12 is a free running VCO operating at 1000 MHz, with +12 V supply, typical tuning range of 100 kHz and phase noise -153 dBc/Hz at 10 kHz offset. This ultra-low-noise VCO is packaged in a compact surface-mount enclosure measuring 12.5 × 12.5 × 4.6 mm. The phase locked option model FCTS1000-X is also available as a surface-mount package measuring 23.9 × 23.9 × 5.6 mm and can be phase locked to an external crystal oscillator source for the required frequency stability. An SMA connectorized package is also available with dual outputs, and can include the internal TCXO or OCXO reference source.

Synergy Microwave Corp.,
Paterson, NJ (973) 881-8800,
www.synergymwave.com.

RS No. 218

GaAs RF Transistors

These 4 W, 4 GHz GaAs RF transistors are highly versatile. TriQuint's newest GaAs PHEMT discrete transistor, TGF2021-04-SG, is a versatile solution for a wide range of applications from 20 MHz to 4 GHz. The TGF2021-04-SG operates at 12 V and produces 4 W (P1dB) with 12 dB gain at 4 GHz. It is well suited as a pre-driver in handheld wireless devices, base station systems or other applications up to 4 GHz.

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

RS No. 219

Components

RF Coaxial Cable Assembly

The CCK40 Series cable assembly is a new addition to the company's line of low-loss RF coaxial cable assemblies. Designed to operate up to 40 GHz, the CCK40 features rugged stainless-steel solder-clamp construction and heavy duty strain reliefs. This low-loss cable provides an attenuation value of 0.90 dB/ft. at 40 GHz. The CCK40 Series cable offers shielding effectiveness of greater than -90 dB with an operating temperature range of -55° to +85°C (extended range of -55° to +125°C available through special order). The CCK40 Series cable offers a minimum bend radius of 1.0" and is available in-stock with 2.92 mm (K) connectors.

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

RS No. 220

Injector-Diplexer

Microlab announced a new low cost injector-diplexer, to separate or combine the VHF-UHF band from 80 to 520 MHz from all the wireless frequency bands from 698 to 2700 MHz. Using suspended substrate, the wireless frequency loss is minimized to less than 0.5 dB, and the loss at VHF-UHF frequencies is less than 0.3 dB. 'Tuned-by-Design' eliminates the high cost of adjusting multiple cavities in conventional designs, while maintaining high isolation between key bands, sufficient for most diplexer applications, such as sharing a common antenna or distributed antenna system.

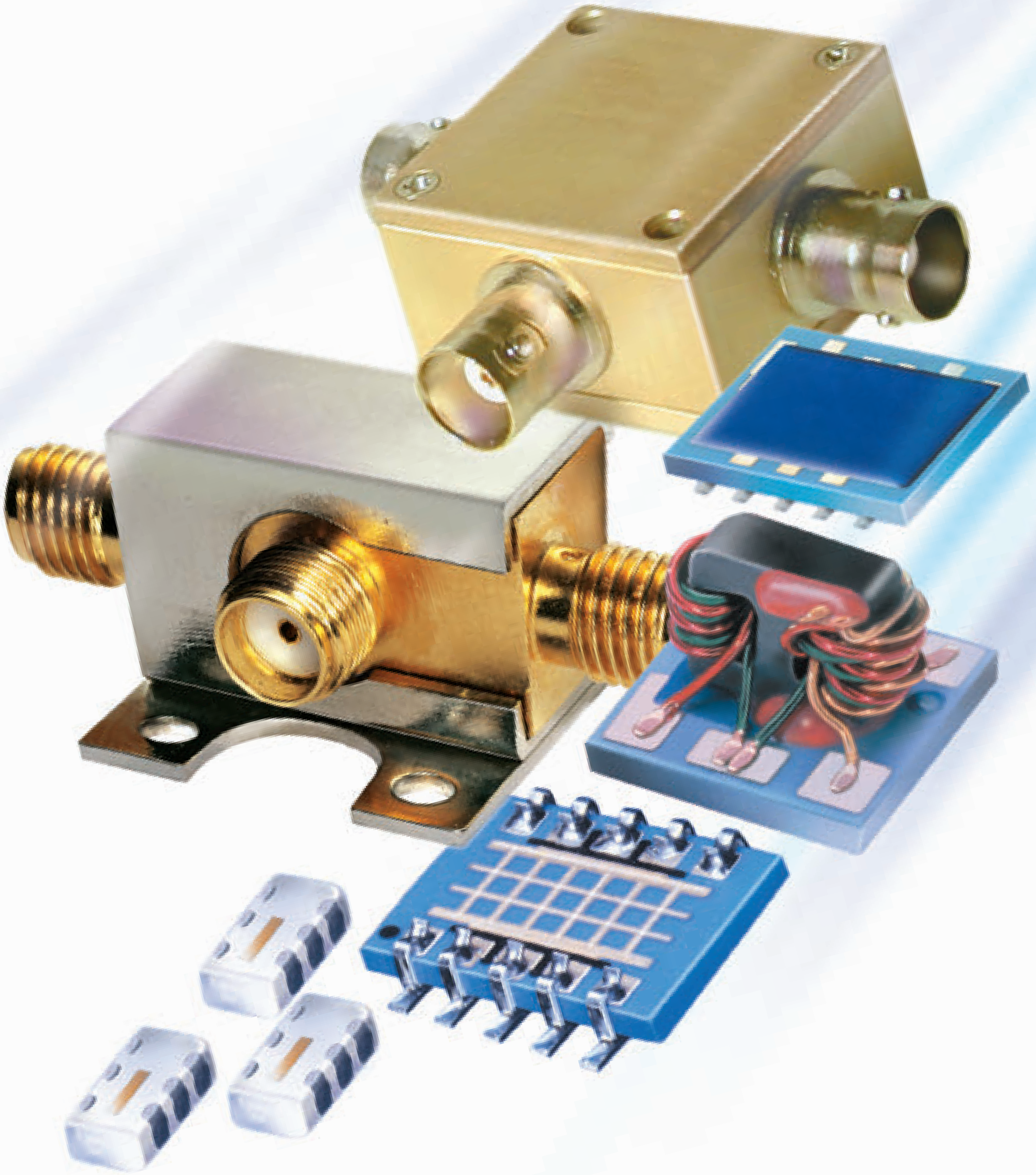
Microlab,
Parsippany, NJ (973) 386-9696,
www.microlab.fxr.com.

RS No. 221

Solid-state RF Switch

VENDORVIEW

The ZFSWA2-63DR+ is a general-purpose SPDT solid-state absorptive RF switch. With its broad frequency range, fast 35 ns switching time and excellent RF performance, the ZFSWA2-63DR+ is an excellent choice for many applications. In addition to its versatility within system block diagrams, the ZFSWA2-63DR+ is designed for easy integration into prototype design applications. This RF switch provides a wide bandwidth of 0.5 to 6 GHz, high isolation of 65 dB at



1 GHz, fast switching of 35 ns and a rugged case with internal hermetically sealed ceramic semiconductor module. Price: $69.95 (Qty. 1 to 9).
Mini-Circuits,
Brooklyn, NY (718) 934-4500,
www.minicircuits.com.

RS No. 222

Even Harmonic Mixer

MITEQ's new even harmonic mixer is now available for radar, communication and related test system applications. The model SBE1040LW1 covers from 10 to 40 GHz on the RF input and only requires 5 to 20 GHz for the LO, with an output IF of DC to 4 GHz. The even harmonic nature of this mixer reduces the need for high frequency LO sources. This model operates over a -54° to +85°C temperature range, and is ideal for rugged military systems applications.

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

RS No. 223

Variable RF Attenuators

The model 794M calibrated 0-to-40-dB variable attenuator provides flat frequency response from 4 to 8 GHz and provides direct readout of attenuation values. Its precision makes the model 794M an excellent choice for measurement applications. Model 794M has attenuation accuracy of ±2.5 dB, handles 10 W average and 5 kW peak RF input power, and has a maximum VSWR of 1.25:1 and insertion loss of 0.5 dB or less. It is housed in a rugged enclosure, utilizes Type-N female input and Type-N male output connectors, and measures 8.5" × 5.2" × 1.7" and weighs 5.7 lb. The model 794M is accompanied by the model 793FM, which has an attenuation range of 0 to 20 dB and has identical characteristics to the model 794M except for accuracy of ± 1 dB. Both models are available from Narda for immediate delivery.
Narda Microwave-East,
Hauppauge, NY (631) 231-1700,
www.nardamicrowave.com.

RS No. 224

Custom Microwave Sub-assemblies

Phase Matrix's Microwave Components group designs and manufactures custom RF and microwave sub-assemblies and components up to 50 GHz for commercial and military applications. Circuit designs include built-in control, monitoring and test functions. Manufacturing techniques employed include soft-board, thin-film chip and wire, and surface-mount assembly as required for specific applications. Phase Matrix specializes in reproducing replacement parts for Avantek and Watkins-Johnson custom oscillator sub-assemblies. In addition, Phase Matrix has supplied custom amplifiers, VCOs, DTOs, up/downconverters, frequency multipliers, diplexers, SPMT switches, filters, variable attenuators and phase-locked oscillators.

Phase Matrix Inc.,
San Jose, CA (408) 428-1000,
www.phasematrix.com.

RS No. 225

Directional Coupler

Pulsar model CS20-52-436-9 is a new 20 dB coupler that operates in the frequency range of 2 to 40 GHz with 1.6 dB insertion loss. Directivity is greater than 10 dB and flatness is ±0.5 dB 2 to 20 GHz and ±1.0 dB 2 to 40 GHz. The VSWR is 1.80:1 maximum and the unit can handle 20 W into a 1.20:1 load. Connectors are 2.92 mm female.
Pulsar Microwave,
Clifton, NJ (973) 779-6262,
www.pulsarmicrowave.com.

RS No. 226

High power, small footprint broadband power amplifiers

Actual size

2-18 GHz

Model Number	Frequency (GHz)	Gain (dB)	Power (dBm)	OIP3 (dBm)	NF (dB)	Supply/Current V/mA
PA020180-3922	2.0 - 18	38	Psat > 39	48	-	+28 / 1200
PA020180-3025	2.0 - 18	30	P1dB> 30	40	9	+12 / 2000
PA002005-21	0.2 - 0.5	20	P1dB> 21	35	1.1	+5 / 100
PA001002-22	0.1 – 0.2	19	P1dB> 23	37	1.5	+5 / 100
PA001040-27	0.1 – 4.0	25	P1dB> 27	40	5	+10 / 290
PA001060-4440	0.1 – 6.0	40	Psat> 44	50	-	+50 / 1000

2 to 18 GHz 8W power amplifiers

- High linearity
- Small and lightweight
- Custom designs available

Space switches

- Direct replacement for legacy switches
- High isolation >45dB
- Compact hermetic packages
- Integrated control logic
- Available in Class K

Broadband power amps

- Designs up to 65GHz
- High efficiency and linearity
- Power up to 150W pulsed, 120W CW
- High reliability

At Aeroflex Plainview, we're all about experience, and offering cost-effective solutions that do not sacrifice performance and quality. We combine extensive space design and packaging expertise with cutting-edge, proven technologies to provide highly-integrated microwave assemblies, amplifiers, switches, and up/down converters that operate up to 65GHz.

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aeroflex.com/bband

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Visit http://mwj.hotims.com/28490-6 or use RS# 6 at www.mwjournal.com/info

Terminated Diplexer

VENDORVIEW

Reactel part number 2DMPX-102-N11 is a terminated diplexer. This unit exhibits superior VSWR performance in both the passband (120 to 1000 MHz) and reject band (20 to 100 MHz). This high power unit offers 0.7 dB of insertion loss and greater than 70 dB of rejection. Please contact the factory for this or any other filter requirement that you have.

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

RS No. 227

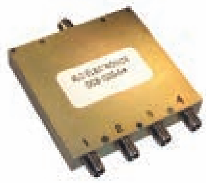
High Frequency Test Cables

RF Industries offers a line of 18 GHz precision test cables in standard or custom lengths, suitable for production or lab environments. Featuring high-grade, passivated, stainless steel SMA males with PTFE insulators, this unique cable is configured for low loss and low VSWR. With triple shielding for optimum EMI protection, they are very phase-stable during mechanical and environmental stresses. The cable is also manufactured in accordance with MIL-DTL-17, type IX specification. Other features include high velocity of propagation, wide operating temperature and blue FEP jacket. Armored versions for rugged field applications are also available.

RF Industries,
San Diego, CA (858) 549-6340,
www.rfp2.com.

RS No. 228

Power Dividers and Combiners



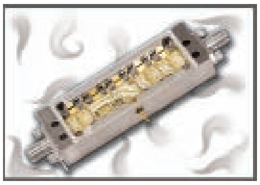
RLC Electronics' series DCB-1020 is an in phase power divider/combiner with high isolation, small size and superior performance in a single package. All microstrip and stripline power dividers typically pass DC on all ports. These units utilize microstrip construction with blocking capacitors on all ports except those that are intended to pass DC.

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

RS No. 229

Amplifiers

X-band Amplifiers



AML announces the availability of a low noise X-band amplifier, model number AML812L3003. This LNA operates in the frequency range of 8 to 12 GHz with small-signal gain over 30 dB and a noise figure of 1.1 dB typical. Output P1dB is +10 dBm minimum. This amplifier is available in a SMA connectorized housing with internal voltage regulation and reverse voltage protection.

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

RS No. 230

100 W Amplifier System

VENDORVIEW

AR Modular RF's model KAW2020M16 is a 100 W amplifier system used in simulated combat training environment. This model operates in a frequency range from 220 to 245 MHz. This newly designed unit is only 2RU high and will run cool at full power in harsh environments. The system features forward and reflected power indication, with full overdrive, VSWR and over-temperature protection.

AR Modular RF,
Bothell, WA (425) 485-9000,
www.ar-worldwide.com.

RS No. 241

Small Form Factor Module Designs

Increasing demands for reductions in size and weight, and ongoing requirements for higher levels of functionality and overall efficiency, are driving innovations in packaging and amplifier design at the module level. Building on device knowledge and integration expertise, Empower has designed and delivered high performance, multi-function modules that are integral building blocks in demanding defense and commercial applications. Features include: internal DC-DC converters for battery operation; advanced control functions and performance monitoring; high efficiency, Doherty designs; and latest GaN on SiC Technology.

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

RS No. 231

S-band Power Amplifier

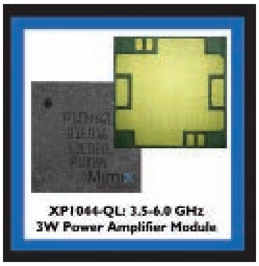
The MKU PA 3430 A is a two-stage S-band power amplifier that has been built using the latest 28 V LDMOS technology. It operates in the 3400 to 3600 MHz frequency range, has a typical output power of 20 W (CW), a minimum saturation power of 30 W (CW), weighs 140 g and measures 80 by 59 by 20 mm. Furthermore, the PA has an ON/OFF function and an output monitor for observing the output power. It has been developed both for digital applications (WiMAX) and analog transmission systems.

Kuhne electronic GmbH,
Berg, Germany 0049-(0)9293-800 939,
www.kuhne-electronic.de.

RS No. 232

Power Amplifier Module

VENDORVIEW



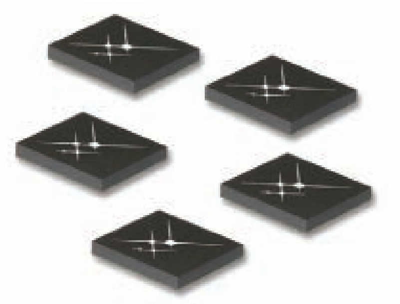
Mimix Broadband Inc. introduces a 3.5 to 6 GHz 3 W power amplifier module (PAM) housed in an RoHS-compliant, 7 × 7 mm package. This highly linear two-stage amplifier delivers 18.5 dB of gain and 34 dBm of power at 1 dB compression point. Identified as XP1044-QL, this PAM provides less than 2.5 percent EVM at 26 dBm output power with 802.16 OFDM signal and peak to average ratio of 9.17 dB. The input and output of the device are internally pre-matched, facilitating a simplified input and output match. The XP1044-QL is designed for WiMAX applications between 4.9 and 5.9 GHz, and the performance can be shifted by adding external matching components to cover applications between 3.5 and 5 GHz.

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

RS No. 233

Power Amplifiers

VENDORVIEW



Skyworks Solutions Inc. has introduced five 3 × 3 mm power amplifier modules (PAM) with an integrated daisy chain coupler for next-generation platforms. These PAMs support all required modulations for a given frequency band including CDMA, WCDMA and LTE handsets and datacards. In addition, they enable a variety of compatible baseband/RF architectures.

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

RS No. 234

Antenna

S-band Blade Antenna

Cobham Sensor Systems, Baltimore announces model 11C22900, a rugged and reliable S-band blade antenna designed for telemetry applications. The antenna frequency range is 2.2 to 2.3 GHz, VSWR is 2:1 maximum, the polarization is vertical and its radiation pattern is similar to a quarter-wave stub. This unit is sealed from water and is capable of handling 250 W CW of power. It is finished in flat black epoxy paint.

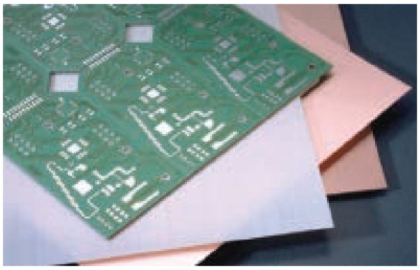
Cobham Sensor Systems,
Baltimore, MD (410) 542-1700,
www.cobham.com.

RS No. 235

Material

High Frequency Laminates

VENDORVIEW



Rogers recently launched the RO4360 high frequency laminates, the latest addition to the RO4000® product family. RO4360 thermoset laminate materials are specially formulated to meet a Dk of 6.15 and exhibit a low dissipation factor of 0.0038 at 10 GHz. RO4360 laminates possess a Z-axis coefficient of thermal expansion of 30 ppm/°C (CTE) for dependable plated-through-hole (PTH) quality in multilayer circuit and package designs and are lead free process capable. Look for Rogers bonding layer with a matching 6.15 dielectric constant coming soon.

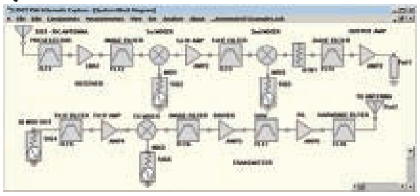
Rogers Corp.,
Chandler, AZ
(480) 961-1382,
www.rogerscorporation.com.

RS No. 236

NEW PRODUCTS

Software

System Simulation Software



ACS recently released Version 1.02 of the LINC2 VSA (Visual System Architect) system simulation software. This new version adds a measurement option for tracking signal levels relative to P1dB (one dB gain compression) at every node in the system. When plotted, Signal/P1dB shows at a glance whether the signal level at any component is at, above or below the component's P1dB compression point.
Applied Computational Sciences (ACS) LLC,
Escondido, CA
(760) 612-6988,
www.appliedmicrowave.com.

RS No. 237

Sources

Frequency Synthesizer

The SLX-4000 is a miniature broadband frequency synthesizer for battery powered military systems and devices. The unit operates from 2000 to 4000 MHz (octave bandwidth) locked to a 10 MHz external reference and features 5 MHz step size. The unit also features +4 dBm output power, low spurs and extremely low current draw (+5 V at 60 mA, typical). Fast switching units are also available. The SLX Series is housed in an ultra-miniature 0.5" square package.
EM Research Inc.,
Reno, NV (775) 345-2411,
www.emresearch.com.

RS No. 238

Voltage-controlled Oscillator

Micronetics introduces a RoHS compliant MW500-1838 voltage-controlled oscillator (VCO). The MW500-1838 1/2" smt VCO has a tuning range of 2570 to 2655 MHz from 1 to 5.5 V tuning using a 5 V supply. Output power is +2 dBm ±1.5 dBm while using less than 30 mA of current.
Micronetics Inc.,
Hudson, NH
(603) 883-2900,
www.micronetics.com.

RS No. 239

Voltage-controlled Oscillator

Z-Communications Inc. announces a new RoHS compliant voltage-controlled oscillator (VCO) model SMV3330A-LF in S-band. The SMV3330A-LF operates at 3300 to 3360 MHz with a tuning voltage range of 0.5 to 2.5 VDC. This VCO features a typical phase noise of -84 dBc/Hz at 10 kHz offset and a typical tuning sensitivity of 125 MHz/V. The SMV3330A-LF is designed to deliver a typical output power of 5 dBm at 3 V DC supply while drawing 14 mA (typical) over the temperature range of -5° to 60°C. This VCO features typical second harmonic suppression of -20 dBc and comes in Z-Comm's SUB-L package measuring 0.3" × 0.3" × 0.08".
Z-Communications Inc.,
San Diego, CA
(858) 621-2700,
www.zcomm.com.

RS No. 240

ERRATA

In "Narrowband Microwave Bandpass Filter Design by Coupling Matrix Synthesis," a Technical Feature by M. Hagensen that appeared on page 218 of the April issue, the first math equation is incorrect; the displacement Δf is divided by the ripple bandwidth BW, not the center frequency f_0.

Also, in "Ultra-fast, Simpler and More Accurate Noise Parameter Measurements," a Technical Feature by Gary Simpson and David Ballo that appeared on page 82 of the March issue, the first math equation is incorrect; the input signal-to-noise ratio is divided by the output signal-to-noise ratio, not the other way around.

SYNERGY® MICROWAVE CORPORATION

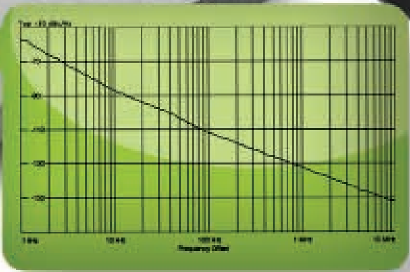
MINIATURE FOOTPRINT VCO'S

Model	Frequency Range (MHz)	Tuning Voltage (VDC)	DC Bias VDC @ I [Typ.]	Phase Noise @ 10 kHz (dBc/Hz) [Typ.]	Size (Inch)
DCO Series					
DCO50100-5	500 - 1000	0.3 - 15	+5 @ 26 mA	-100	0.3 x 0.3 x 0.1
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



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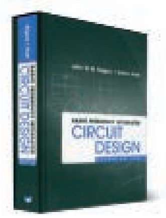
RoHS COMPLIANT



Radio Frequency Integrated Circuit Design, Second Edition

John W.M. Rogers and Calvin Plett

This newly revised and expanded edition of the 2003 Artech House classic, *Radio Frequency Integrated Circuit Design*, serves as an up-to-date, practical reference for RFIC design. This edition includes numerous updates, including greater coverage of CMOS PA design, RFIC design with on-chip components, and more worked examples with simulation results. The RFIC designs examined include RF integrated LC-based filters, voltage-controlled oscillator (VCO) automatic amplitude control loops, and fully integrated transformer-based circuits, as well as image reject mixers and power amplifiers.

The book starts off with an introduction to communications circuits and reviews important theory like noise, linearity, filtering, system architecture and technology issues. The book demonstrates how linearity and noise arise by including specific circuits and numerical examples. The book proceeds to cover impedance matching and design of passive circuit elements, low noise amplifiers (LNA), mixers, VCOs, synthesizers and power amplifiers. This second edition has more information on RFIC design using CMOS transistors than the original, which concentrated more on bipolar transistors.

If you are new to RFIC design, you can benefit from the introduction to basic theory and quickly come up to speed on how RFICs perform and work together in a communications device. This is an advanced level book, however, and the reader should have some background in basic circuits and transmission lines. The book includes a thorough examination of RFIC technology and explains when RFICs are the right choice for designing a communication device. It has over 1,000 equations and more than 435 illustrations that support key topics. *Radio Frequency Integrated Circuit Design* thoroughly covers the subject and is recommended as a good source for designers in industry and academia.

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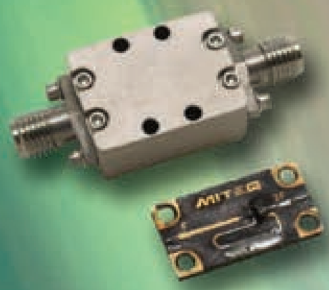
MIXERS

Model Number	RF/LO Frequency (GHz)	IF Frequency (GHz)	LO Power (dBm)	Conversion Loss (dB) Typ./Max.	LO-to-RF Isolation (dB) Min.
DOUBLE-BALANCED VERSIONS					
DM0052LA2	0.5 – 2	DC – 0.5	7 – 13	6.5/8.5	30
DM0104LA1	1 – 4	DC – 1	7 – 13	5.5/7	30
DM0208LW2	2 – 8	DC – 2	7 – 13	7/8	30
DM0408LW2	4 – 8	DC – 2	7 – 13	5/6	30
DM0812LW2	8 – 12	DC – 4	7 – 13	4.5/6	30
DM0416LW2	4 – 16	DC – 4	7 – 13	7/8	30
DB0218LW2	2 – 18	DC – 0.75	7 – 13	6.5/8.5	22
DB0226LA1	2 – 26	DC – 0.5	7 – 13	9/10	20
DB0440LW1	4 – 40	DC – 2	10 – 15	9/10	20
M2640W1	26 – 40	DC – 12	10 – 15	10/12	28
TRIPLE-BALANCED VERSIONS					
TB0218LW2	2 – 18	0.5 – 8	10 – 15	7.5/9.5	20
TB0426LW1	4 – 26	0.5 – 8	10 – 15	10/12	20
TB0440LW1	4 – 40	0.5 – 20	10 – 15	10/12	18

PASSIVE DOUBLERS



Model Number	Input Frequency (GHz)	Input Power (dBm)	Output Frequency (GHz)	Conversion Loss (dB) Typ./Max.	Rejection (dBc) Typ. Fund.	Odd Harm.
DROP-IN VERSIONS						
SXS01M	0.5 – 3	8 – 12	1 – 6	13/16	-20	-25
SXS04M	2 – 9	8 – 12	4 – 18	13/15	-20	-25
SXS07M	3 – 13	8 – 12	6 – 26	13/18	-18	-25
CONNECTORIZED VERSIONS						
SXS2M010060	0.5 – 3	8 – 12	1 – 6	13/16	-20	-25
SXS2M040180	2 – 9	8 – 12	4 – 18	13/15	-20	-25
SXS2M060260	3 – 13	8 – 12	6 – 26	13/17	-18	-25
MX2M130260	6.5 – 13	8 – 12	13 – 26	11/13	-15	-15
MX2M004010	0.02 – 0.5	8 – 12	0.04 – 1	10.5/13	-25	-25

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ACROSS

3 Largest pure play GaAs foundry (2 words)
8 Class of in-phase, equal power split, N-way power dividers combines resistive and reactive dividers (2 words)
9 A fourth metal terminal added to a FET structure and biased to improve device performance by affecting the charge or current flow around the gate area (2 words)
11 Heterojunction bipolar transistor
15 A type of power divider circuit that can achieve isolation between the output ports while maintaining a matched condition on all ports
17 Pseudo-metamorphic high electron mobility transistor
19 PCB (3 words)
21 The amount of time it takes for a switch to change state (the measured parameter has reached 90% of its steady-state value) (2 words)
22 Largest GaAs foundry
23 Complementary metal-oxide semiconductor
24 Device technology that integrates HBT and PHEMT devices on the same die
25 ______ is the future and always will be

DOWN

1 A type of transformer that can convert signals that are balanced to signals that are unbalanced and vice versa
2 The current controlling terminal in a FET
4 The ratio of the amplitudes of a single pair of voltage and current waves propagating along the line in the absence of reflections (2 words)
5 Monolithic microwave integrated circuit
6 The amount of time it takes for a switch to settle to a completely changed state after 90% of its value has been reached (2 words)
7 A type of wire bonding that uses a combination of pressure, heat and ultrasonic to attach a flat ribbon to a bonding pad (2 words)
10 A specialized electronic package where multiple ICs or other discrete components are packaged onto a unifying substrate (3 words)
12 The contact between a metal and a semiconductor that does not allow carriers to flow in and out of the semiconductor (high contact resistance) (2 words)
13 When all devices are tested and the reject die are marked and/or removed so only fully tested, good die are sold/delivered (3 words)
14 The tendency of a high frequency signal to distribute current within a conductor so that the current density near the surface of the conductor is greater than that at its core (2 words)
16 A type of wire bonding that uses a combination of pressure, heat and ultrasonic energy to attach a round wire to a bonding pad (2 words)
18 Metal-eptiaxial semiconductor field-effect transistor
20 The contact between a metal and a semiconductor to allow carriers to flow in and out of the semiconductor (low contact resistance) (2 words)

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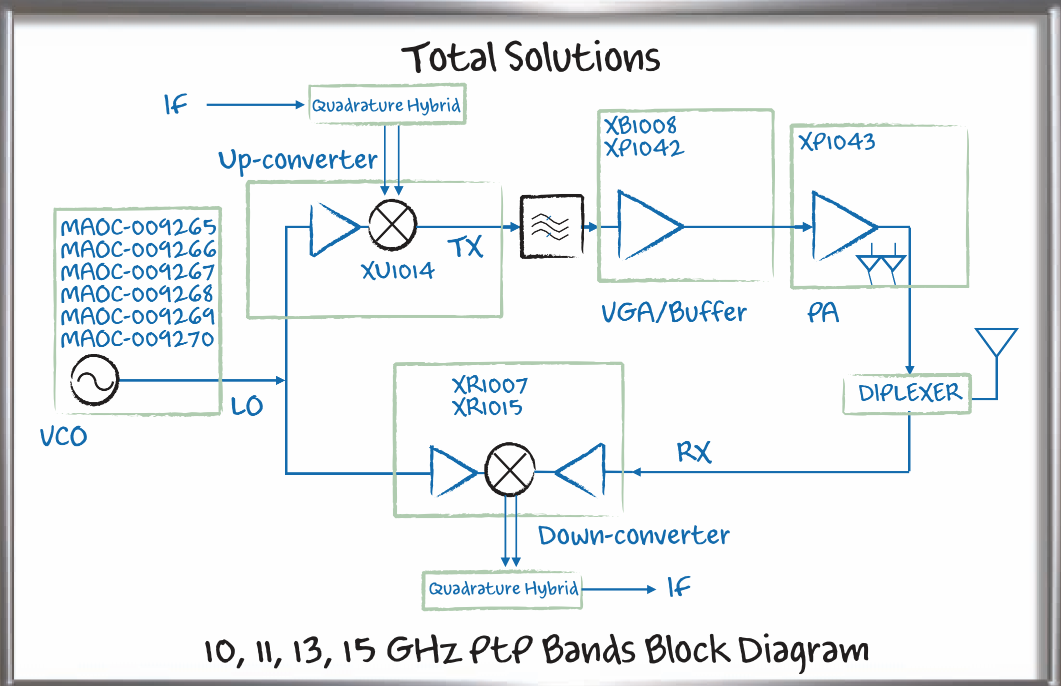

t h e m ² a d v a n t a g e

Device	Frequency (GHz)	Gain (dB)	P1dB (dBm)	OIP3 (dBm)	NF (dB)	Pout (dBm)	PN at 100 kHz (dBc/Hz)	Current (mA)	Voltage (V)	Package (mm)
XP1043-QH	12.0-16.0	21.5	30.0	41.0				700	7.0	4x4
XP1042-QT	12.0-16.0	21.0	25.0	38.0				500	5.0	3x3
XB1008-QT	10.0-21.0	17.0	19.0	32.0				100	4.0	3x3
XU1014-QH	8.0-18.0	-10.0	2.0	12.0				80	4.0	4x4
XR1007-QD	10.0-18.0	13.5		4.0 (I/P)	2.7			150	5.0	7x7
XR1015-QH	10.0-16.0	12.0		2.0 (I/P)	2.5			170	4.0	4x4
MAOC-009265	9.4-10.8					6.0	-110	175	5.0	5x5
MAOC-009266	10.2-11.3					9.0	-114	185	5.0	5x5
MAOC-009267	11.2-12.6					3.5	-110	165	5.0	5x5
MAOC-009268	12.7-14.2					7.0	-105	175	5.0	5x5
MAOC-009269	11.4-12.8					3.0	-110	165	5.0	5x5
MAOC-009270	12.2-13.8					6.5	-105	155	5.0	5x5

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