Vol. 56 • No. 9

September 2013

Microwave Journal
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ENGINEERING AUTOMOTIVE RADAR

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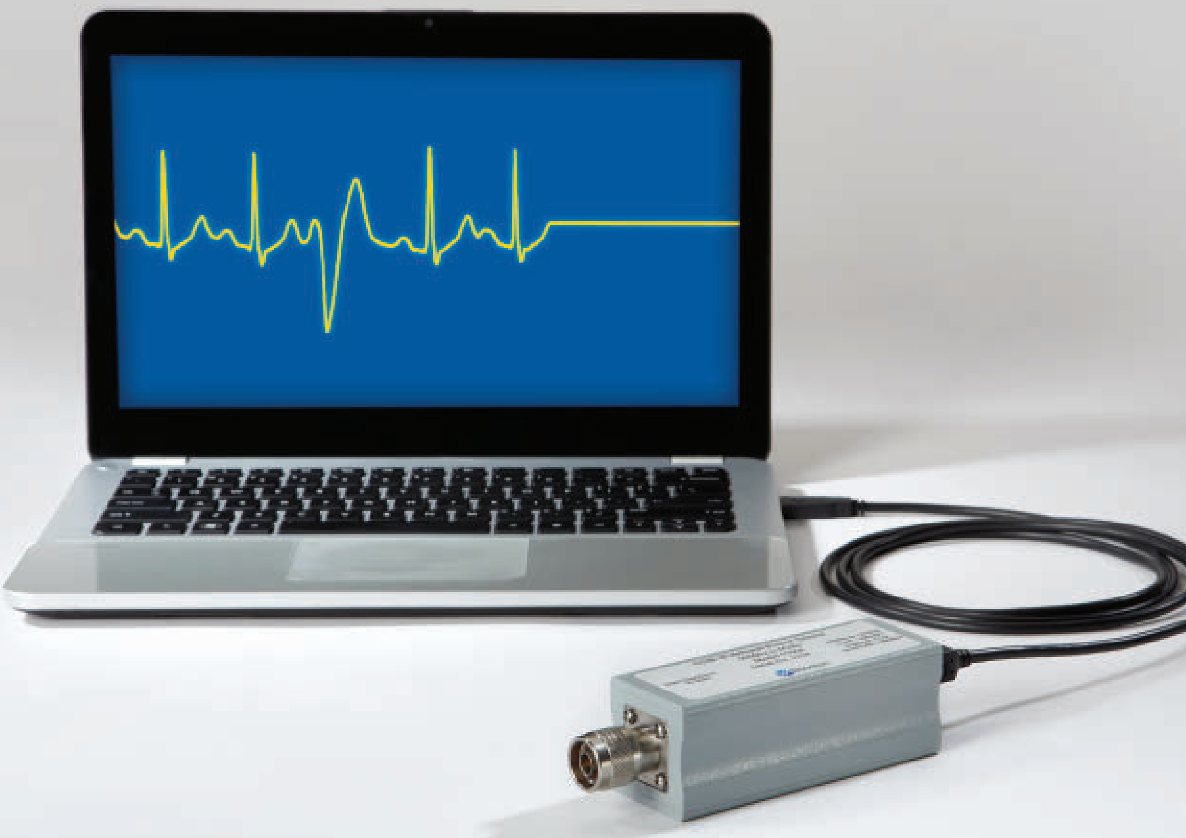
Issue

Missing a Pulse Can Be Deadly.



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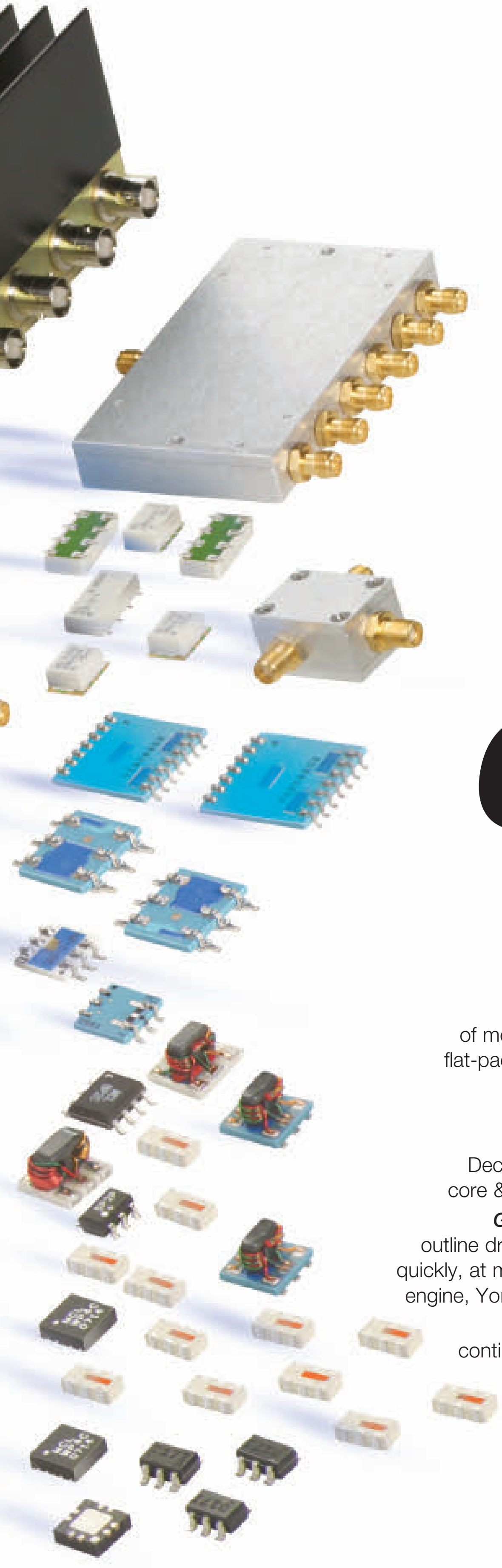

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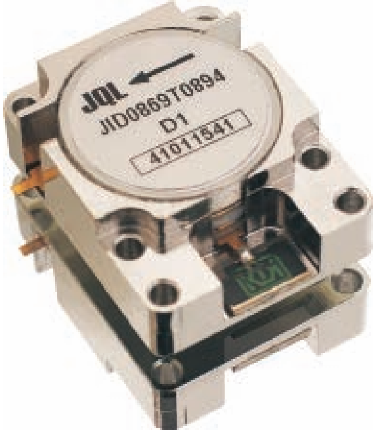
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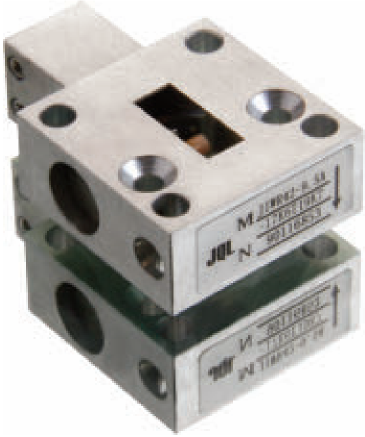

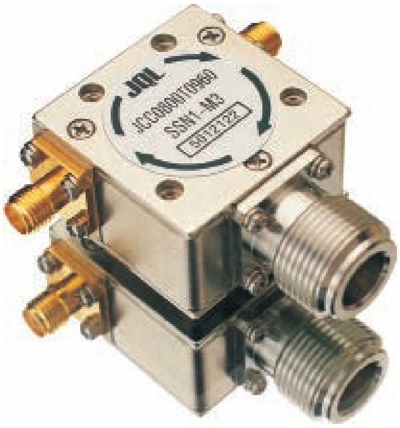

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Apollo 17

Mars Science Lab

Mars Opportunity Rover

Mars Spirit Rover

Iridium Satellite Constellation

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GPS-3

GPS-R

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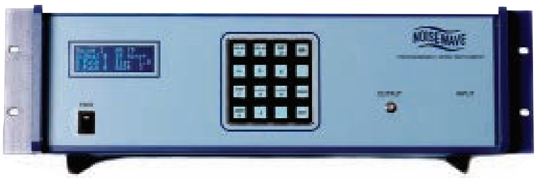

Under powered and over budget? Problem solved.

Eval Boards Available From Stock

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PIN Diode Switch and Driver Combinations

Part Number	Configuration	Drive Voltage*	Recommended Switch Driver	Frequency Band (MHz)
MSW2000–200	T-R Switch, TX Left	+V Only	MPD2T28125-700	10 to 1,000
MSW2001–200	T-R Switch, TX Left	+V Only	MPD2T28125-700	400 to 4,000
MSW2002–200	T-R Switch, TX Left	+V Only	MPD2T28125-700	2,000 to 6,000
MSW2022-200	T-R Switch, TX Right	+V & -V	MPD2T5N200-702	2,000 to 6,000
MSW2050–205	T-R Switch, TX Left	+V Only	MPD2T28125-700	20 to1,000
MSW2051–205	T-R Switch, TX Left	+V Only	MPD2T28125-700	400 to 4,000
MSW2030–203	Symmetrical SP2T	+V Only	MPD2T28125-700	10 to 1,000
MSW2031–203	Symmetrical SP2T	+V Only	MPD2T28125-700	400 to 4,000
MSW2032–203	Symmetrical SP2T	+V Only	MPD2T28125-700	2,000 to 6,000
MSW2040–204	Symmetrical SP2T	+V Only	MPD2T28125-700	50 to 1,000
MSW2041–204	Symmetrical SP2T	+V Only	MPD2T28125-700	400 to 4,000
MSW2060-206	Symmetrical SP2T	+V & -V	MPD2T5N200-702	10 to 1,000
MSW2061-206	Symmetrical SP2T	+V & -V	MPD2T5N200-702	400 to 4,000
MSW2062-206	Symmetrical SP2T	+V & -V	MPD2T5N200-702	2,000 to 6,000
MSW3100–310	Symmetrical SP3T	+V Only	MPD3T28125-701	10 to 1,000
MSW3101–310	Symmetrical SP3T	+V Only	MPD3T28125-701	400 to 4,000
MSW3200-320	Symmetrical SP3T	+V & -V	MPD3T5N200-703	10 to 1,000
MSW3201-320	Symmetrical SP3T	+V & -V	MPD3T5N200-703	400 to 4,000
MSW4102-410	Symmetrical SP4T	+V Only	MPD2T28125-700 (2 each)	4,000 to 6,000
MSW5000-500	Symmetrical SP5T	+V Only	MPD2T28125-700 & MPD3T28125-702 (1 each)	30 to 512
MSW6000-600	Symmetrical SP6T	+V Only	MPD3T28125-702 (2 each)	30 to 512
MSWLM2420-242	Asymmetric T-R with Rx limiter	+V Only	MPD2T28125-700	2,000 to 4,000

+V Only = +5 V and +28 V to +125 V
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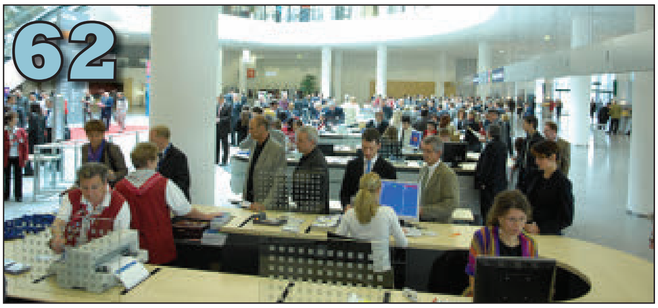
Note from the Editor

Cover Feature

European Microwave Week 2013



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Application Note

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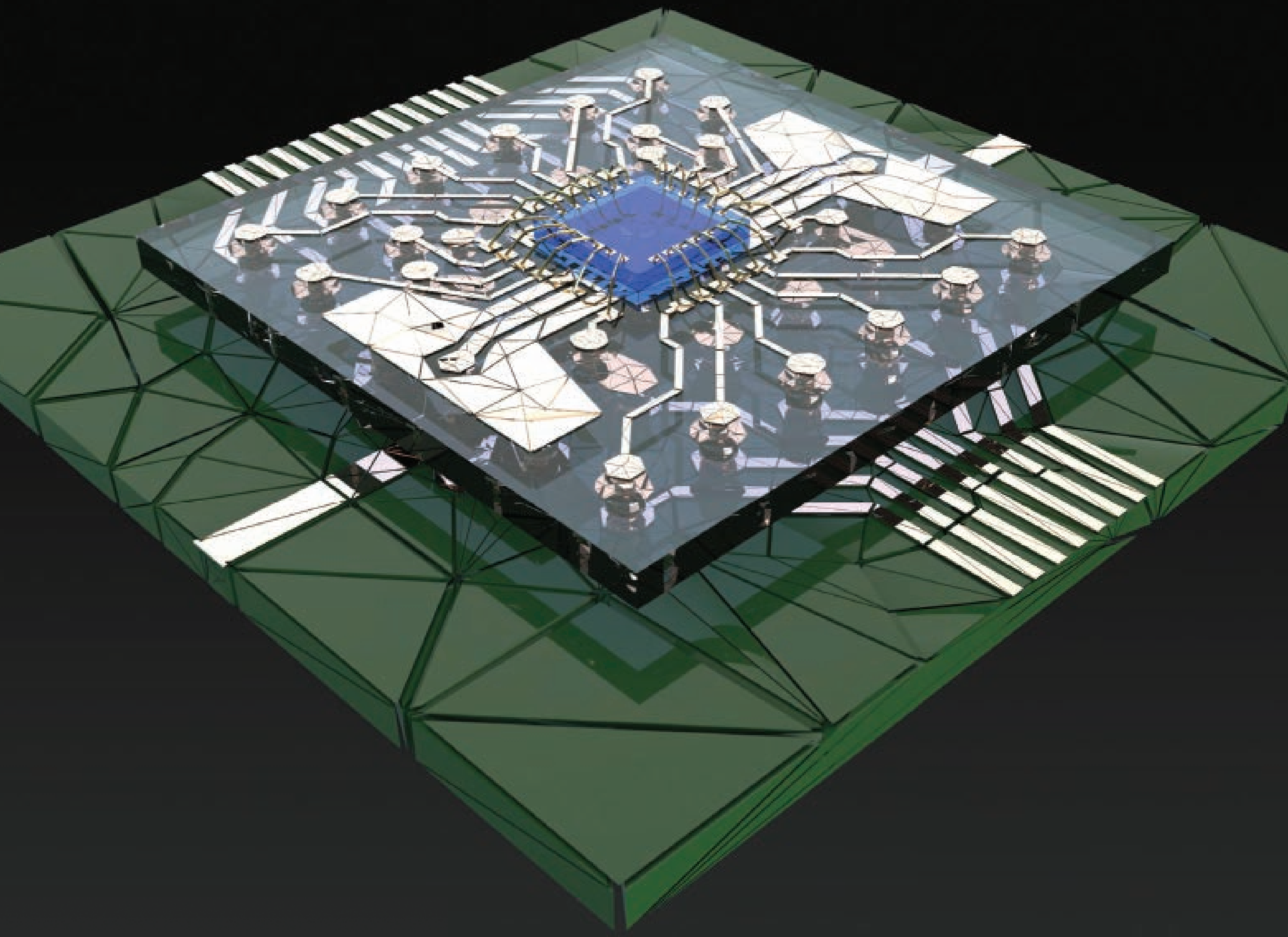

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CST 2013 Webinar Series

High Speed and High Power Connector Design	9/19
Modeling and Simulation of Metamaterial-based Devices for Industrial Applications	9/26

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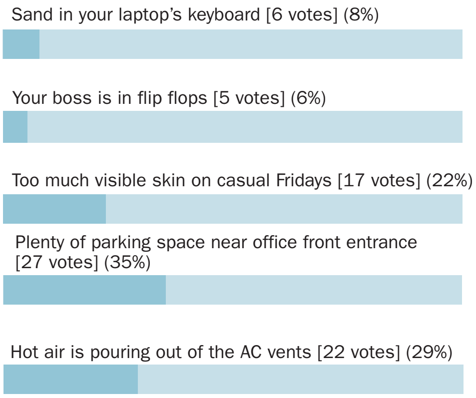
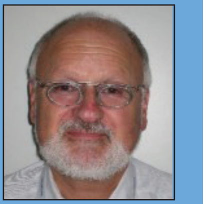
July Survey

A sure sign it's summertime in the office...



Executive Interviews



Holger H. Meinel, responsible for technology management and research policy at **Daimler AG**, offers an insight into his 40 years in the industry, his involvement in the founding of EuMA and EuMW and his passion for the development of automotive radar technology.

President and CEO of **Pivotone**, **Dr. Guochun (GC) Liang**, shares some insights on his unique philosophy on life and business.

White Papers

VNAs High-Speed Architecture Advances Radar Pulse Measurement Timing Resolution and Accuracy
Anritsu

EDA Software Design Flow Considerations for the RF/Microwave Module Designer
AWR

RF and Microwave Fiber Optic Delay Line Techniques
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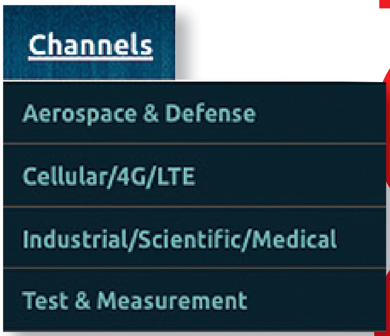

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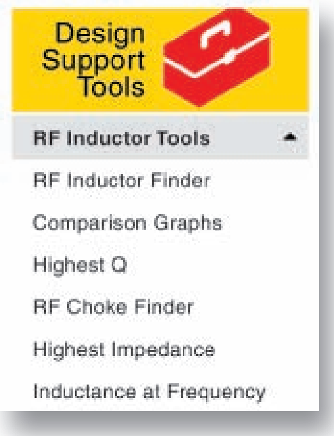

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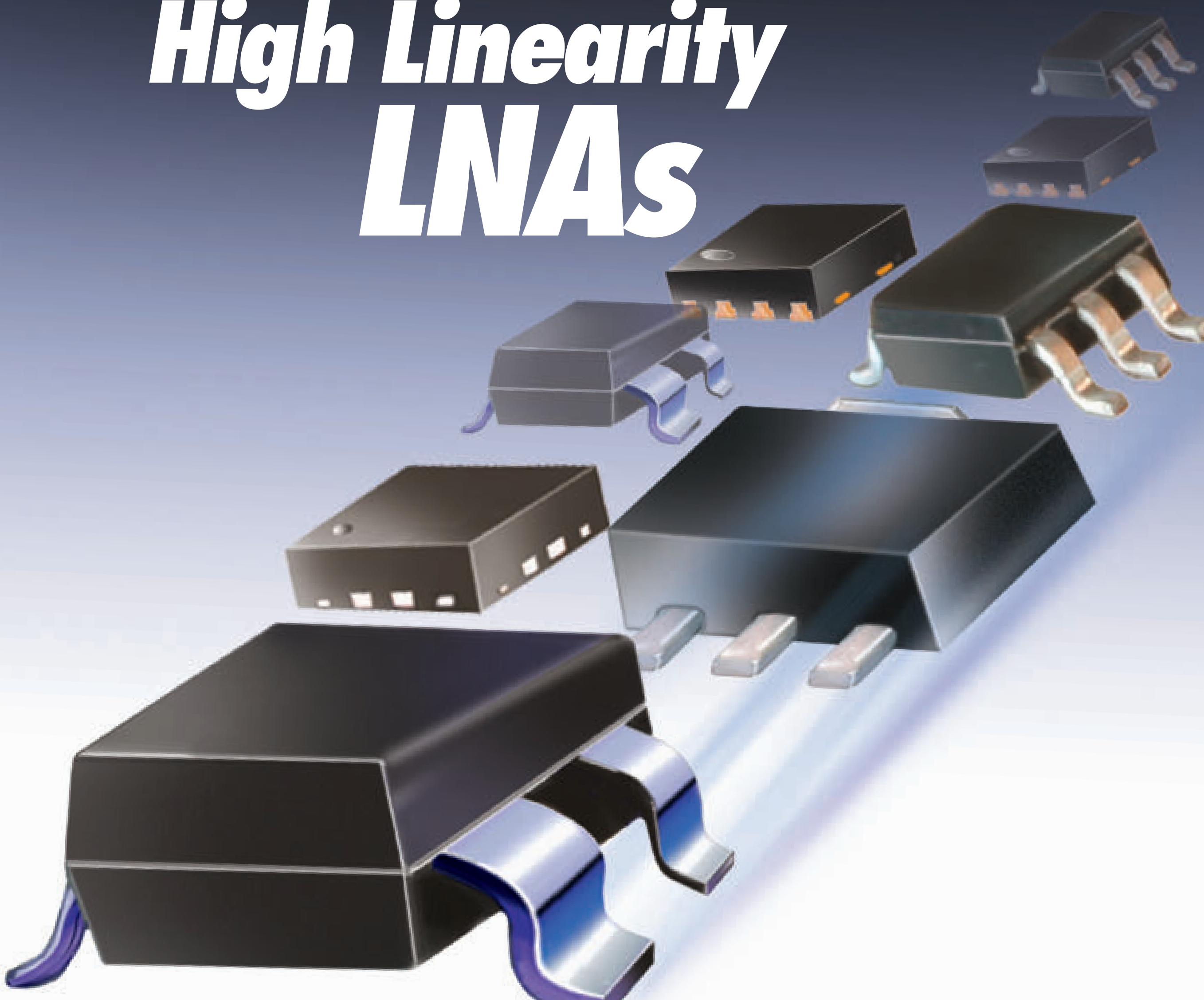

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PSA4-5043+	50-4000	18.4	**0.75**	**34**	19	33 (3V) 58 (5V)	2.50
PMA-5455+	50-6000	14.0	**0.8**	**33**	19	40	1.49
PMA-5451+	50-6000	13.7	**0.8**	**31**	17	30	1.49
PMA2-252LN+	1500-2500	15-19	**0.8**	**30**	18	25-55 (3V) 37-80 (4V)	2.87
PMA-545G3+	700-1000	31.3	**0.9**	**33**	22	158	4.95
PMA-5454+	50-6000	13.5	**0.9**	**28**	15	20	1.49

Model	Freq. (MHz)	Gain (dB)	NF (dB)	IP3 (dBm)	P_{out} (dBm)	Current (mA)	Price $ (qty. 20)
PGA-103+	50-4000	11.0	**0.9**	**43**	22	60 (3V) 97 (5V)	1.99
PMA-5453+	50-6000	14.3	**0.7**	**37**	20	60	1.49
PSA-5453+	50-4000	14.7	**1.0**	**37**	19	60	1.49
PMA-5456+	50-6000	14.4	**0.8**	**36**	22	60	1.49
PMA-545+	50-6000	14.2	**0.8**	**36**	20	80	1.49
PSA-545+	50-4000	14.9	**1.0**	**36**	20	80	1.49
PMA-545G1+	400-2200	31.3	**1.0**	**34**	22	158	4.95
PMA-545G2+	1100-1600	30.4	**1.0**	**34**	22	158	4.95
PSA-5455+	50-4000	14.4	**1.0**	**32**	19	40	1.49

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29	30	1 **Webinar:** **Modeling a High-Speed Serial Link** Sponsored by CST	2 **Besser Webinar:** **RF and Microwave Filters** Sponsored by AWR®	3 **Webinar:** **Designing with 4G Modulated Signals for Optimized Multi-Standard Transceiver ICs** Sponsored by Agilent Technologies	4	5
6 EUROPEAN MICROWAVE WEEK NCC NUREMBERG, GERMANY 6-11 OCTOBER 2013 www.eumweek.com MEET EXPERTS MAKE FRIENDS **35TH Annual Symposium of the Antenna Measurement Techniques Association** Columbus, OH	7	8	9 COMSOL CONFERENCE BOSTON 2013	10	11	12
13	14	15 IEEE **PHASED ARRAY 2013** Boston, MA	16 **Webinar:** **Fundamentals of Noise Figure Measurements** Sponsored by Agilent Technologies	17 **Webinar:** **Simulation and Measurement** Sponsored by CST	18 Microwave Update 2013 October 18-19, 2013 Morehead, Kentucky	19
20	21 IEEE COMCAS 2013 The International IEEE Conference on Microwaves, Communications, Antennas and Electronic Systems	22	23 IME/China 2013 Shanghai, China **Webinar:** **FieldFox** Sponsored by Agilent Technologies	24 **Webinar:** **MIMO Antenna Systems** Sponsored by CST	25	26
27	28 **MWP 2013 IEEE International Topical Meeting on Microwave Photonics** Alexandria, VA **4G WORLD 2013** Dallas, TX	29	30 **Webinar:** **Very-Near-Field Measurement Technique to Test Large Directional Antennas in Minutes** Sponsored by EMSCAN	31 **Webinar:** **Electromagnetic Simulation** Sponsored by CST	1	2

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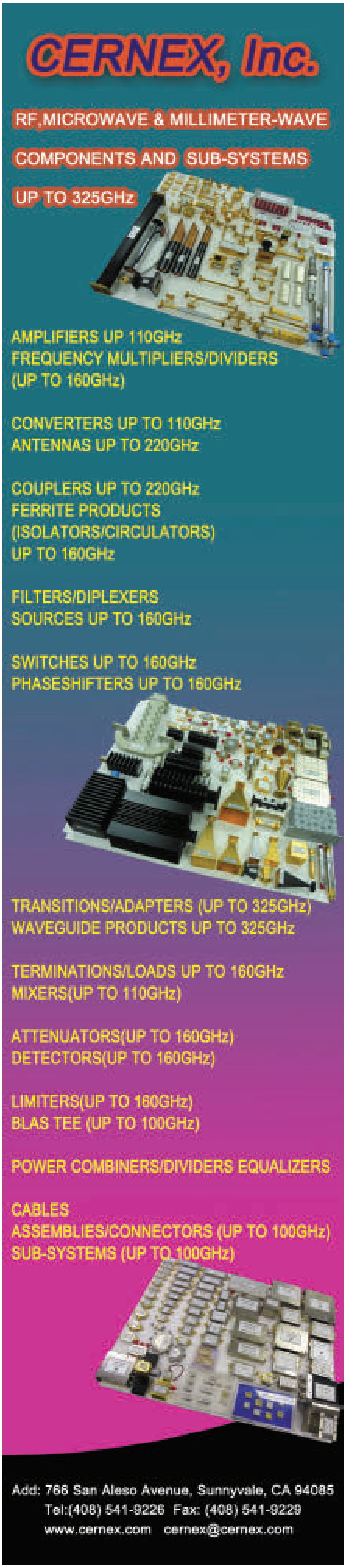

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December 9, 2013

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December 9, 2013

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December 31, 2013

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September 17–18, 2013 • Washington D.C.
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OCTOBER

AMTA 2013
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October 6–11, 2013 • Columbus, OH
www.amta2013.org

EuMW 2013
European Microwave Week
October 6–11, 2013 • Nuremberg, Germany
www.eumweek.com

COMSOL Conference 2013
October 9–11, 2013 • Boston, MA
www.comsol.com/conference2013/usa

Phased Array 2013
IEEE International Symposium on Phased Array Systems & Technology
October 15–18, 2013 • Boston, MA
www.array2013.org

Microwave Update 2013
October 18–19, 2013 • Morehead, KY
www.microwaveupdate.org

IEEE COMCAS 2013
International Conference on Microwaves, Communications, Antennas and Electronic Systems
October 21–23, 2013 • Tel Aviv, Israel
www.comcas.org

IME/China 2013
8th International Conference and Exhibition on Microwave and Antenna
October 23–25, 2013 • Shanghai, China
www.imwexpo.com

4G World 2013
October 28–30, 2013 • Dallas, TX
www.4gworld.com

MWP 2013
IEEE International Topical Meeting on Microwave Photonics
October 28–31, 2013 • Alexandria, VA
www.mwp2013.org

NOVEMBER

APMC 2013
Asia-Pacific Microwave Conference
November 5–8, 2013 • Seoul, Korea
www.apmc2013.org

2013 Loughborough Antennas & Propagation Conference
November 11–12, 2013 • Loughborough, UK
www.lapconf.co.uk

MILCOM 2013
Military Communications Conference
November 17–20, 2013 • San Diego, CA
www.milcom.org

DECEMBER

IMaRC 2013
IEEE International Microwave and RF Conference
December 14–16, 2013 • New Delhi, India
www.imarc-ieee.org

AEMC
4th Applied Electromagnetics Conference
December 18–20, 2013 • Bhubaneswar, India
www.ieee-aemc.org

JANUARY

IEEE RWW 2014
Radio Wireless Week
January 20–23, 2014 • Newport Beach, CA
www.radiowirelessweek.org

FEBRUARY

MWC 2014
Mobile World Congress
February 24–27, 2014 • Barcelona, Spain
www.mobileworldcongress.com

MARCH

SATELLITE 2014
March 10–13, 2014 • Washington D.C.
www.satellite2014.com

TAEECE 2014
2nd International Conference on Technological Advances in Electrical, Electronics and Computer Engineering
March 18–20, 2014 • Kuala Lumpur, Malaysia
www.sdiwc.net/conferences/2014/taeece2014

APRIL

EDI CON 2014
Electronic Design Innovation Conference
April 8–10, 2014 • Beijing, China
www.ediconchina.com

MAY

NEMO 2014
International Conference on Numerical Electromagnetic Modeling and Optimization for RF, Microwave and Terahertz Applications
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In April 2014, Horizon House, *Microwave Journal* and ACT International will host the second Electronic Design Innovation Conference (EDI CON) in Beijing, China. This annual event offers an industry-centric technical program on the latest technologies and techniques available to commercial organizations and academia addressing high-frequency electronic design and system integration. After a highly-successful debut this year, this technical conference and exhibition will expand its size and scope next year, adding a full third day to the technical program and nearly doubling the exhibition of test & measurement, design software, component, semiconductor device, materials and cable/connector manufacturers and semiconductor foundries. The event will bring together engineers engaged in RF/microwave, high-speed digital and EMI/EMC design with technologists offering information and products to help them achieve greater design success.

The conference program will consist of peer-reviewed papers from across the globe presented in four technical tracks: Design, Measurement & Modeling, System Engineering and Commercial Resources. In addition, the conference will feature industry-focused workshops and technical panels as well as plenary keynote talks examining the broader market and technology trends in high frequency systems, semiconductors, test and component design. Workshops and panels will cover the hot topics that concern today's engineers as determined by the industry itself. Building on this year's popular talks, conference organizers are anticipating content that will focus on developments in GaN, highly integrated front ends, RF CMOS, envelope tracking and DPD techniques, carrier aggregation, cognitive radio and high-speed channel design, to name a few.

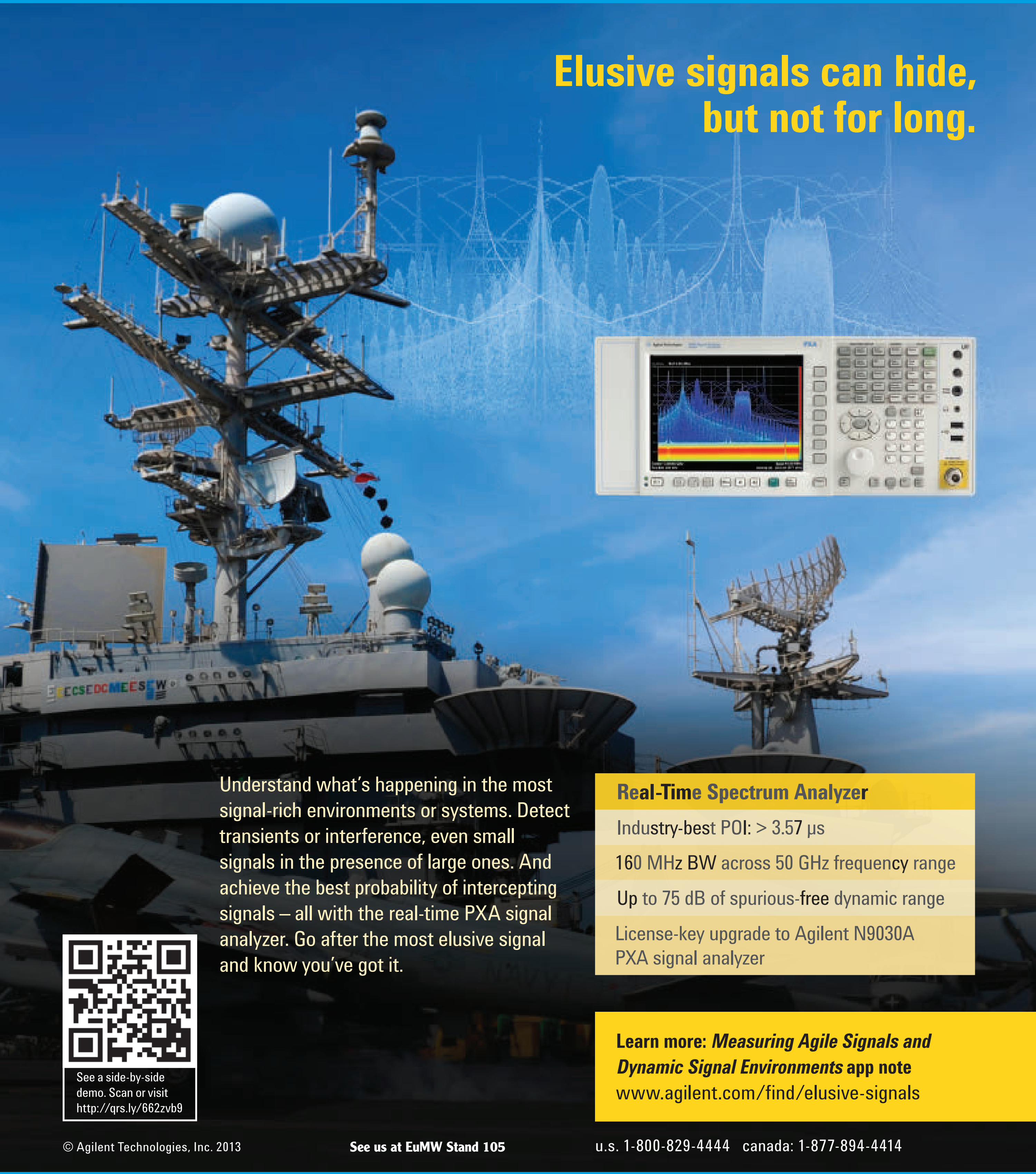
In areas where participating companies offer alternative solutions, special panels are being organized to present alternate perspectives on topics such as optimal device characterization techniques, design software needs, design-to-production testing and the role of modular instruments, over-the-air testing, selecting the "right" semiconductor technology and foundry services, etc. EDI CON panels and workshops will examine high-frequency electronic engineering in the context of today's changing communication standards and component requirements.

MWJ publisher Carl Sheffres and I traveled to Shanghai and Beijing last month to meet with EDI CON sponsors, potential exhibitors and speakers. Meeting directly with OEMs, component manufacturers, distributors, marketers and representatives from academia and several technical societies has provided insights into the leading trends in China's telecommunication market and the global supply chain. By working with organizations engaged in China, EDI CON is better able to identify and attract its targeted audience and ensure that the conference content is of the highest interest and relevancy.

Thanks to the success of the first year's event, EDI CON 2014 intends to double the exhibition space. Next year's event will feature a West Hall for test and measurement solutions and software providers and an East Hall for integrated device and active/passive component manufacturers, material providers and manufacturing services, cable assembly and connector manufacturers, semiconductor foundries and distributers. Organizers will be working with all exhibitors to ensure that the exhibition itself is well-integrated into the overall educational opportunities being offered. In-booth product demonstrations and tutorials will be encouraged and promoted to delegates. While North American and European engineers are very familiar with the professional RF/microwave exhibition, opportunities for a skilled local and international technical staff to interact directly with engineers at a professional exhibition is a relatively new occurrence in China and was extremely well-received at this year's event. Next year's event date will allow companies to re-introduce products released at early season trade shows (DesignCon, Mobile World Congress, Autotestcon, etc.) to the Chinese engineer. As a result of this year's success, new and returning exhibitors have committed to participating in next April's event and the exhibition hall is expected to sell out early.

This is a very exciting time in the expansion of microwave technology across the globe. As we covered in our lead story last May, telecommunication equipment deployments throughout Asia, the Middle East, Africa and Latin America are creating global engineering opportunities. *Microwave Journal China* and EDI CON will play a leading role in helping companies across the globe interface with design engineers and system integrators operating in China. With the print Chinese version now at 10,000 qualified readers and over 2,000 attendees from the first year's event, a beachhead for our industry to exchange information with this market is now well-established. We anticipate 2014 will build on this foundation and lead to new opportunities for all who participate.

DAVID VYE
Microwave Journal Editor



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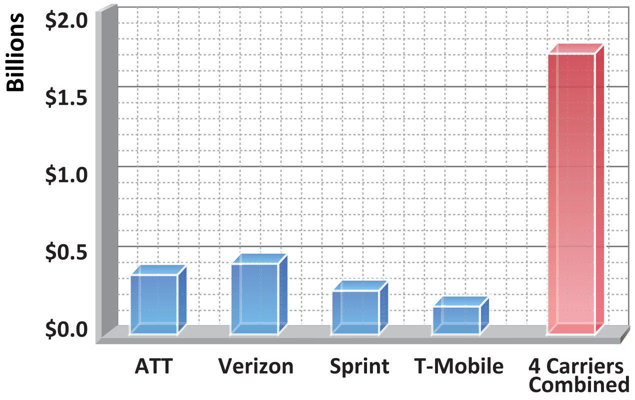

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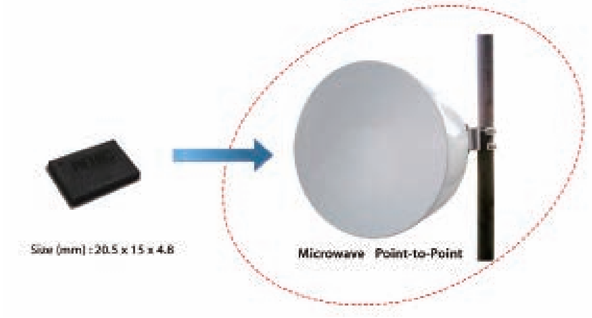
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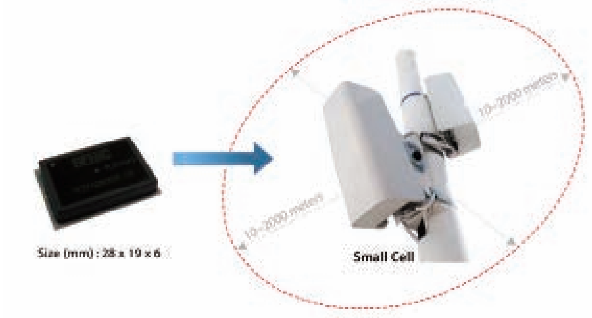
Microwave Point-to-Point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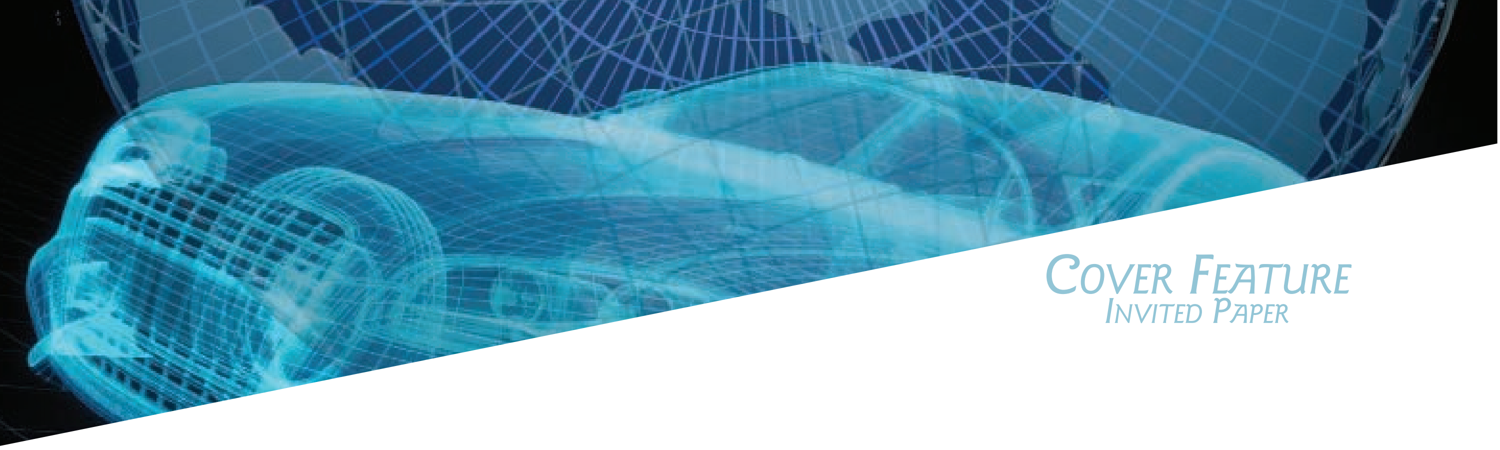
10~2000 meters
10~2000 meters
Small Cell



Automotive Radar: From Its Origins to Future Directions

The development of automotive radar was a little stop-start early on but has gained considerable momentum, interest and investment in recent years. This article plots the path from innovation to application and the move to commercialisation for automotive radar. It considers its early beginnings and current activity and identifies the technological trends driving the sector forward.

Let's begin by briefly offering some background into the roadmap for the development of automotive radar. Automatic cruise control (ACC) systems based on millimetre-wave radar have been the focus of significant research and development for several decades now. In the early 1970s, the first test vehicles with 35 GHz sensors were set on the road because, for the first time, 35 GHz antennas were small enough to fit into the front grill of a normal sedan.

It was not until 1998 that the Mercedes-Benz DISTRONIC system at 77 GHz became the first operational series product within the Mercedes-Benz S-Class, a premium type sedan. Eight years later this was followed by the DISTRONIC PLUS system, which combined a 77 GHz long range radar (LRR) sensor with two 24 GHz short range radar (SRR) sensors, making the system fit for urban traffic. Today this technology has moved to the commercial stage with all major automotive manufacturers introducing ACC systems, including the small car sector.

Besides 77 GHz for LRR, the 24/26 GHz frequency range was adopted for short range automotive radar sensors, employed either for blind spot detection (BSD) or as a lane change warner (LCW). Narrowband (NB) systems, operating in the ISM-Band (24.05 to 24.25 GHz) and ultra-wideband (UWB) systems between 21.65 to 26.65 GHz, with different advantages and disadvantages, are on the market today. Very recently digital beam forming (DBF) antenna technology combined with electronic scanning techniques have been introduced.

Today, existing radar sensors can be easily adjusted for new applications. For example, a BSD sensor can be adopted to function as a rear cross traffic alert (RCTA) sensor. Entirely new market opportunities are opening up, such as the adoption of medium range radar (MRR) systems in the 24/26 GHz range. In 2011, with the introduction of the Mercedes-Benz B-Class, COLLISION PREVENTION ASSIST (CPA) at 24 GHz became available as a standard series product in smaller cars and thus the democratisation of automotive radar has clearly begun.

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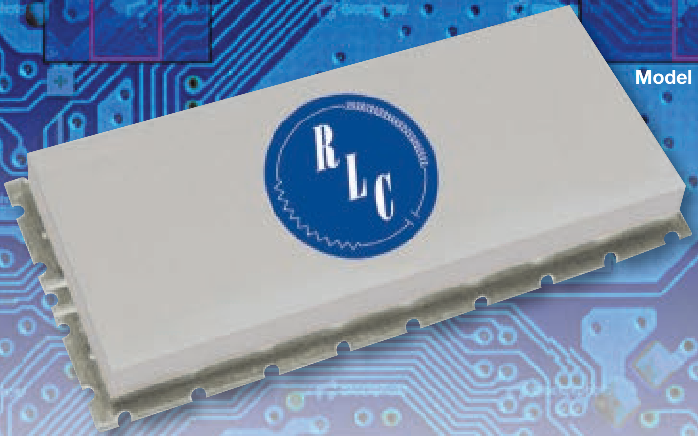
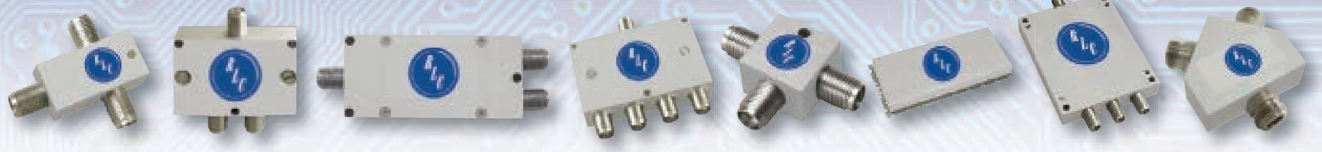


Model DSM-0520-2
shown here



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▲ *Fig. 1 10 GHz automotive radar system built by VDO in the early 1970s (Source: private collection of the author).*

▲ *Fig. 2 16 GHz automotive radar system built by Standard Electric Lorenz (SEL) in 1975 (Source: private collection of the author).*

▲ *Fig. 3 35 GHz automotive radar system built by AEG-Telefunken in 1974 (Source: private collection of the author).*

HISTORY

In the early 1970s, the general requirements for automotive radar applications were developed within NTÖ 49, a German research program supported by what was then the Ministry of Science and Technology (BMFT). The necessary range (100 m) and corresponding antenna requirements (2.5 by 3.5° for az and el) were theoretically calculated and tested. This demonstrates that even then, the idea of using automotive radar as a means to reduce the accident rates on our streets was being considered.

Applying the newly developed 35 GHz technology, based on two terminal devices, like IMPATT, GUNN and Schottky diodes, made it possible, for the first time, to fit such a radar unit into the front of a standard sedan. Before that, a 10 GHz roof installation or a front bumper set up at 16 GHz had been the only options. Various cars, buses and trucks were equipped with radar sensors (see ***Figures 1-3*** and Figure 8) and tested worldwide – in the beginning at very different frequencies: 24, 35, 47, 60 and 94 GHz; the latter being a 'leftover' from military applications and thus available components.

The Japanese 60 GHz approach was political; both mm-wave radar and communication systems could be investigated, employing the same semiconductor devices and mm-wave components. The introduction of 77 GHz as a worldwide standard for automotive LRR (see ***Figure 4***) within WARC 89 clarified the situation.

A first BSD sensor was presented as early as 1971 by Bendix Research Laboratories in Southfield, MI, USA, employing slotted array type antennas with waveguide feeds at 16 GHz. The description given was: "The antenna patterns intersect adjacent lines to illuminate the blind spot areas and to warn of the presence of approaching automobiles with a light or audible signal."

More than 20 years later, in 1995, HE Microwave Corp. (Hughes Elec-

▲ *Fig. 4 Antenna configuration schematic of DISTRONIC PLUS, where orange is a 77 GHz LRR-sensor and green is a 24 GHz SRR-sensor (Source: Daimler AG, Stuttgart, Germany).*

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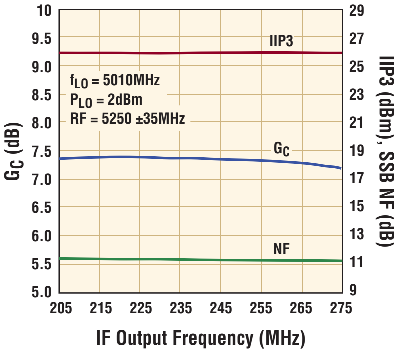

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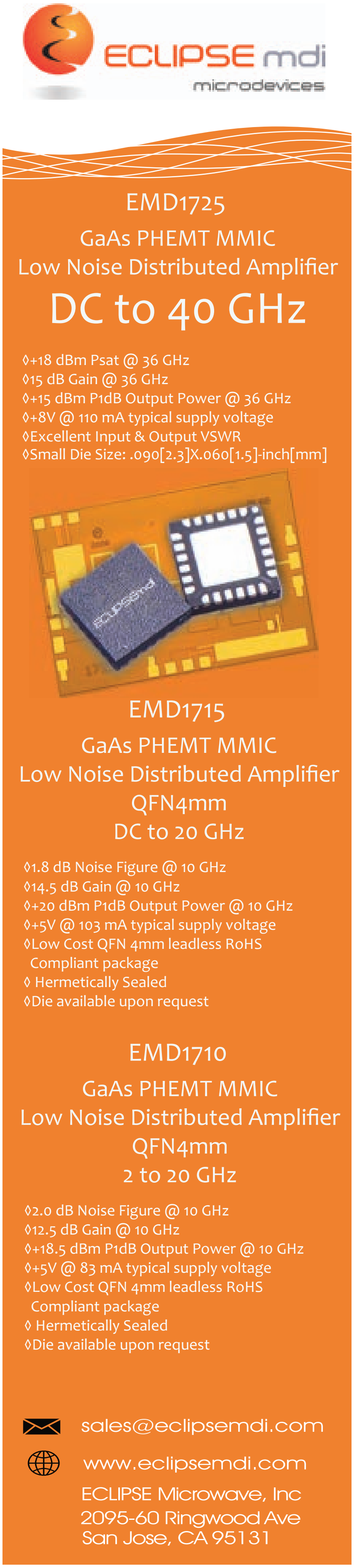
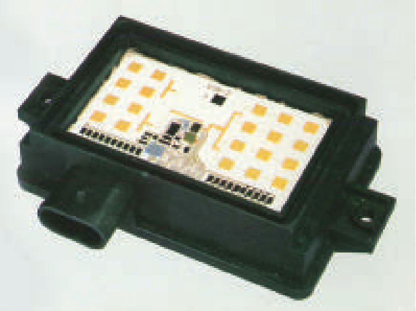




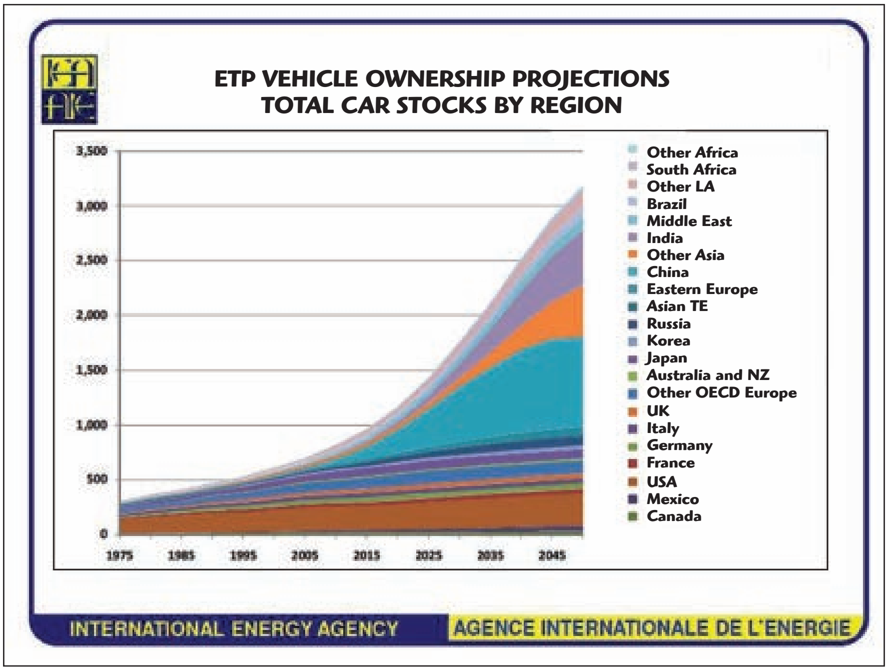
▲ *Fig. 5 24 GHz SDS system built by HE Microwave, 1995 (Source: HE Microwave publication, IEEE MTT-S, 1995, San Francisco, USA).*

▲ *Fig. 6 Blind spot detection (BSD) incorporating two separate 24/26 GHz SRR sensors (Source: Daimler AG, Stuttgart, Germany).*

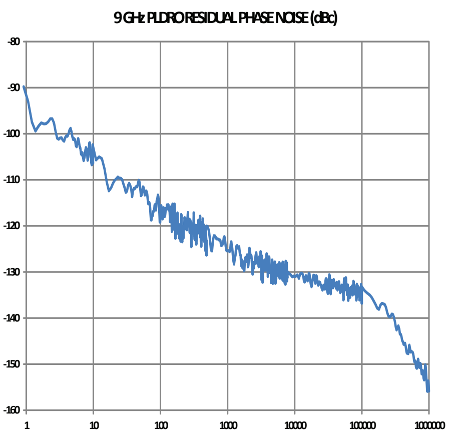
tronics) in Tucson, AZ, USA, proposed 24 GHz for their side detection sensor (SDS) system for trucks (shown in ***Figure 5***). The description here was: "The SDS was conceived to assist the driver in accessing the viability of lane change." Today 24/26 GHz is the general frequency approach, being taken for BSD sensing (see ***Figure 6***). Companies, like Valeo or Hella in Germany, to mention just two, already produce more than one million such sensors each per year (2012 statistics).

New market developments for technically innovative products like automotive radar are typically a reaction to social developments and specific emerging needs. The trend towards megacities worldwide accompanied by the democratization of mobility in highly populated countries (shown in ***Figure 7***) like the BRIC (Brazil, Russia, India and China) countries, which accounted for more than 40 percent of all car sales in 2012, has led to a dramatic increase in traffic density and thus accident rates on the streets, prompting the need for enhanced vehicle safety and more driver assistance.

Due to their unique physical performance, automotive radar sensors are the worldwide backbone of modern vehicle safety and driver assistance systems. Though they are not the only means – laser scanner and video camera systems are competing technologies. Based on expected trends, it is quite simple to forecast that the density of radar systems will explode like the worldwide number of cars over the next few decades. The higher the growth in radar density, the more important it will be to guarantee the interoperability of such sensors, especially as we move from simple comfort to highly sophisticated safety applications, employing automotive radar systems.



▲ *Fig. 7 Total car stocks by region – projections (Source: International Energy Agency (IEA)).*



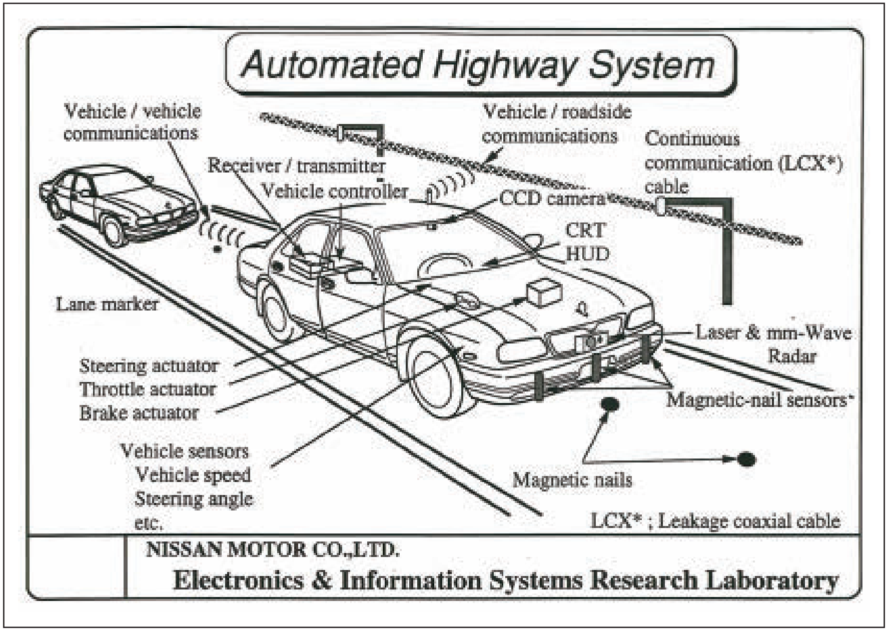
▲ *Fig. 8 24 GHz CWS system built by EATON-VORAD, 1996 (Source: private collection of the author).*

EARLY SYSTEMS AND RESULTS

As early as 1992, the EATON-VORAD collision warning system (CWS) at 24 GHz was installed in more than 4000 buses and trucks in the U.S., from Greyhound buses (see ***Figure 8***) to rental trucks, providing an acoustic warning for the driver only. Having been driven on more than 900 million kilometres of road, it can be confirmed that the amount of accidents per km travelled could be reduced by more than 50 percent; more than that, the resulting severity of accidents still occurring was heavily reduced. However, the radar units had to be de-installed, due to protests from the U.S.-driver-unions as the CWS radar made drivers 'transparent' to their employers and the drivers objected. Clearly, the time was not yet ready for such a system.

In the 1990s, an automated highway system was built and tested in Japan on about 100 km of a newly built highway. Vehicle2roadside communication, using a leakage coaxial cable (LCX), magnetic nails in the road surface and corresponding sensors for lane control, as well as mm-wave radar for distance control, dubbed the automotive collision avoidance system (ACAS), were utilized for these first driverless cars, not forgetting a CCD camera for lane marker detection (see ***Figure 9***). The Electronic Information Systems Research Laboratory of Nissan Motor Co. Ltd. was one of the protagonists of this system. The achieved results were quite promising, however, at the time, the necessary environmental installations – LCX, magnetic nails, etc. – were thought to be too expensive.

Later that decade, when Mercedes-Benz first introduced the Distronic system, the take-up rate was not at all favorable at the beginning, and the timed spread from S-Class to other classes was quite slow. However, since the introduction of DISTRONIC PLUS eight years later, the situation has changed significantly. With Brake Assist Plus and PRE-SAFE Brake having



▲ *Fig. 9 Automated Highway System built by NISSAN Motor Co. Ltd. (Source: Nissan Motor Co. Ltd.).*

PLASMONICS: Model of an electromagnetic plane wave incident on a plasmonic wire grating.

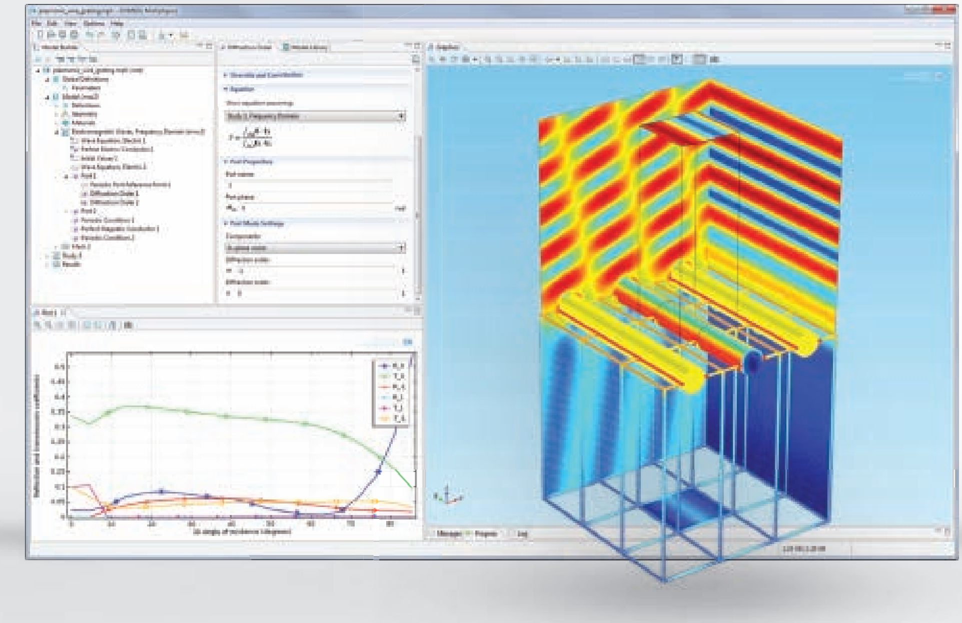


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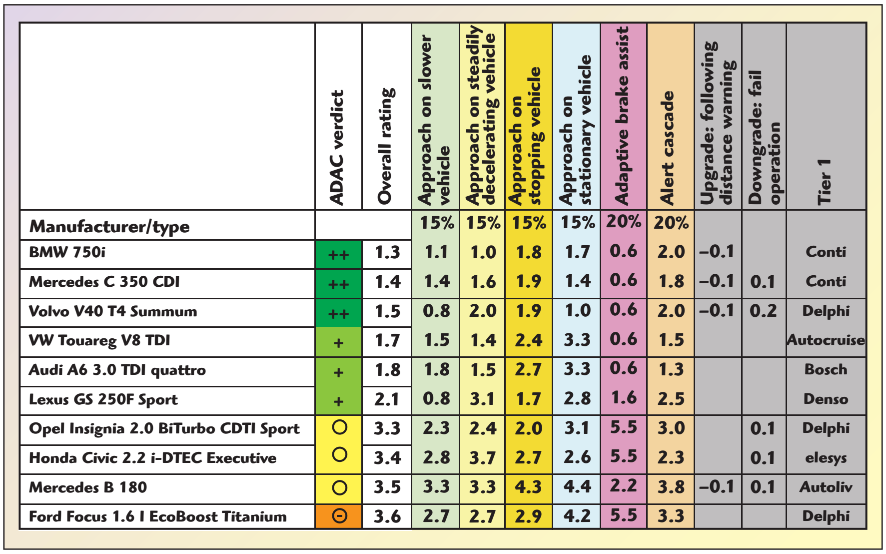
Fig. 10 Pre-safe brake – developed and confirmed for sedans – now in trucks (Source: Daimler AG, Stuttgart, Germany).

become part of the system package (shown in ***Figure 10***), these systems have become directly driver recognizable and well perceived by the public. The paradigm change from comfort to safety systems has started to take place.

STATE-OF-THE-ART

In September 2012, the ADAC, Germany's major automobile club and thus the political driver lobby, tested all the available automotive radar systems in Germany. Ten different cars: BMW 750i, Mercedes C 350 CDI, Volvo V40 T4 Summum, VW Touareg V8 TDI, Audi A6 3.0 TDI quattro, Lexus GS 250F Sport, Opel Insignia 2.0 BiTurbo CDTI Sport, Honda Civic 2.2 i-DTEC Executive, Mercedes B 180 and Ford Focus 1.6 EcoBoost Titanium were tested.

Different radar sensors being built-in and commercially available from seven – mostly European – manufacturers, including TRW-Autocruise,



	ADAC verdict	Overall rating	Approach on slower vehicle	Approach on steadily decelerating vehicle	Approach on stopping vehicle	Approach on stationary vehicle	Adaptive brake assist	Alert cascade	Upgrade: following distance warning	Downgrade: fail operation	Tier 1
Manufacturer/type			15%	15%	15%	15%	20%	20%			
BMW 750i	++	1.3	1.1	1.0	1.8	1.7	0.6	2.0	–0.1		Conti
Mercedes C 350 CDI	++	1.4	1.4	1.6	1.9	1.4	0.6	1.8	–0.1	0.1	Conti
Volvo V40 T4 Summum	++	1.5	0.8	2.0	1.9	1.0	0.6	2.0	–0.1	0.2	Delphi
VW Touareg V8 TDI	+	1.7	1.5	1.4	2.4	3.3	0.6	1.5			Autocruise
Audi A6 3.0 TDI quattro	+	1.8	1.8	1.5	2.7	3.3	0.6	1.3			Bosch
Lexus GS 250F Sport	+	2.1	0.8	3.1	1.7	2.8	1.6	2.5			Denso
Opel Insignia 2.0 BiTurbo CDTI Sport	○	3.3	2.3	2.4	2.0	3.1	5.5	3.0		0.1	Delphi
Honda Civic 2.2 i-DTEC Executive	○	3.4	2.8	3.7	2.7	2.6	5.5	2.3		0.1	elesys
Mercedes B 180	○	3.5	3.3	3.3	4.3	4.4	2.2	3.8	–0.1	0.1	Autoliv
Ford Focus 1.6 l EcoBoost Titanium	⊖	3.6	2.7	2.7	2.9	4.2	5.5	3.3			Delphi

Fig. 11 Available ADAS systems in Germany (Source: ADAC Test Zentrum, Landsberg, Germany).

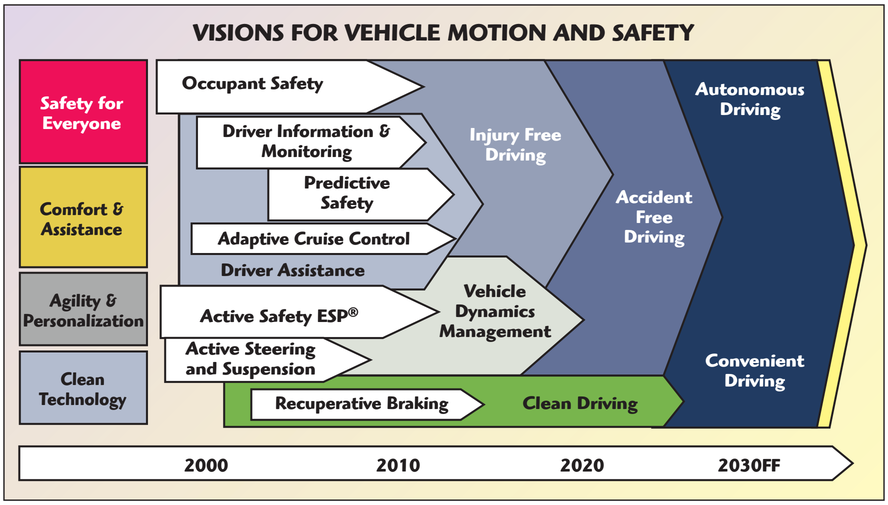
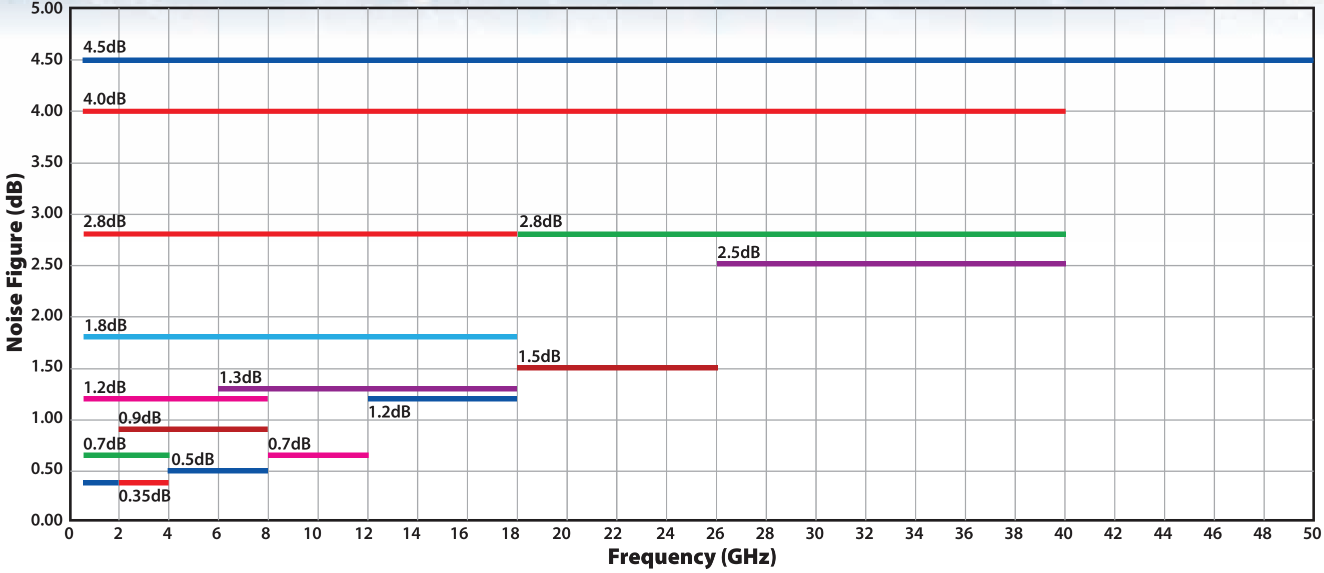


Fig. 12 Visions for Vehicle Motion and Safety (Source: Bosch GmbH, Stuttgart, Germany, during EuMW 2012).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Noise Figure (dB)
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0.7dB
0.5dB
0.35dB

Autoliv, Bosch, Continental, Delphi, elesys (U.S.) and Denso (Japan) were carefully investigated (see ***Figure 11***). The results are quite good, ratings from "++" to "0-" were given, as well as tips for specific car systems to be enhanced in the future with some minor adaptations. However, the main issue of significant safety enhancements due to these systems being installed could be confirmed by these tests.

Under such conditions, it is quite obvious for any OEM investigating the next generation of radar that it will not be sufficient to utilize a sensor that has demonstrated to be insensitive compared to others. The sensor itself has also to be proven not to disturb or to blind others. To check this for the OEM, as well as for the corresponding supplier, it would be advisable to use something like a norm-interferer as a qualification or test device. Such a device should be able to cover a large variety of modulation schemes and bandwidths that the sensor under question could be tested against.

Another goal has to be keeping the opportunities open to meet future demands in the move towards interoperability. One prominent issue of concern is the corresponding frequency band as well as the bandwidth taken per sensor to allow for, e.g., frequency hopping. Future frequency regulation strategies should aim to get worldwide access to higher frequency bands, using larger bandwidths per sensor. A minimum bandwidth of 2 to 3 GHz is very likely to be required for future traffic scenarios, like pedestrian recognition or side-impact-alert.

As a consequence, this requires a concerted effort by radar manufacturers, backed by their corresponding OEMs, to identify and to agree upon a common design rule book. Such guidelines should quote commonly agreed countermeasures to combat interference, while keeping opportunities open for each manufacturer to develop his individual radar. The EU-funded MOre Safety for All by Radar Interference Mitigation (MOSARIM) project was a first step in the right direction. MOSARIM was openly described and broadly discussed within the community during EuMW 2012 in Amsterdam; the EuMC/EuRAD WS23 being the official and final event of the program.

- The technical requirements of future (and more complex) driver assistance and vehicle safety systems, demanding higher resolution and accuracy in space and time.
- Vehicle integration and sensor packaging demands miniaturisation, while enhancing sensor performance.
- Cost reduction based on 'economies of scale' – shifting to the 76 to 81 GHz range enables the development of radar modules that can be used for all automotive radar types from LRR via MRR to SRR.
- Interoperability, since the market penetration of automotive radars will explode; interference mitigation has to become the key for further market growth. A large bandwidth enabling frequency hopping or other efficient frequency separation procedures has to be manda-

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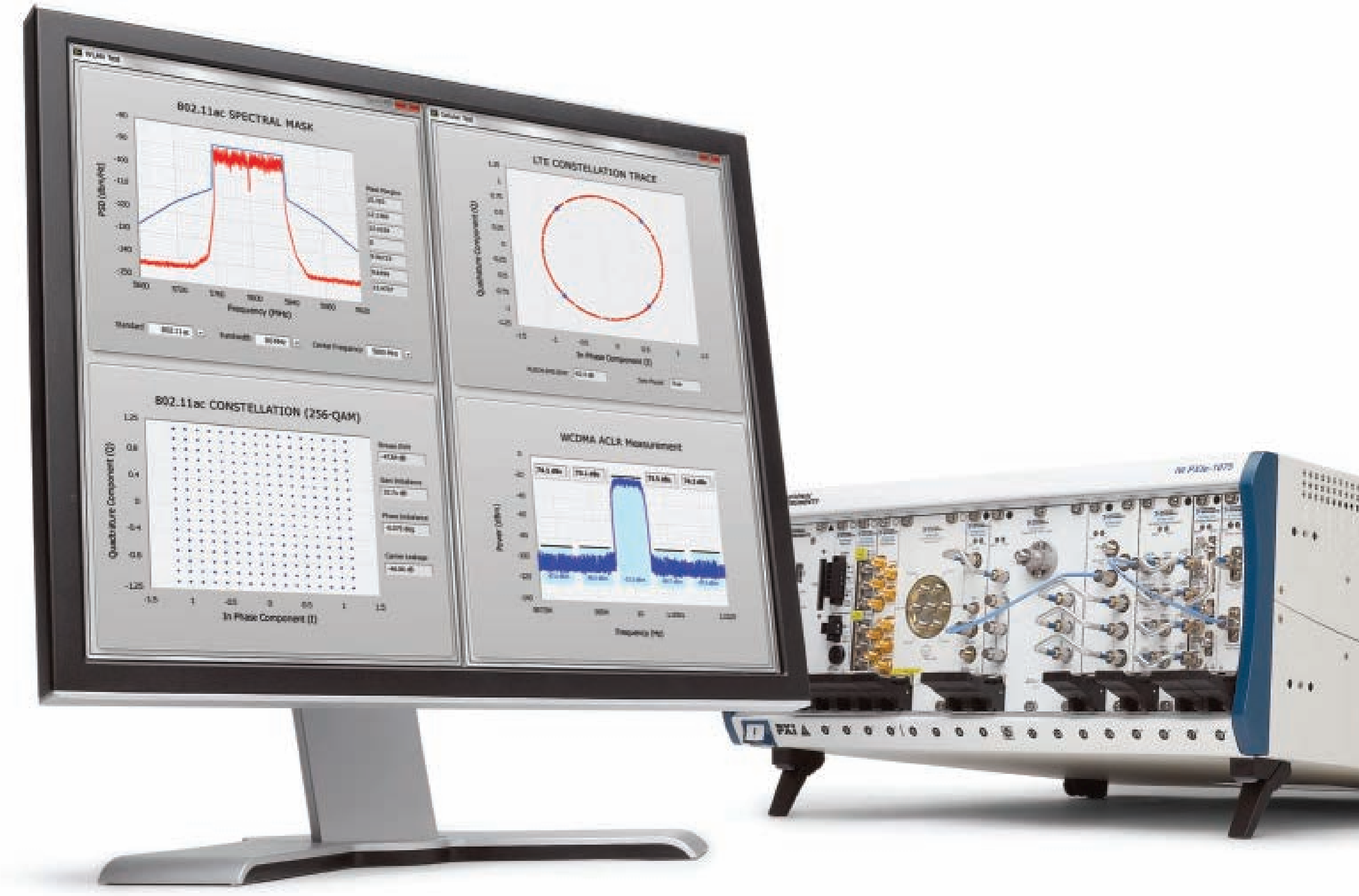

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tory and is available worldwide only between 76 to 81 GHz.

However, more ongoing efforts concerning automotive radar performance necessary to meet future requirements are already under development. This can be evidenced at European Microwave Week 2013 where workshops (W20, 24, 26), the EuMC and EuRAD opening ceremonies, as well as regular sessions (EuRAD 12, 13), The Defence and Security Forum and the MicroApps (Thursday morning session), within the European Microwave Exhibition, will describe and discuss automotive radar issues thoroughly and put them into context.

FUTURE DIRECTIONS AND TRENDS

Following on from today's radar sensors that are already available on the market, injury free driving and better and more efficient vehicle management, resulting in lower consumption, will be an imminent future issue (see ***Figure 12***). Applications like RCTA, supporting a driver while backing-up from a parking lot or rear-pre-crash (RPC), detecting and calculating critical objects approaching from the rear, are being implemented, e.g., in the new MB S-Class, launched in July 2013 (shown in ***Figure 13***). Accident free driving and subsequently autonomous driving can technically be viewed as a medium to long range vision.

▲ *Fig. 13 New Mercedes-Benz S-Class, featuring a rear-pre-crash sensor alongside a LRR and four SRR sensors (Source: Daimler AG, Stuttgart, Germany).*

Within Horizon 2020, the upcoming new six year research plan of the EU, the further reduction of traffic fatalities is a major consideration, taking automotive radar sensors besides cameras into focus for the future. The European slogan of the current decade with regards to the direction of automotive sensor development is: 2011-2020 – the Decade of Action for Road Safety.

The rollout of EuroNCAP is one of these EU road safety targets for 2020, asking for ACC, BSD, LCA, RCTA and other back-up aids, as is the autonomous emergency braking system (AEBS) for trucks. The mandatory implementation of AEBS for commercial vehicles in Europe – a very near term issue – will significantly increase the take-up rate in trucks from a few percent in 2013 to full installation in 2015.

It has to be assumed that the already established 77 GHz technology will be used when the AEBS function becomes mandatory. After 2015, an annual growth rate of 3 percent has to be envisioned. However, other sensor technologies or radar systems using different frequencies may take over parts of this huge market, which amounts to about 1 million sensors per annum for trucks in Europe alone.

Autonomous driving as such is the final and long term direction of EU research. However, China and Japan are on this track too. In China, a driverless car (a Hongqi Q3) drove from Changsha to Wuhan (286 km) with a


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speed of about 90 km/h, while passing 67 vehicles on the way (see ***Figure 14***). This car was developed and built by the University of Defense Technology and unlike foreign unmanned vehicles, relying on GPS information and digital mapping, China's Hongqi Q3 used surround sensing systems and intelligent decision making to control the vehicle.

Being part of the China Intelligent Vehicle Challenge, the goal was set to: "in 2015 China should have the technologies for completely unmanned vehicles, able to operate continuously for more than 200 km in a natural environment, and on 2,000 km on the expressway, respectively." The Hongqi Group – one of China's major vehicle manufacturers, as well as First Automotive Works (FAW), cooperating with Volkwagen AG of Germany, have been part of the challenge since 2011, with the National natural Science Foundation Commission of China (NSFC) coordinating the competition.

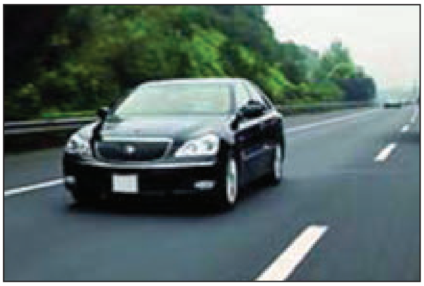


Fig. 14 The Hongqi Q3 test car on the Beijing-Zhuhai-Highway (Source: Hongqi, China).

Fig. 15 The Lexus Advanced Safety Research Vehicle (Source: Toyota, Japan).

In Japan, the organizer of the autonomous driving project is the Ministry of Land, Infrastructure, Transport and Tourism (MLIT). The OEM participants of the project are Toyota Motor Corp., Nissan Motor Co. Ltd., Fuji Heavy Industries Ltd., Honda Motor Co. Ltd., and Mazda Motor Corp., with the Tokyo Institute of Technology taking the chair. Toyota announced details of its entry into the autonomous vehicle race at the annual Consumer Electronics Show (CES) 2013 in Las Vegas, USA in January. The Advanced Safety Research Vehicle, a Lexus RS (see ***Figure 15***), utilized a variety of technologies, including GPS, mm-wave radar, laser tracking and stereo cameras, to achieve its autonomy.

A very interesting idea was proposed by MLIT: an operating company undertakes the operation of the driverless vehicle for a certain period of time or a certain distance. To use this service, the owner of this car makes a contract with the operating company and pays a fee. If an accident occurs during automated driving, the operating company will take responsibility. As a result, neither the car maker nor the driver has to take responsibility in the case of an accident instigated by the use of automated cars.

Within EU-projects like 'Interactive,' the utmost benefit of adding a la-

ser scanner and a mono vision camera system to long and short range radar has been evaluated. It could be demonstrated that radar and laser scanners are intelligent additions to each other, solving the majority of perception challenges. What they leave unsolved is done by mono vision camera support. Hence, for the foreseeable future, LRR and SRR sensors will remain the workhorse of the automotive industry.

The EU commission's ICT for Transport is searching for new solutions; C2C RadCom, utilizing the 76 to 81 GHz radar bands on a time-shared basis (e.g., by means of OFDM modulation) for ID and information exchange between closely operating cars, is such an application, enhancing radar operation.

The concept of employing even higher frequency bands than the 77 GHz range for automotive use, e.g., 158 GHz for ACC or 122 GHz for near-range parking sensors are trends being encouraged by the EU commission. Within the European 'success-project,' which was finalized in May this year, the appropriate technology for 122 GHz was developed and investigated.

Other EU projects should be mentioned, such as SAfe Road TRains for the Environment (SARTRE), whereby research is ongoing under the lead of Volvo Trucks for platooning, i.e., enabling very close separation distances between trucks at normal speeds by means of highly automated longitudinal and lateral control in a road train. Some years ago Mercedes-Benz Trucks worked on a similar project dubbed "elektronische Deichsel" (electronic towbar). The applicability and usefulness of this approach was tested during several test campaigns carried out on the Brenner highway between Austria and Italy in the 1990s. Issues like the ones just described will be discussed in detail within W24 on Automotive Radar, as part of the EuMC/EuRAD program at EuMW 2013.

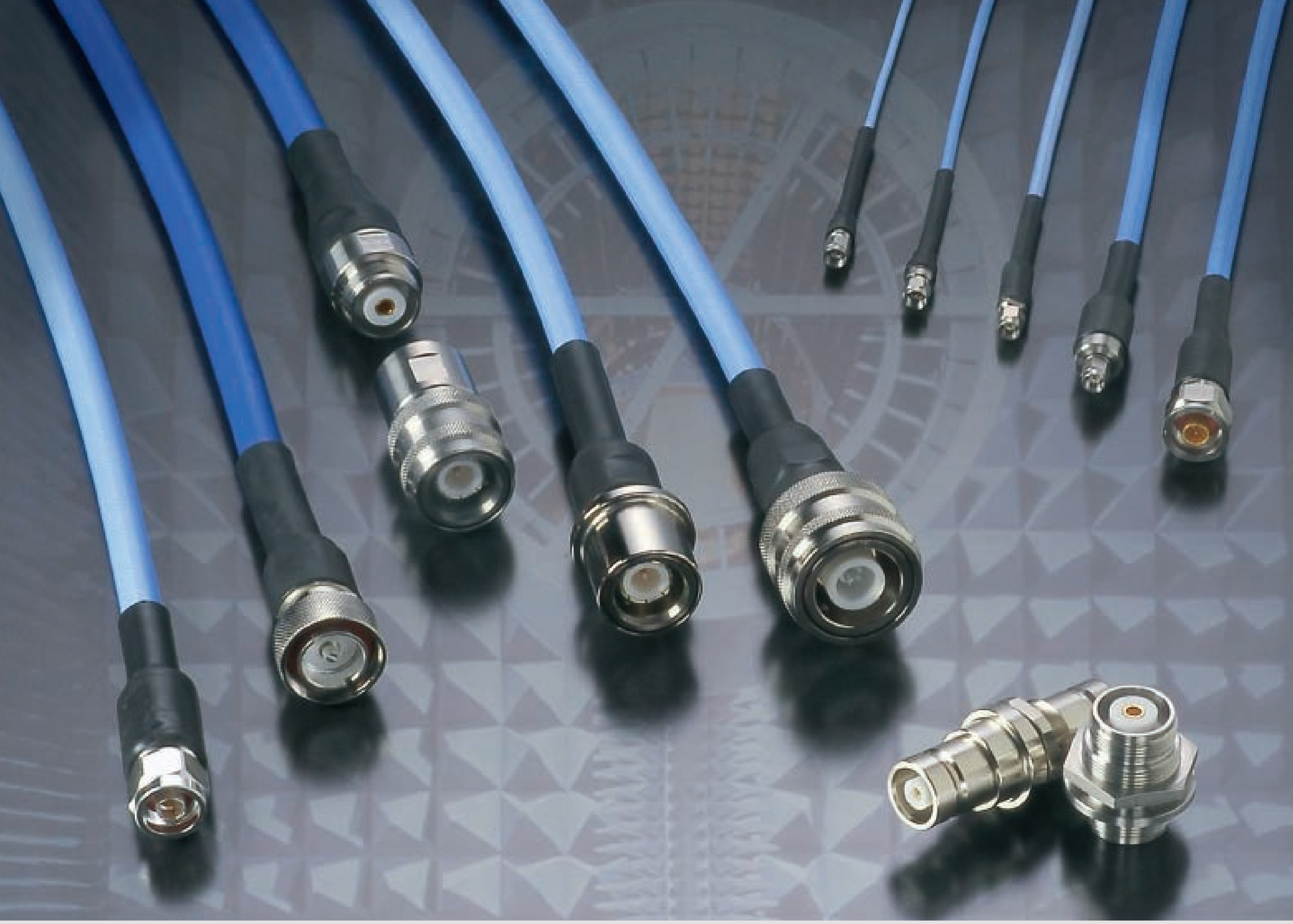
CONCLUSION

Taking all of the trends and assumptions described as a whole, it is apparent that the paradigm change that had to come, has already taken place: Until today all automotive systems had only a narrow planning horizon – the driver takes action with the system re-acting; in the future we will have a substantially longer planning horizon – the system will take action, while the driver is in control only; and advanced driver-control systems need a very good explanation for proper use – ADAC requires easy-to-understand demo video(s) to make it easy for people to comprehend.

Automotive radar in all its facets, from LRR via MRR to SRR, has shown that it has the capability to reduce the number and the severity of road accidents. We are currently in the "decade of action for road safety 2011-2020" and autonomous driving has come into direct focus with automotive radar being the workhorse for this ADAS approach in the future.

To put it into words: today we are already able to drive with:

- "Feet off" – employing ACC systems like Distronic Plus
- "Hands off" – becomes feasible using the upcoming 'Autobahn Pilot'
- "Eyes off" – has still to be demonstrated and made possible. ■



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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

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

Cliff Drubin, Associate Technical Editor

UAVs Proved Useful During Peacekeeping Missions and the Global War on Terror

With surveillance taking an increasingly important role both on and off the battlefield, ASDNews' report – The Global UAV Market 2013-2023 – forecasts robust spending in the global UAV market to 2023, with the market expanding from US$7.3 billion in 2013 to US$14.0 billion by 2023 – a CAGR of 6.75 percent. This substantial growth is fueled by the growing need for persistent surveillance of large areas, providing enhanced situational awareness and responsiveness to military forces.

North America Dominates Market

The U.S. is the largest defense spender in the world – a position that is well reflected in its domination of the UAV market. Strategic Defence Intelligence's research indicates that it will spend US$52.1 billion on UAVs between 2013 and 2023.

While Europe has borne the brunt of the global economic crisis – which has had severely detrimental consequences for military spending – the region is still expected to increase its UAV spending over the next decade, though it will be overtaken by the ever more powerful Asia Pacific region, which is expected to hold the second largest share of the UAV market by 2023.

Demand Driven by Security Threats

UAVs have proved to be exceedingly useful not only during peacekeeping missions, but also in the ongoing global war on terror in Afghanistan and Pakistan, finding applications across ISR and combat roles. Furthermore, enhanced capabilities in areas such as endurance, data processing and communications have broadened ISR UAV use in both defense and intelligence roles.

Security threats posed by cross-border insurgents, illegal immigrants, pirates, hostile nations and terrorist organizations have created a need for defense systems capable of carrying out surveillance and intelligence gathering missions. UAVs provide enhanced coverage along remote sections of a country's border, and UAVs equipped with electro-optical (EO) sensors can identify images from an altitude of 60,000 feet, providing real-time imagery to a ground control operator. This enables fast and informed decisions to be made regarding deployment of border patrol agents.

UAVs also have a wider range than border security forces on patrol or stationary surveillance equipment, and have a higher probability of tracking illegal immigrants seeking to enter a country through dense woods or mountainous terrain. Moreover, compared to a manned defense system such as a helicopter, UAVs have a longer flight time: the Predator B UAV can fly for 30 hours without refueling, while a helicopter's average fuel time is an estimated two hours. Owing to all these factors, countries across the globe are investing in the procurement – as well as research and development – of UAVs.

Demand Driven by Border Disputes

Territorial disputes among countries lead to a competitive acquisition of defense systems within a region. Such contemporary disputes involve India and Pakistan, South Korea and North Korea, Thailand and Cambodia, and China and Taiwan; all are driving the global UAV market.

Moreover, China's increasing dominance in the South China Sea, coupled with an unstable regional environment, has more broadly increased demand for UAVs in the Asia-Pacific region. China plans to launch UAVs in 11 provinces to survey and patrol the nation's coastal borders. It is also pursuing an aggressive development and production plan for Unmanned Combat Air Vehicles (UCAV) such as the Lijian and CH3.

China has laid claims to the entire South China Sea – a move that has precipitated territorial disputes with a number of countries, including Japan, Taiwan and Vietnam. This has led to Japanese authorities borrowing Global Hawk UAVs from the U.S. to monitor its coasts, and they have now expressed interest in purchasing about three of them by 2015.

Northrop Grumman, U.S. Navy Complete First Arrested Landing

Northrop Grumman Corp. and the U.S. Navy have completed the first arrested landing of the X-47B Unmanned Combat Air System (UCAS) carrier demonstration aircraft on the deck of the USS George H.W. Bush (CVN 77). The Northrop Grumman-built aircraft landed at 12:23 PM eastern time while the aircraft carrier was under way off the coast of Virginia, and marks the latest and most significant achievement for the program during carrier sea trials, which began in May.

"Today's historic carrier landing and our operations aboard USS George H.W. Bush show, beyond a shadow of a doubt, that tailless unmanned aircraft can integrate seamlessly and operate safely from an aircraft carrier at sea," said Capt. Jaime Engdahl, Navy UCAS program manager. "Beyond X-47B, this moment in history was made possible by an extremely disciplined and dedicated government-industry team that took a brand new unmanned combat air system from initial concept to highly successful demonstration in one of the most demanding operating environments in the world."

The X-47B aircraft took off from Naval Air Station (NAS) Patuxent River, MD, July 10. A mission operator aboard the carrier took control of the aircraft and monitored the flight operations, which included several planned precision approaches in preparation for the first arrested landing.

During the testing, the X-47B completed the 35 minute journey from Pax River to the carrier and caught the three-wire with the aircraft's tailhook. The arrested landing effectively brought the aircraft from approximately 145 knots to stop in less than 350 feet.

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"Although it looks like it could be an easy maneuver, this successful arrested landing points back to a rigorous test plan focused on software development and system maturity to prove today that an autonomous unmanned system such as the X-47B can safely, seamlessly and predictably integrate into Navy carrier operations," said Carl Johnson, vice president and Navy UCAS program manager for Northrop Grumman Aerospace Systems.

The arrested landings aboard the Bush mark the third major aviation achievement by the UCAS-D program since May. On May 14, the X-47B became the first unmanned aircraft to be catapult launched from a Nimitz class aircraft carrier. On May 17, the aircraft performed the first in a series of precision approaches and touch-and-go landings on a carrier by an unmanned system.

Northrop Grumman is the Navy's UCAS-D prime contractor. The company designed and produced the program's two X-47B air vehicles. An integrated test team of Northrop Grumman and Navy personnel executed the rigorous flight test and carrier suitability test sequence that culminated in this first arrested landing of an autonomous unmanned aircraft.

Northrop Grumman's UCAS-D industry team includes Pratt & Whitney, GKN Aerospace, Eaton, General Electric, UTC Aerospace Systems, Dell, Honeywell, Moog, Wind River, Parker Aerospace, Rockwell Collins and Lockheed Martin.

U.S. Army Takes Control of JLENS Airships During Final "Test-Drive" in Utah Desert

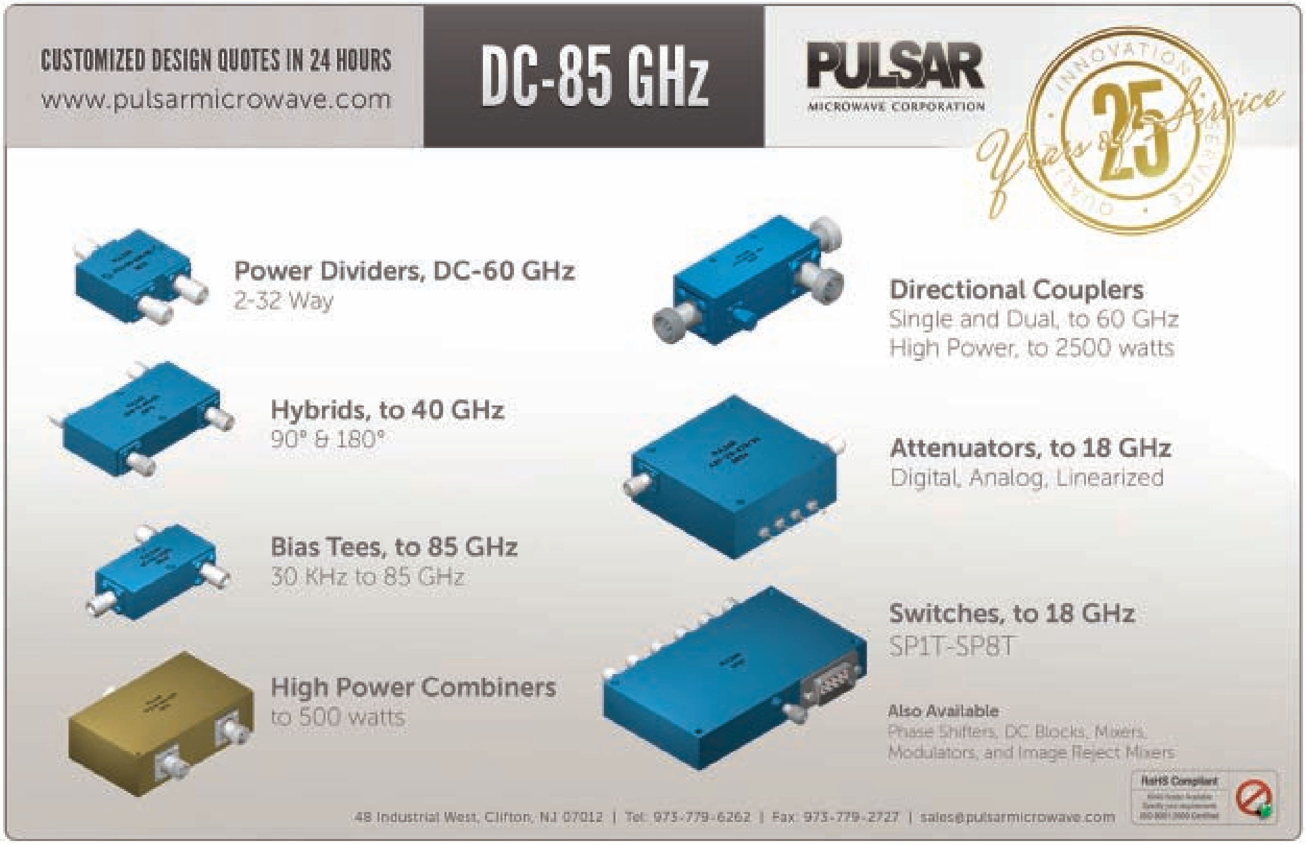
They tracked targets in the desert, practiced battening down the hatches for storms and reviewed every switch, button and computer system. Now, after a six-week-long "test-drive" in the Utah wilderness, U.S. Army soldiers are ready to take full control of Raytheon's enormous JLENS airships. Next stop: Aberdeen Proving Ground in Maryland, where the twin-radar system will begin a long-term trial watching over Washington D.C.

JLENS – which is short for Joint Land Attack Cruise Missile Defense Elevated Netted Sensor System – is a system of two aerostats, or tethered airships, that float 10,000 feet in the air. The aerostats, each nearly as long as a football field, carry powerful radars that can look deep into enemy territory.

The Army recently put the system and the soldiers who operate it through their paces during a grueling six-week period known as Early User Testing. Previously, Raytheon employees were the primary operators as the military put the system through numerous trials.

"EUT is when the training wheels come off, Raytheon steps out of the picture, and it's up to the soldiers to use JLENS the same way they would fight," said Doug Burgess, Raytheon's JLENS program director.

JLENS allows the military to defend hundreds of miles of territory at a fraction of the cost of fixed wing aircraft. In February the military used it to track four ballistic missile targets.



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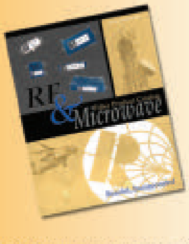

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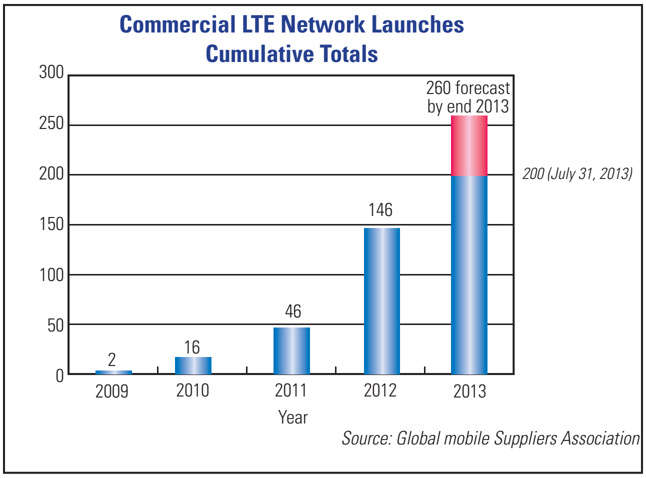
GSA Confirms 200 LTE Networks Launched in 76 Countries

The "Evolution to LTE" report from the Global mobile Suppliers Association (GSA), confirms that 200 LTE networks in 76 countries were commercially launched by 31 July 2013. At the end of 2012, 146 commercial LTE networks were in service and an additional 54 operators have launched LTE service in the first seven months of 2013.

Of the 200 commercially launched networks, 182 networks were deployed using the FDD mode, nine networks were deployed in TDD mode (also referred to as TD-LTE) and nine networks are using both FDD and TDD modes.

Alan Hadden, president of the GSA, said: "In this interim announcement GSA confirms that 106 LTE networks were commercially launched in the last 12 months, representing 112 percent annual growth. LTE is a mainstream mobile broadband technology and is the fastest developing mobile system technology ever."

LTE service has been introduced to 12 new markets so far this year: Chile, Iceland, Iraq, Lebanon, Malaysia, New Zealand, Paraguay, Qatar, Spain, Thailand, U.S. Virgin Islands and Venezuela.



Commercial LTE Network Launches
Cumulative Totals

Source: Global mobile Suppliers Association

Enhanced Wireless Technology for Body Implants and Sensors

Body implants such as pacemakers and hearing aids have been used to counter organ dysfunction for decades. The WiserBAN project, under the EU Seventh Framework Programme (FP7), is making a giant leap in their development: aiming to provide smarter communications among such devices, with reduced size and lower energy consumption.

WiserBAN is focusing on the extreme miniaturisation of body-area network (BAN) devices. It touches on the areas of RF communications, Microelectromechanical systems (MEMS) and miniature components, miniature reconfigurable antennas, miniaturised and cost-effective system-in-package (SiP), ultra-low power MEMS-based radio system-on-chip (SoC), sensor signal processing and flexible communication protocols.

WiserBAN is focusing on the extreme miniaturisation of body-area networks...

The requirements for achieving a nearly invisible WiserBAN radio microsystem are: the sensor nodes must be ultra-miniature, the wireless link must be ultra low-power, the antenna and radio must adapt to around-the-body propagation losses due to various node placements on or in the body, but also variable conditions due to moving parts, and the node must include high performance data-processing capability, which is needed to process, fusion the sensor data coming from many sensors placed around the body, and extract the relevant features for further transmission.

Current available solutions addressing the increasing demand for BAN specific solutions are using non-specific personal-area-network (PAN) solutions. These WPAN, which are typified by Bluetooth or ZigBee wireless solutions, enable the realization of proto-BAN solutions that allow basic BAN system realisations.

WiserBAN will develop a highly integrated radio and antenna and data-processing microsystem, which will reduce significantly the barriers in terms of size and power consumption of existing wireless solutions.

Astrium Signs Contract with Korean Aerospace Research Institute

Astrium, Europe's leading space technology company, has signed a contract with the Korea Aerospace Research Institute (KARI), the South Korean space agency. Under the terms of this contract, Astrium and KARI will jointly design and manufacture the Geostationary Ocean Colour Imager II (GOCI-II) for the future Korean GEO Kompsat 2B mission, scheduled for launch in 2019.

Eric Béranger, CEO of Astrium Satellites stated: "This contract is also a great commercial success for Astrium, confirming our place as the world's leading exporter of Earth observation space systems."

GOCI-II is the next generation to the GOCI first generation imager onboard the COMS satellite. GOCI was also developed by Astrium and has been successfully operated by the South Korean space agency since its launch in 2010.

GOCI-II has been designed using the latest generation technologies developed by Astrium for space applications, including a seven-million pixel CMOS sensor, a silicon carbide telescope and a high-precision pointing mechanism.

The contract also stipulates that six Korean engineers will help to develop the instrument at the Astrium site in

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Toulouse, France. Astrium has agreed to use South Korean industrial services amounting to 5 percent of the contract price. In addition, test resources made available by KARI at its Daejeon site in Korea will be used for environment testing.

EU Project to Harmonise Aircraft Communication

The EU funded Seamless Aeronautical Networking through integration of Data links Radios and Antennas (SANDRA) project is working to integrate today's complex and disparate aircraft communications into a coherent digital architecture, merging a full range of applications and services.

"We use digital communications in every facet of our lives. Just look at the number of people who have smartphones and tablets. But often aircraft rely on a combination of decades-old analogue communications and a separate satellite-based system, making cockpit communications both complex to use and inefficient. SANDRA is bringing cockpit communications into the 21st century by simplifying the process for pilots and providing the platform for many more advanced services," said Dr. Markus Werner, managing director of project partner TriaGnoSys.

> *"SANDRA is bringing cockpit communications into the 21st century..."*

SANDRA researchers are looking at innovative strategies to coordinate cabin crew operations, in-flight and on-ground passenger services, air traffic management and security services. The consortium identified four main areas that would require integrated solutions including service, network, radio and antenna-based systems.

Project partners say SANDRA will provide an opportunity for new Air Transport Management (ATM) services able to transfer a vast amount of data. They foresee a paradigm shift in the next ten years from voice communications between air traffic controllers and pilots, to air traffic control management systems based on data communication between computers.

In June this year, the consortium successfully trialled flights at the German Aerospace Centre to test AeroMACS, a new avionic communication system based on modular and flexible radio architecture. The flight tests identified SANDRA's potential benefits in areas of better integrity and safety of flight due to the flexible usage of all the available connections and improved reliability as a result of an integrated network.


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15 dB
GVA-84+
24 dB

Commercial Market

Cliff Drubin, Associate Technical Editor

Global Smartphone Shipments Hit Record

According to the latest research from Strategy Analytics, global smartphone shipments grew 47 percent annually to reach a record 230 million units in the second quarter of 2013. Samsung captured one-third of all smartphone volumes worldwide, while Apple's marketshare fell to its lowest level for three years.

Neil Shah, senior analyst at Strategy Analytics, said, "Global smartphone shipments grew 47 percent annually from 156.5 million units in Q2 2012 to 229.6 million in Q2 2013. This was the largest volume of smartphones ever shipped in a single quarter. Smartphones accounted for 59 percent of all mobile phones shipped globally. The smartphone industry's shipment growth rate, which is higher today than a year ago, is being driven by surging demand for 4G models in developed regions like the U.S. and 3G models in emerging markets such as India."

Neil Mawston, executive director at Strategy Analytics, added, "Samsung grew 56 percent annually and shipped a record 76 million smartphones worldwide, capturing 33 percent marketshare in Q2 2013. Samsung shipped over two times more smartphones than Apple during the quarter. The flagship Galaxy S4 model experienced solid demand in China and worldwide and helped to lift volumes. Samsung's next major flagship launch is likely to be the rumored Note 3 model later this year. Apple shipped 31.2 million iPhones worldwide in Q2 2013, up from 26 million a year earlier. Apple grew just 20 percent annually during Q2 2013, which is less than half the overall smartphone industry average of 47 percent. Apple's global smartphone marketshare of 14 percent is at its lowest level since the second quarter of 2010. The current iPhone portfolio is under-performing and Apple is at risk of being trapped in a pincer movement between rival 3-inch Android models at the low-end and 5-inch Android models at the high-end."

Almost 600,000 Base Stations to be Upgraded to LTE-A by 2018

Aota launched the first LTE-Advanced (LTE-A) network in Russia last October; however, with the first compatible handset, SK Telecom was the earliest to make the technology commercially available in June 2013. Within two weeks, the South Korean operator has already claimed over 150,000 subscriptions, roughly 0.6 percent of its total. The United States will have at least four LTE-A networks in service by the end of this year as well. This fierce competition will see more than half of the LTE subscribers in North America using LTE-A by 2017.

Underpinning this rapid adoption is the upgrade of base stations to support LTE-A worldwide, which is increasing at a CAGR of ~200 percent between 2012 and 2018 to reach more than half-a-million strong. "It's about boosting capacity as data consumption soars," said Ying Kang Tan, research associate. "Besides acquiring more spectrums, operators need to use the scarce resources more efficiently. Thus, despite all the clamor about a spectrum crunch, spectrum is one option — but not the only one — to enhance capacity. LTE-A provides part of the answer."

"Nevertheless, spectrum is essential. Operators are keenly reaching out to secure whatever spectrum they can get. As a result, they are ending up with a variety of different frequency bands. This is where carrier aggregation technology becomes useful," added Jake Saunders, VP and practice director.

802.15.4-Enabled Device Market Set to Grow 5× from 2012 to 2018

Annual shipments of 802.15.4-enabled devices are forecast to grow more than five times from 2012 to 2018, with a CAGR of over 30 percent. ZigBee continues to be the primary driver toward standardization and interoperability and will see further strong growth across many markets, accounting for almost 80 percent of total 802.15.4-enabled device shipments in 2018.

"It's been quite a turbulent time for ZigBee over the last couple of years," said Peter Cooney, practice director. "Markets that seemed to be sure-fire bets for rapid growth, such as smart meters, have not delivered what was expected, while smart home markets continue to flourish."

There are a number of markets that the ZigBee Alliance and its members have targeted, and many standards have been developed to address them. To date, most of the focus and success has been with ZigBee Energy for smart meter applications and ZigBee RF4CE Control for home entertainment.

The smart meter market has seen a dramatic change in fortunes for ZigBee. Previous industry estimates have assumed the market would grow to hundreds of units per annum, with ZigBee as the primary connection technology globally. While we have seen strong growth for ZigBee-enabled smart meters in the United States, adoption and rollout elsewhere have been sporadic and it doesn't seem likely that ZigBee will see mass adoption worldwide.

Small Cells Market Returns to Growth

ABI Research's latest forecasts for Indoor Small Cells, which are also referred to as Enterprise and Consumer Femtocells, predicts a return to growth after lackluster 2011 and 2012 with an increase in unit volumes in 2013 and 2014 and year-on-year growth outpacing last forecasts. This growth will come thanks to operators like AT&T, Vodafone, Telefonica, Softbank and Sprint all being at the forefront of driving shipments in both enterprise and residential settings.

In ABI Research's latest forecast, overall Enterprise and Consumer Femtocell shipments will reach 5.7 million

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units in 2014 compared to 3.8 million units in 2013. While 3G indoor small cells will continue to represent the vast majority of shipments, it is LTE indoor small cells that are expected to ramp up significantly starting in 2013.

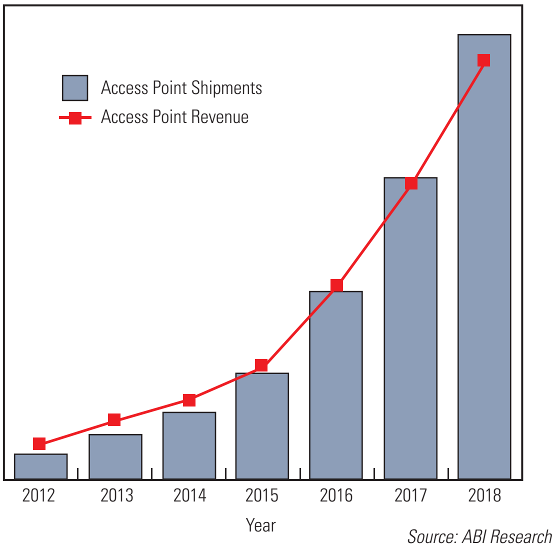
This picture is repeated in forecasts for outdoor small cells with year-on-year unit growth of 125 percent predicted for 2014 for a value of almost $3.6 billion, with LTE outdoor small cells exhibiting strong growth in the same time period as demonstrated by the recent announcements from AT&T, Sprint, Verizon and China Mobile, which are all among the MNOs driving this market.

Not to be outdone, carrier or service provider Wi-Fi is also emerging as an effective "carrier-grade" small-cell solution for decongestion of mobile networks and we expect the initiatives from the Wi-Fi Alliance, Wireless Broadband Alliance, Small Cell Forum, GSMA, and 3GPP to continue to ease the deployment of carrier Wi-Fi for MNOs and MSOs alike. ABI Research predicts that the number of carrier Wi-Fi access points shipped in 2014 will be three times the number which was shipped in 2012.

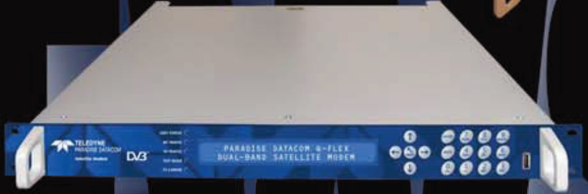
"The recent Small Cell World Summit in London also offered some positive signs that the market is growing with attendance up by 50 percent including 230 operator delegates from 110 companies and with Cisco's recent acquisition of Ubiquisys there is some real momentum building now," says Nick Marshall principal analyst at ABI Research.

"Another strong indicator of the emergence of a meaningful and growing indoor small cells market was the almost simultaneous announcements by both Qualcomm and Texas Instruments of latest generation baseband SoC's for small cells."

Femtocell Shipments and Revenues
World Market, Forecast: 2012–2018



Source: ABI Research



Around the Circuit

Laura Glazer, Staff Editor

COLLABORATIONS

Nujira Ltd. and **TowerJazz** have extended their partnership agreement to include production of Nujira's latest NCT-L1300 Coolteq.L envelope tracking modulator chip for LTE handsets. Nujira selected TowerJazz as its manufacturing partner in early 2012. With the launch of Nujira's NCT-L1300 ET modulator IC in June 2013, the partnership is being extended as the new chip is geared up for volume production to support 4G smartphone shipments in 2014.

Teseq UK strengthened its relationship with **TATA Power Co. Ltd.** in India, following successful recalibration of its Bangalore 10 m, semi-anechoic EMC chamber to the CISPR 16-1-4 standard. TATA power systems is in discussions with Teseq Ltd. for a further six chambers based in Bangalore, Chennai and Coimbatore and the overall project requires detailed logistic planning to ensure success. Working closely with Rainford EMC, Teseq Ltd. was able to provide SVSWR and NSA testing plus shielding effectiveness certification at short notice, and to tight timetables, to minimize disruption at the Bangalore site.

ACHIEVEMENTS

The **U.S. Navy** got its first look at the upgraded MQ-8 Fire Scout unmanned system when **Northrop Grumman Corp.** delivered its first MQ-8C system this month. Northrop Grumman is the Navy's prime contractor for the MQ-8 Fire Scout program of record. The company delivered the first MQ-8C aircraft to the Navy in early July in preparation for ground and flight testing. The upcoming tests will be used to validate and mature the upgraded MQ-8 system for operational use. Initial ground testing will ensure that the systems work properly and communicate with the ground control station prior to conducting first flight.

The National Quality Assurance (NQA) U.S.A., an accredited organization under the ANSI-ASQ National Accreditation Board, has assessed and approved **CTS Electronic Components,** a division of CTS Corp., for ISO 9001:2008 certification for its Hopkinton, MA location. The ISO 9001:2008 standard specifies requirements for a quality management system where an organization: needs to demonstrate its ability to consistently provide product that meets customer and applicable statutory and regulatory requirements; and aims to enhance customer satisfaction through the effective application of the system, including processes for continual improvement of the system and the assurance of conformity to customer and applicable statutory and regulatory requirements.

Advanced Test Equipment Rentals (ATEC) announced it has been awarded ISO/IEC 17025-2005 & ANSI/NCSL Z540-1-1994 accreditation for calibration by the American Association for Laboratory Accreditation (A2LA). Accreditation to ISO/IEC 17025 is obtained through an assessment of a laboratory's compliance in carrying out specific tests and calibrations precisely to the scope of accreditation. ISO/IEC 17025 accreditation also demonstrates that ATEC has successfully completed the ISO evaluation process which includes recognition of technical competency.

Thales Alenia Space announced an important milestone regarding the satellite integration and test center built in Turkey, which was part of the contract signed in 2010 with **Telespazio** in the frame of the Göktürk observation satellite program for the Turkish Ministry of Defense. The building is air and water tight, and installation of the main test systems is well underway. The new satellite integration and test center will be able to integrate several telecommunications or observation satellites at the same time and delivery of the complete building is scheduled for October 2013, with final acceptance, including all test systems, slated for May 2014.

Isola Group S.a.r.l. has expanded its Suzhou, China manufacturing facility. The substantial upgrade includes two additional hot oil presses, semi-automatic layup lines and an additional clean room. As part of the company's commitment to continuous quality improvement, these upgrades will increase capacity of its high-performance laminate materials by 70,000 sheets per month, significantly reduce lead-times and enhance its quick turnaround capability. The project will be completed in September.

CONTRACTS

Astrium has been selected by the **European Space Agency** (ESA) to supply the MicroWave Sounder (MWS) instruments for the MetOp Second Generation series of satellites (MetOp-SG). The contract for the MWS instruments, worth up to €155.5 million, has been awarded to Astrium in the UK and the satellites will be operated by EUMETSAT, the European Organisation for the Exploitation of Meteorological Satellites. There will be a minimum of two MWS instruments, each with a mission life of 7.5 years. The first MetOp-SG satellite is due to be launched in 2021.

Cree Inc. announced that it signed a non-exclusive worldwide patent license agreement with **Transphorm Inc.** that provides access to Cree's extensive family of patents related to GaN high electron mobility transistor (HEMT) and GaN Schottky diode devices for use in the field of power conversion devices. The licensed family of patents addresses various aspects of making GaN power devices including nitride materials, HEMT and Schottky diode designs and processing technology.

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Model #	Frequency (MHz)	Insertion Loss (dB) [Typ./Max.] ◊	Amplitude Unbalance (dB) [Typ./Max.]	Phase Unbalance (Deg.) [Typ./Max.]	Isolation (dB) [Typ./Min.]	VSWR (Typ.)	Input Power (Watts) [Max.] ▫	Package
2-WAY								
CSBK260S	20 - 600	0.28 / 0.4	0.05 / 0.4	0.8 / 3.0	25 / 20	1.15:1	50	377
DSK-729S	800 - 2200	0.5 / 0.8	0.05 / 0.4	1 / 2	25 / 20	1.3:1	10	215
DSK-H3N	800 - 2400	0.5 / 0.8	0.25 / 0.5	1 / 4	23 / 18	1.5:1	30	220
P2D100800	1000 - 8000	0.6 / 1.1	0.05 / 0.2	1 / 2	28 / 22	1.2:1	2	329
DSK100800	1000 - 8000	0.6 / 1.1	0.05 / 0.2	1 / 2	28 / 22	1.2:1	20	330
DHK-H1N	1700 - 2200	0.3 / 0.4	0.1 / 0.3	1 / 3	20 / 18	1.3:1	100	220
P2D180900L	1800 - 9000	0.4 / 0.8	0.05 / 0.2	1 / 2	27 / 23	1.2:1	2	331
DSK180900	1800 - 9000	0.4 / 0.8	0.05 / 0.2	1 / 2	27 / 23	1.2:1	20	330
3-WAY								
S3D1723	1700 - 2300	0.2 / 0.35	0.3 / 0.6	2 / 3	22 / 16	1.3:1	5	316
4-WAY								
CSDK3100S	30 - 1000	0.7 / 1.1	0.05 / 0.2	0.3 / 2.0	28 / 20	1.15:1	5	169S

▫ With matched operating conditions

HYBRIDS RoHS ✓

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

◊ In excess of theoretical coupling loss of 3.0 dB

COUPLERS RoHS ✓

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

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

Unless noted, products are RoHS compliant.

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Around the Circuit

Raytheon Co. received an $80.5 million production contract award from the **U.S. Navy** to procure Joint Standoff Weapon (JSOW) C-1s. The contract was awarded in Raytheon's second quarter of 2013. Work on the contract will be performed in Tucson, AZ; Cedar Rapids, IA; McAlester, OK; and Dallas, TX. Delivery of the missiles is scheduled to begin in the second quarter of 2014.

Ceragon Networks Ltd. announced that a large Asia Pacific (APAC) mobile operator is deploying the company's solutions as part of its LTE network upgrade. Adding to its large existing install base, these new orders, valued at over $3.5 million, will enable the operator to expand both network capacity and availability, thereby providing the necessary infrastructure to support current and future data traffic needs. Ceragon is also supplying a range of professional turnkey services including planning, network design and project management to ensure fast time to market for the operator and fast time to service for its customers.

Boeing and **Panasonic Avionics Corp.** are preparing to open a new market for Panasonic's secure, satellite-based, in-flight broadband service known as eXConnect. Under a new agreement, Boeing will offer eXConnect service to government customers within and outside the United States. While final terms are still being negotiated, the companies have agreed on a framework for Boeing to offer the eXConnect service and sell aeronautical terminals to the government market.

Denver International Airport and **Lambert-St. Louis International Airport** will use the **ITT Exelis** vehicle movement area transmitter (VMAT) solution to enhance airport surface safety and efficiency. VMAT is a device that permits ground vehicles operating on the airport surface to broadcast their positions and uniquely identifiable call signs. Air traffic controllers can then view and track the vehicles, as well as appropriately equipped aircraft operating near the airport and on the airport surface. Forty VMAT devices are currently operational at STL, and 55 VMAT devices will soon be operational at DEN.

REP APPOINTMENTS

San-tron Inc. announced the hiring of four new sales representatives. **McBride Scientific Sales** will handle customer relationships in TX, LA, OK and AR. **Compomill Nordic Components** will handle Denmark, Norway, Sweden, Finland and the Baltic States. **Southeast Atlantic Sales** will cover the southern states of AL, FL, GA, NC, SC, TN and MS. **TX Sales** will cover sales in the states of IN, MI, OH, KY, northern IL and western PA.

Sub10 Systems confirmed a new distribution partnership with **Horsebridge Network Systems**, a UK-based international network and security infrastructure supplier. Under the terms of the agreement, Horsebridge will supply Sub10's full range of wireless Ethernet links to its international customer base of fixed and mobile telecoms operators, government and military organizations, transport and utility bodies and 'blue-light' services.

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WELCOME TO EUROPEAN MICROWAVE WEEK 2013

For complete coverage of the EuMW conference, event news, exhibitor product information and special reports from the editors of *Microwave Journal*, visit our online show daily at www.mwjournal.com/eumw2013.

Grüß Gott and welcome to the 16th European Microwave Week, which will be held at the Nürnberg Convention Center (NCC), from Sunday 6th to Friday 11th October 2013. As our motto suggests, we invite you to *Meet Experts, Make Friends* as Nuremberg, the regional metropolis of Franconia in the northern part of Bavaria, plays host to three conferences: the 43rd European Microwave Conference (EuMC), the 8th European Microwave Integrated Circuits Conference (EuMIC) and the 10th European Radar Conference (EuRAD), alongside the European Microwave Exhibition and complemented by workshops, short courses and seminars.

Although it is the first time that EuMW has been held in Nuremberg, exactly 30 years ago, in the days when Germany was divided into East and West, the city was the venue for the 13th European Microwave Conference. In the three decades since, the Wall has come down, along with barriers to trade, and superseded by the building of a structure of cooperation that advances initiatives and funding in Europe aimed at nurturing and encouraging technological innovation. Since its inception, European Microwave Week has played its part in marrying the needs and aspirations of academia and industry, grown in content and stature and established itself as the premier RF and microwave event in Europe.

Due to its active and productive industry, both established and developing, geographical location and robust economy, Germany is a key destination for EuMW. The 2013 event aims to capitalize on the strength of national and local industry and academia to build on the event's strengths, develop initiatives and move forward.

It will also embrace the international audience that the week attracts and encourages to participate. This is demonstrated by the fact that the opening and closing plenary sessions of each of the three conferences will feature keynote speeches by world leaders in their fields and a welcome address by the president of the IEEE. Acknowledging the increasing significance and influence of the Asian market, there is a special all-invited session on the Asia-Pacific Microwave Conference.

Three exciting panel sessions will be integrated into the week's programme. The increasingly popular Women in Microwave Engineering (WIE) event will focus on the challenges induced by the current trends towards the Internet of Things and cyber physical systems. How can we do better for the microwave community? – a key question raised by the rapidly changing knowledge and information based society will be addressed by the presidents of EuMA, IEEE, IEEE MTT-S and VDE/ITG in a Presidents' Panel. An equally significant is-

ROBERT WEIGEL
General Chairman, EuMW 2013
IVAR BAZZY
President, Horizon House Publications

sue will be addressed by an executive panel session featuring experts and executives involved in today's electronic systems development trends who will discuss whether Europe can afford for its capabilities to produce and test electronics to increasingly be shifted to Asia.

The success story of the Defence and Security Forum continues, with the event that began in 2010 as a two-hour Executive Forum now spanning one and a half days. It will encompass the Opening Session of EuRAD for the second year and the EuMIC Closing Session for the first time. The forum features presentations from industry leaders and concludes with the Executive Forum. More information can be found on page 72.

An integral and vital constituent of EuMW is the European Microwave Exhibition, which, this year, will expand to take up over 8500 square metres of gross space and has attracted over 300 exhibiting companies. The exhibition hall will not only be a focal point for innovation where companies from around the globe will showcase and demonstrate their products and services, but will also be a platform for interaction.

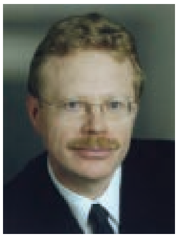
As in 2012, the latest in automotive radar sensor technology will be demonstrated on the show floor and beyond, while a valuable bridge between industry and academia will be provided by the European Microwave Week Microwave Application Seminars (MicroApps) that will take place in the MicroApps Auditorium for the entire three days of the exhibition. The exhibition hall will also be the home of the conference poster sessions, coffee breaks, Publisher's Corner and the ever popular Cyber Café.

EuMW has a valuable past, embraces current activities and also looks forward, both in terms of technology and the development of the engineers who will shape the future. At EuMW 2013, two European microwave schools and two student competitions will be offered especially for students and PhD students. The European Microwave Doctoral School features world leading microwave scientists and engineers as distinguished lecturers, whereas the European Microwave Student School is devoted to microwave measurement techniques; here the students can earn credit (ECTS) points. In addition, eligible students will compete in the Student Challenge, which is a poster competition, as well as in the Student Design Competition, which is a design and measurement competition.

The *Meet Experts, Make Friends* motto will not be epitomised better than at the Welcome Reception on Tuesday evening. It is designed to be both convivial and favorable for networking and to encourage interaction between delegate and industry. Furthermore, mixing business and pleasure can be enjoyed throughout the week through the strong calendar of social events.

From conference sessions to coffee breaks and exhibition stands to excursions, every effort has been made to make the week memorable. So on behalf of the Local Organising Committee, we would like to thank the Technical Programme Committees of the three conferences along with over 500 reviewers who worked tirelessly to shape the conference programmes. We would like to acknowledge the EuMA board for its continued advice and guidance and thank the Horizon House personnel assigned to EuMW for their indispensable expertise and support in organising this major event. Recognition should also go to the organizers of workshops, special sessions and student events and we also acknowledge the significant financial and in-kind sponsorship of many industrial companies and organisations.

Nuremberg is ready and waiting to host and welcome the RF and microwave community and we are looking forward to seeing you there. ■



Robert Weigel

Ivar Bazzy

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ATTENDING EUROPEAN MICROWAVE WEEK 2013

Although Nuremberg will be the venue for EuMW for the first time, Germany is no stranger to playing host to Europe's premier RF and microwave event. Like previous German venues, the Nürnberg Convention Center, NCC Ost will feature conferences, workshops and seminars offering quality content and a dynamic exhibition showcasing companies from across the globe, which together will attract a large and focused audience.

The motto for the 16th European Microwave Week that will be held from Sunday 6th to Friday 11th October is *Meet Experts, Make Friends* and Nuremberg is the perfect place to foster relationships, both professionally and personally. This beautiful city offers the culture, entertainment and history of a large metropolis, while also affording the charm and warmth of a much smaller city.

With more than 1000 papers submitted from all over the world, the EuMC, EuMIC and EuRAD conferences demonstrate the importance and attractiveness of microwave engineering in the modern world. In total, 630 submissions have been selected to be presented in three poster sessions and 106 regular sessions, 11 focused and five special sessions and a total of 48 workshops and short courses.

This year, particular emphasis is placed on displaying recent scientific and industrial microwave achievements in Germany's eastern neighbouring countries by means of a series of three special sessions. Furthermore, based on an agreement between EuMA and the organizers of the Asia-Pacific Microwave Conference, three invited speakers from Asia will contribute with views from their home countries.

Bringing industry, academia and commerce together, European Microwave Week 2013 will see an estimated 2000 conference delegates, over 5000 visitors and 300 plus exhibiting companies spread over more than 8500 m^2 (gross).

Networking, interaction and exchanging ideas are a key to academic and commercial success today and EuMW will offer every opportunity to do so. None more so than at the EuMW Welcome Reception, which will be held on Level 1 at Hall Sydney and the Restaurant Vasco da Gama. The evening will begin with a cocktail reception at 18:30, when guests will be addressed by the 2013 EuMW chairmen, who will hand over to the 2014 EuMW chairman for Rome, followed by Platinum Sponsor Agilent Technologies, after which a three course buffet for 1000 people will be served.

Other social events have been organized throughout the week and although convivial interaction is essential to a successful event, of course, the main focus is to provide attendees with the opportunity to fulfill their specific goals. To help visitors to achieve these aims, the following quick reference guide is designed to complement the Conference Program and Exhibition Show Guide, where you will find more detailed information.

CONFERENCES

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

- **The 8th European Microwave Integrated Circuits Conference** (EuMIC) takes

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Microwave Journal *International Editor*

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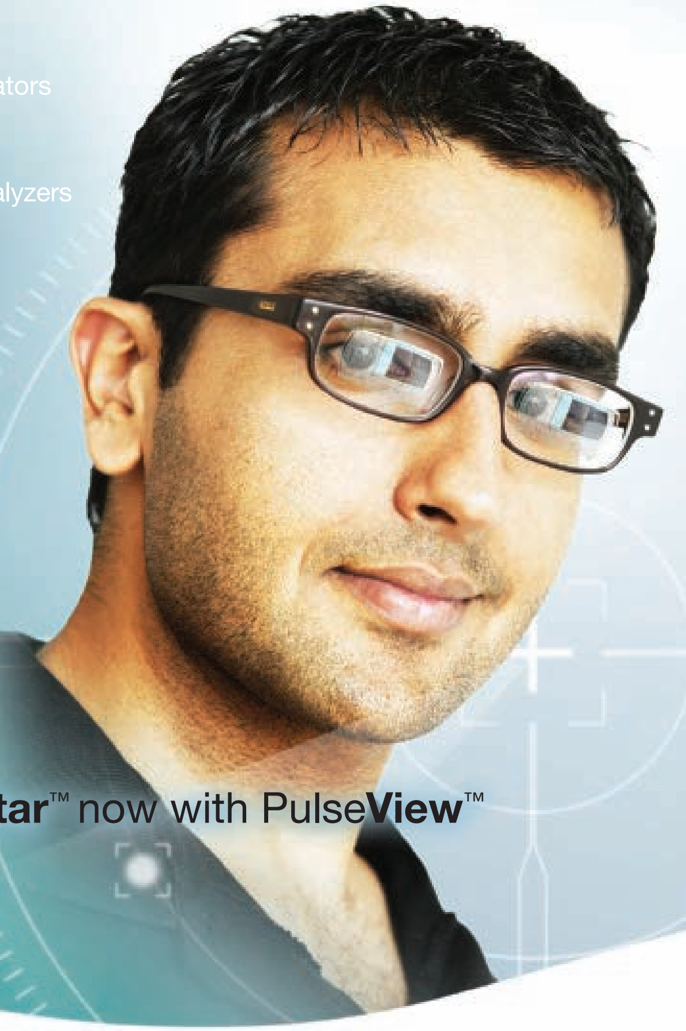

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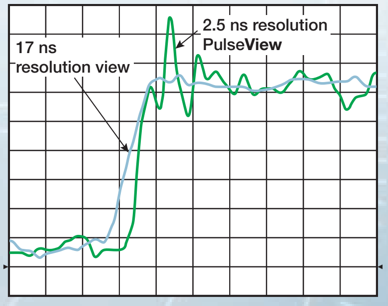

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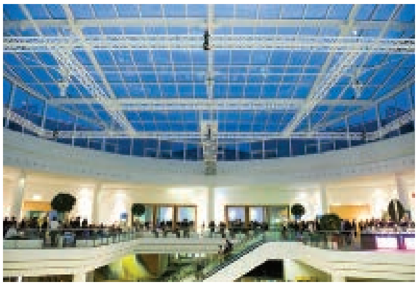


Photo courtesy of NürnbergMesse.

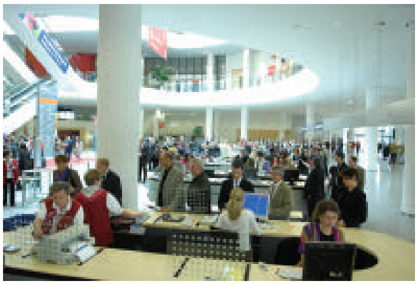


Photo courtesy of NürnbergMesse.

place on Monday 7 and Tuesday 8 October

- **The 43rd European Microwave Conference** (EuMC) extends from Tuesday 8 to Thursday 10 October
- **The 9th European Radar Conference** (EuRAD) ends the week and runs from Wednesday 9 to Friday 11 October.

The conferences cover a wide range of subject areas including: microwave, millimeter-wave and submillimeter-wave systems, antennas and propagation, wireless technologies and telecommunication, encompassing RF, microwave and optical. There is also specific focus on: ICs, semiconductor materials and packaging, radar architectures, systems and subsystems, not forgetting sensors and remote systems and test and measurement. Many of these areas will also be covered by the workshops and short courses that start from Sunday 6 October.

Registration, sponsored by Rohde & Schwarz, opened online on 1st June 2013 and remains open up to and during the event until 11th October. There will be onsite registration from Saturday 5 October from 16:00 to 19:00 and from 07:30 each morning from Sunday 6 October to Friday 11 October.

The registration area will be located at the entrance, Level 0 within the NCC Ost. All those who have pre-registered should bring their badge barcodes and confirmations with them to the conference where they can print out their badges by scanning their barcodes at the Fast Track desk onsite. For those who have not pre-registered, there will be onsite registration terminals located within the registration area, where delegates can enter their details and pay immediately by swiping their credit or debit cards through the card readers attached to the terminals. Alternatively, there is the facility to pay at the cashier desk for those who require a printed receipt.

Once in possession of their badges, delegates can collect their delegate bags, sponsored by Infineon and Fredrich-Alexander Universität, Erlangen-Nürnberg, from collection points to the right of the registration area. The bags will include a USB stick containing the conference presentations.

THE EUROPEAN MICROWAVE CONFERENCE

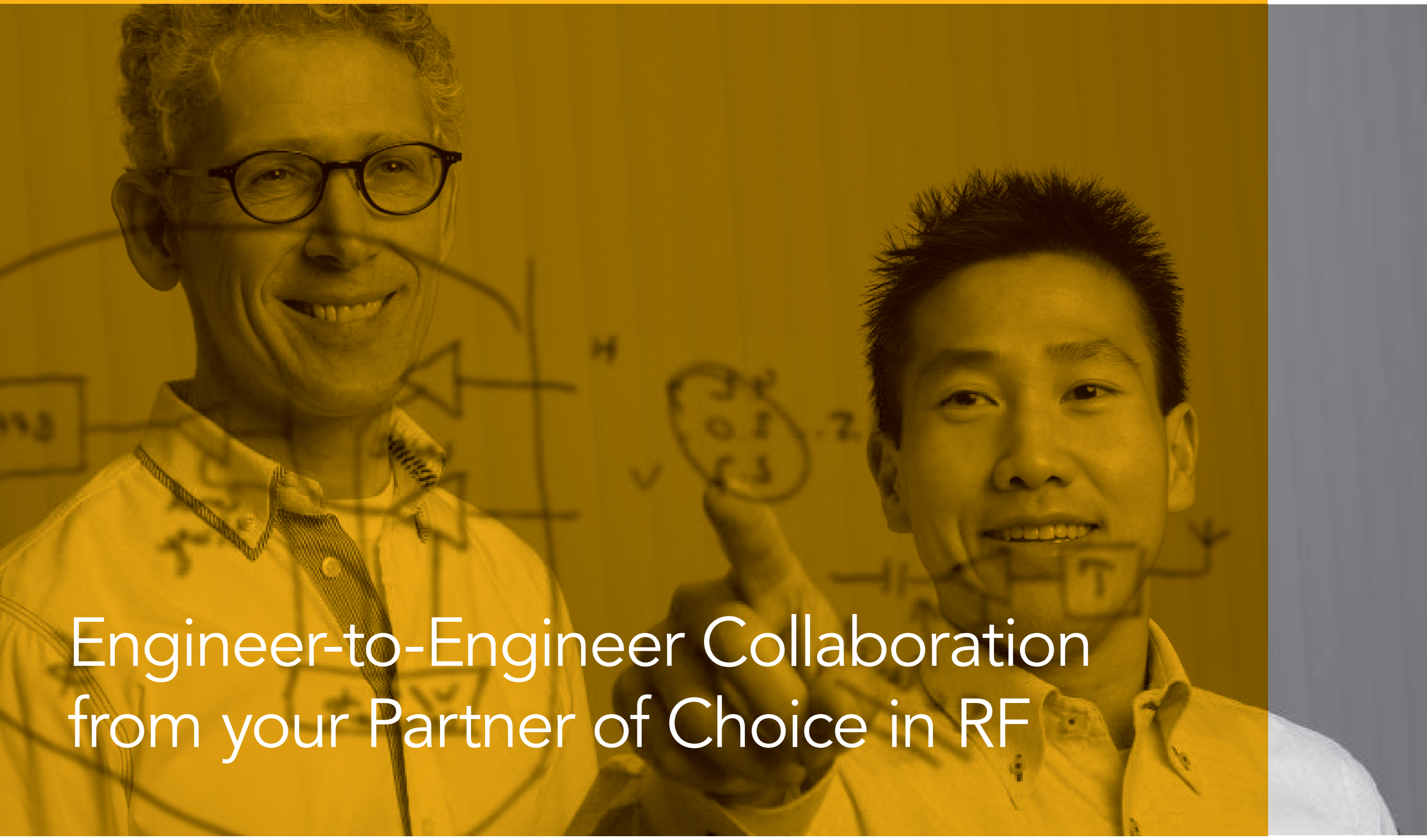
Exactly 30 years ago, the EuMC was staged on its own in Nuremberg. Now it returns as the centrepiece and the biggest of the three conferences of European Microwave Week. It covers a broad range of high frequency related topics.

It will address the latest developments for passive components, modelling and design of high frequency and high data rate microwave photonics, highly stable and low-noise microwave sources, new linearization techniques, electronically steered antenna arrays and the impact of new packaging technologies on development applications.

Special emphasis will be placed on emerging technologies and materials for microwave components such as MEMS, meta-material structures and devices, tunable and reconfigurable RF systems, and systems-in-package. There will be specific focus on microwave components and systems for the rapidly growing field of wireless communications, radar with wireless communication capability, millimetre-wave imaging systems, and microwaves in medical applications.

The EuMC Opening and Closing Sessions are the formal opening and closing events of the entire week and both feature prominent keynote

UNLEASH RF



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To learn more, visit the NXP booth 120 at EuMW2013, October 8-10 in Nuremberg Germany

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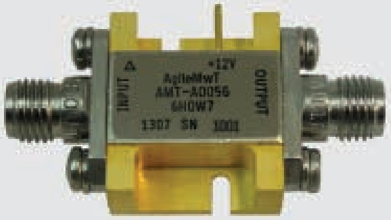


Photo courtesy of NürnbergMesse.

speakers. The Opening Session features Reinhard Ploss, CEO of Infineon Technologies, Munich, and Ralf G. Herrtwich, director driver assistance and chassis systems, Daimler, Böblingen. Erich R. Reinhardt, president of Medical Valley EMN, Erlangen, and Dirk Beernaert, adviser to the DG for interdisciplinary and integrating activities, European Commission, Brussels are the Closing Session speakers.

THE EUROPEAN MICROWAVE INTEGRATED CIRCUITS CONFERENCE

As the successor to the former GAAS Conference since 2006, EuMIC covers a wide range of semiconductor materials and monolithic integration techniques. It is the premier European technical conference on technologies, modelling, simulation, design and characterization of integrated devices and circuits for RF, microwave, millimeter-wave and THz applications. The conference will focus on the increase of data rates and energy efficiency being key aspects in the design of future wireless systems, while power amplifiers and integrated antennas are also hot topics.

Two eminent plenary keynote speakers – Hermann Eul, corporate vice president and general manager mobile and communications group, Intel, USA, and Sorin Voinigescu, University of Toronto, Canada – should not be missed, while the Closing Session will include a foundry panel discussion and an invited talk from Zhigong Wang, Southeast University, Nanjing, China on future challenges of integrated circuits in China.

THE EUROPEAN RADAR CONFERENCE

One of the most prominent radar events, not only in Europe but worldwide, EuRAD covers all relevant aspects of modern radar technology, including components and subsystems, architectures and applications, and signal processing.

The Opening Session, which forms part of the Defence & Security Forum, features keynote talks from two internationally recognised experts. Alberto Moreira, DLR, Germany, will highlight outstanding space-based SAR applications, while Jürgen Sachs, TU Ilmenau, Germany, will address the latest advances in ultra-wideband radar and sensing. During the Closing Session Andreas Stelzer, a leader in industrial radar applications from the Johannes Kepler University Linz, Austria, will report on the most recent developments in this field.

Finally, in the Closing Sessions for all three conferences, prestigious awards will be handed out for the Best Paper and Best Young Engineer Presenters, with the papers and presenters carefully selected by a special awards committee.

EXHIBITION

Central to the week both chronologically and metaphorically, the European Microwave Exhibition will be housed in Hall 7A of the Nürnberg Convention Center from Tuesday 8 October to Thursday 10 October. Larger in gross space and the number of exhibiting companies than in 2012, it will be the hub of activity generated by the multitude of companies eager to display and demonstrate their latest introductions. As well as a platform for innovation that leading manufacturers often choose to launch new products and float future concepts, the show floor also offers visitors the opportunity to discuss their current work with the experts.

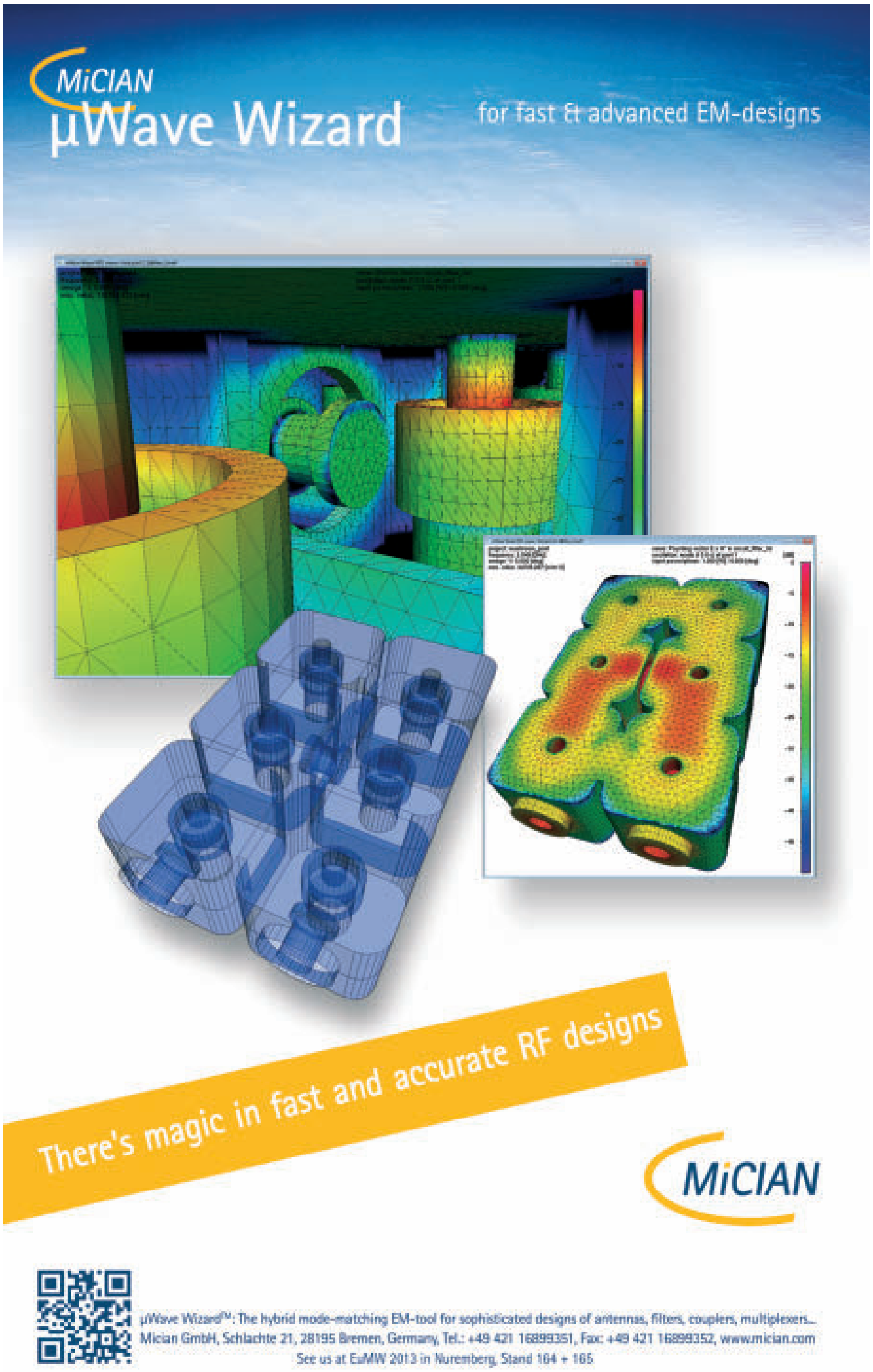
Hall 7A will feature companies large and small, established and emerging. Of course, European companies are to the fore, with both Germany and France having their own national pavilions. As always, the USA and Asia are well represented with the Chinese Pavilion expanding in 2013, demonstrating the country's continued emergence as a force in the RF and microwave sector.

The established and popular exhibitor workshops offered by leaders in their respective fields will continue, of-

fering attendees the opportunity to see live demonstrations and gain hands-on experience. To find out which companies will be exhibiting at the Nürnberg Convention Center see the latest exhibitor list, starting on page 178.

Germany is a powerhouse in the automotive sector, reflected in the fact that for the second year, the exhibition hall will house at least three vehicles that demonstrate that automotive technology is emerging from the lab and onto the road. All of the cars will be equipped with different 24 GHz, as well as 77 GHz radar sensors. The cars, a brand new S-Class from Mercedes-Benz and a Golf 7 from Volkswagen as well as an Actros II, a tractor trailer from Mercedes-Benz, will feature radar sensors from Bosch, Conti and Valeo respectively, demonstrating the upcoming democratization process of Advanced Driver Assistance Systems (ADAS).

Photo courtesy of Shmuel Auster.



Specifically, the Actros II will demonstrate the implementation of Automatic Emergency Braking Systems (AEBS), which will be mandatory for trucks and buses from November 1st 2013. At the time of going to press there is also the possibility of a fourth car – a VW Golf 6 equipped with radar sensors from Hella. Furthermore, there will be a demo on Tuesday, 8 October on a 250 m strip of street adjacent to the hall exit, organized by Mercedes-Benz.

Now in their third year the European Microwave Week Microwave Application Seminars (MicroApps) has become a recognised event in itself. The AWR, Horizon House and National Instruments sponsored seminars will take place in the MicroApps Auditorium for the entire three days of the exhibition. Hall 7A will also be the home of the conference poster sessions, coffee breaks and the Publisher's Corner.

Once again, CST is sponsoring a Cyber Café located within the Exhibition Hall for all delegates, exhibitors and visitors to use, as well as free WiFi access for delegates in all conference areas.

EXHIBITION OPENING HOURS

- Tuesday 8 October: 09:30 to 17:30 (followed by the Welcome Reception)
- Wednesday 9 October: 09:30 to 17:30
- Thursday 10 October: 09:30 to 16:30

GETTING TO THE NCC, NUREMBERG

Nuremberg (German: Nürnberg) is located in the south of Germany and it is well connected to the European motorway, rail and flight networks, which allow easy access to the Nürnberg Convention Center. The NCC is connected by subway lines to the main railway station (about eight minutes) and to the airport (about 25 minutes).

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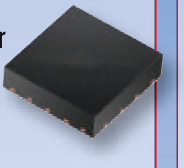
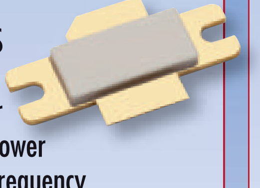


RF AMPLIFIERS

- Gain Blocks
- Coaxial Module
- Low-Noise
- Linear Drivers
- High Power
- Variable Gain

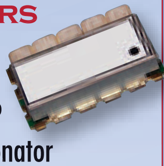
RF TRANSISTORS

- GaN
- LDMOS
- GaAs
- Bipolar
- High Power
- High Frequency



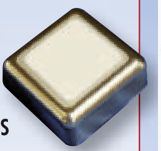
RF FILTERS

- Monoblock
- SAW / BAW
- HP / LP / BP
- Ceramic Resonator
- Duplexer / Diplexer
- Cavity



RF OSCILLATORS

- OCXO
- VCXO
- TCXO
- PLL Synthesizers
- RF Generators



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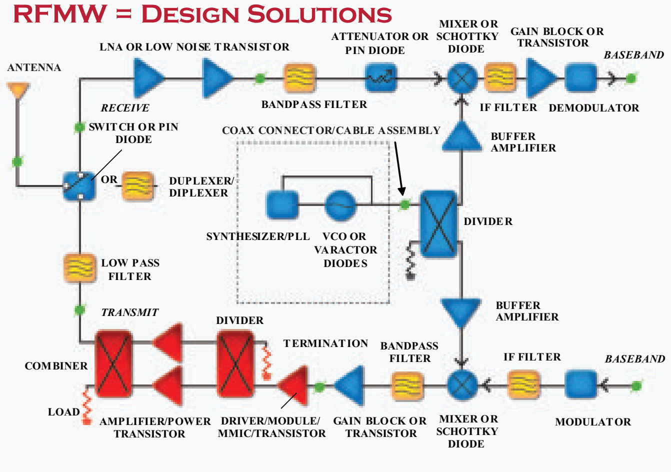
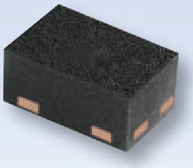


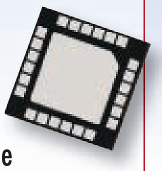
RF DIODES

- PIN
- Schottky
- Varactor
- Limiter
- Gunn



RF ATTENUATORS

- Fixed
- Digital
- Coaxial
- Chip
- Voltage Variable
- Temperature Variable



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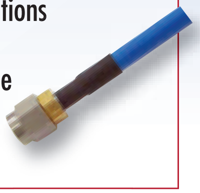

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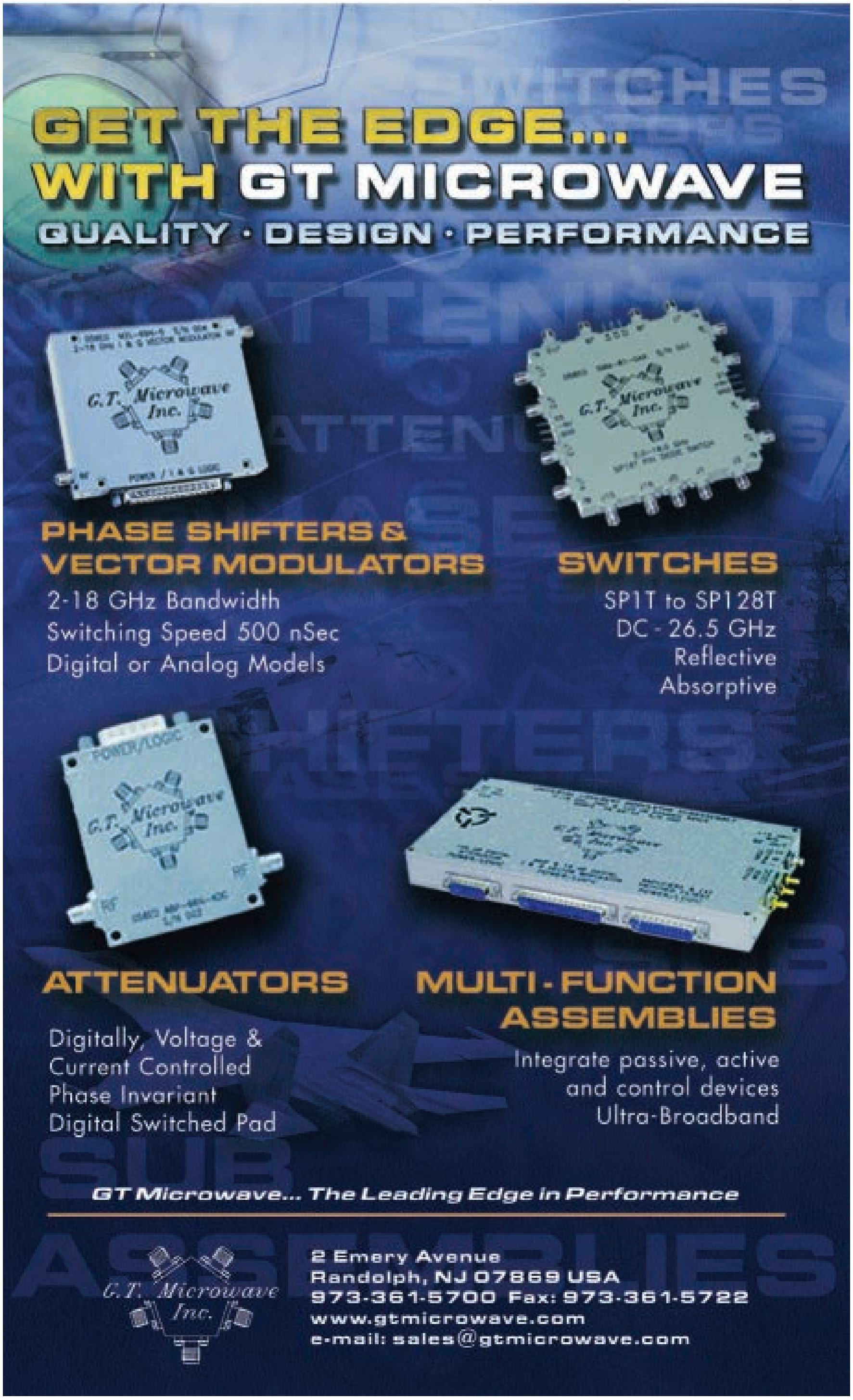
BY CAR

Navigation systems will find the NCC by inserting the address: Karl-Schönleben-Strasse, Nuremberg, Germany or entering Messezentrum, Nuremberg as a special destination.

BY RAIL

Nuremberg is served by four different kinds of trains: ICE (Intercity Express), IC (Intercity), RE or RB (local trains) and the S (commuter train). ICE trains are the fastest and enable access to Nuremberg from Frankfurt am Main and Munich in two hours and one hour respectively. For more information for connections within the German railway system (Deutsche Bahn) visit: www.bahn.com. To obtain more information for local connections and subway lines in and around Nuremberg visit: www.vgn.de/home_engl/.



BY PLANE

Nuremberg Airport (NUE) offers numerous direct flights from nearly all major European cities (more than 50 European direct connections are available). From overseas, NUE is easily reached by international flights via Frankfurt am Main or Munich. Within Germany, there are also excellent national flight connections. To get more information for connections to Nuremberg Airport visit: www.airport-nuernberg.de/english.

HOTELS

Horizon House has teamed up with Hotelzon to offer a wide range of accommodations at competitive rates. To make a booking simply visit Hotelzon's booking page at www.hotelzon.com/en/uk/events-eumw or email sally.garland@hotelzon.co.uk.

SHOPPING & SIGHTSEEING

The Old Town of Nuremberg offers the experience of almost one thousand years of history. The city presents numerous shopping possibilities, whether it is on the Main Market Square with its fruit and vegetable stalls under their red and white umbrellas, or the glass facades of elegant shopping malls. The inner city offers a unique shopping atmosphere with 500 shops in an historical backdrop that are open until 20:00 during the week.

The city has an active art and culture scene and for those with culinary aspirations picturesque roast sausage 'kitchens' entice guests to sample Franconian specialities, while star rated restaurants offer gastronomic delights even for the most discerning palate.

Locals suggest that one should not leave Nuremberg without: having watched the Männleinlaufen clockwork on the facade of the Frauenkirche on the Main Market Square just five minutes before noon; looking down on the roofs of the city from the Imperial Castle; or eating some of the famous Nuremberg roast sausages or a 'Schäuferle.'

There are various tours and excursions organised as part of the Social Events & Partner Programme and www.nuernberg.de/internet/portal_e/kultur offers information on shopping and sightseeing. ■

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THE 2013 EuMW DEFENCE AND SECURITY FORUM

A one and a half day forum addressing defence and security issues and featuring the EuMW Defence and Security Executive Forum. Attendance is free and open to all EuMW 2013 conference delegates, exhibitors and visitors.

Room St. Petersburg

Nürnberg Convention Centre (NCC)

Tuesday 8 and Wednesday 9 October 2013

On personal, national and international levels, the defence and security industry protects citizens, offers reassurance, shapes societies and provides employment. Over the years, the emphasis has shifted with priorities, technologies and financial investment changing with the times. The Defence and Security Forum, now in its fourth year and a one and a half day event in 2013, aims to reflect how the sector has evolved. For the first time the forum will incorporate commercial applications in order to show the differences and commonalities between markets, with special emphasis being given to differences and similarities between the two major radar applications today – defence and automotive.

While defence has utilized this sensor capability for years with improved techniques and performance, the automotive radar sensor market has begun to boom and exhibit a tremendous increase in volume over recent years. This huge success raises the question of whether both markets exist independently or if cross-fertilization can be expected.

Consequently, this year's forum will address such questions and try to provide information from both markets regarding developments, technical requirements, production techniques, quality assurance measures and future trends. The program is also well embedded into the other sessions of the various EuMW conferences, which it complements – namely the EuMIC Closing Session and the EuRAD Opening Session.

THE FORUM FORMAT

The forum will begin on Tuesday 8 October with a session (13:50-15:30) that will consider: Development and production requirements for automotive and military radar. Here experts on radar manufacturing from the different markets will present their views on the various volume

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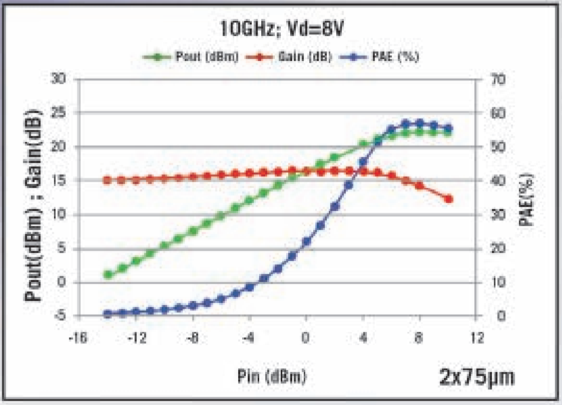

Gain (dB)	P1dB (dBm)	P1dB (mW/mm)	Psat (dBm)	Psat (mW/mm)	PAE Max(%)
15.0	22.1	1086	22.2	1114	56.8

2x75µm device @8V, 10GHz, 150 mA/mm

Summary of WIN mmWave pHEMT portfolio

	PP25-21	PP15-50/51	PL15-12	PP10-10/11
Gate length	0.25 µm	0.15 µm	0.15 µm	0.1 µm
Max Drain Bias	8 V	6 V	4 V	4 V
Idmax (Vg=0.5V)	490 mA/mm	620 mA/mm	525 mA/mm	760 mA/mm
Peak Gm	410 mS/mm	460 mS/mm	580 mS/mm	725 mS/mm
Vto	-1.15 V	-1.3 V	-0.7 V	-0.95 V
BVGD	20V(18V min)	16V(14V min)	9V(8V min)	10V(8V min)
f_T	65 GHz	90 GHz	100 GHz	130 GHz
f_{max}	190 GHz	185 GHz	150 GHz	180 GHz
Power Density (2x75µm)	1100 mW/mm @ 8V, 10GHz	870 mW/mm @ 6V, 29GHz	580 mW/mm @ 4V, 29GHz	860 mW/mm @ 4V, 29GHz (2x50µm)

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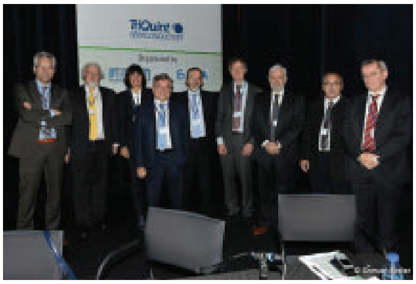


production aspects and trends for the next generation of radar manufacturing. Methods applied by the different industries for quality assurance (testing and qualification, PPAP, change management) will also be addressed. It will be followed at 16:00-17:40 by the EuMIC Closing Session.

Wednesday 9 October will begin with the Microwave Journal Industry Panel Session (08:30-10:10), which will address: Defence and automotive radar – differences and commonalities. Speakers will demonstrate how microwave technology is meeting the design and test challenges facing those at the forefront of innovation, including developments that are significant today and those perceived for the future. These initiatives will then be discussed by the industry panel who will also take questions from the floor. The morning will conclude with the EuRAD Opening Session (10:40-12:20)

The Strategy Analytics Lunch & Learn Session (12:30-13:30) will add a further dimension to the defence and automotive radar theme by offering a market analysis perspective, illustrating the status, development and potential of the market.

The 13:50-15:30 session will consider: Experience and future expectations regarding automotive and military radars. Although radar sensors were originally developed for military purposes, their use is increasingly entering into everyday life. This session reports on the experiences obtained with such sensors. Advantages, weaknesses and further operational aspects will be described by users of highly sophisticated defence radars as well as low cost automotive radars and other applications.

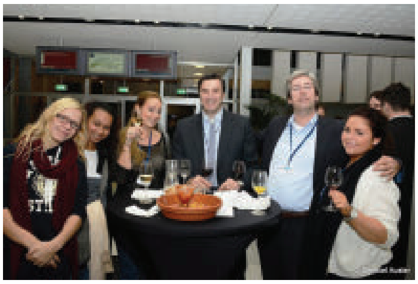
The early evening (16:00-17:40) Executive Forum will feature executives from defence and security agencies and leading companies as well as experts and executives from companies involved in automotive radars. They will discuss the challenges and trends of the future and will further elaborate on their views regarding the cross-fertilization, in development and production, between these different market sectors.

The day's proceedings will conclude with a cocktail reception which will give delegates the unique opportunity to discuss the issues raised in an informal setting.

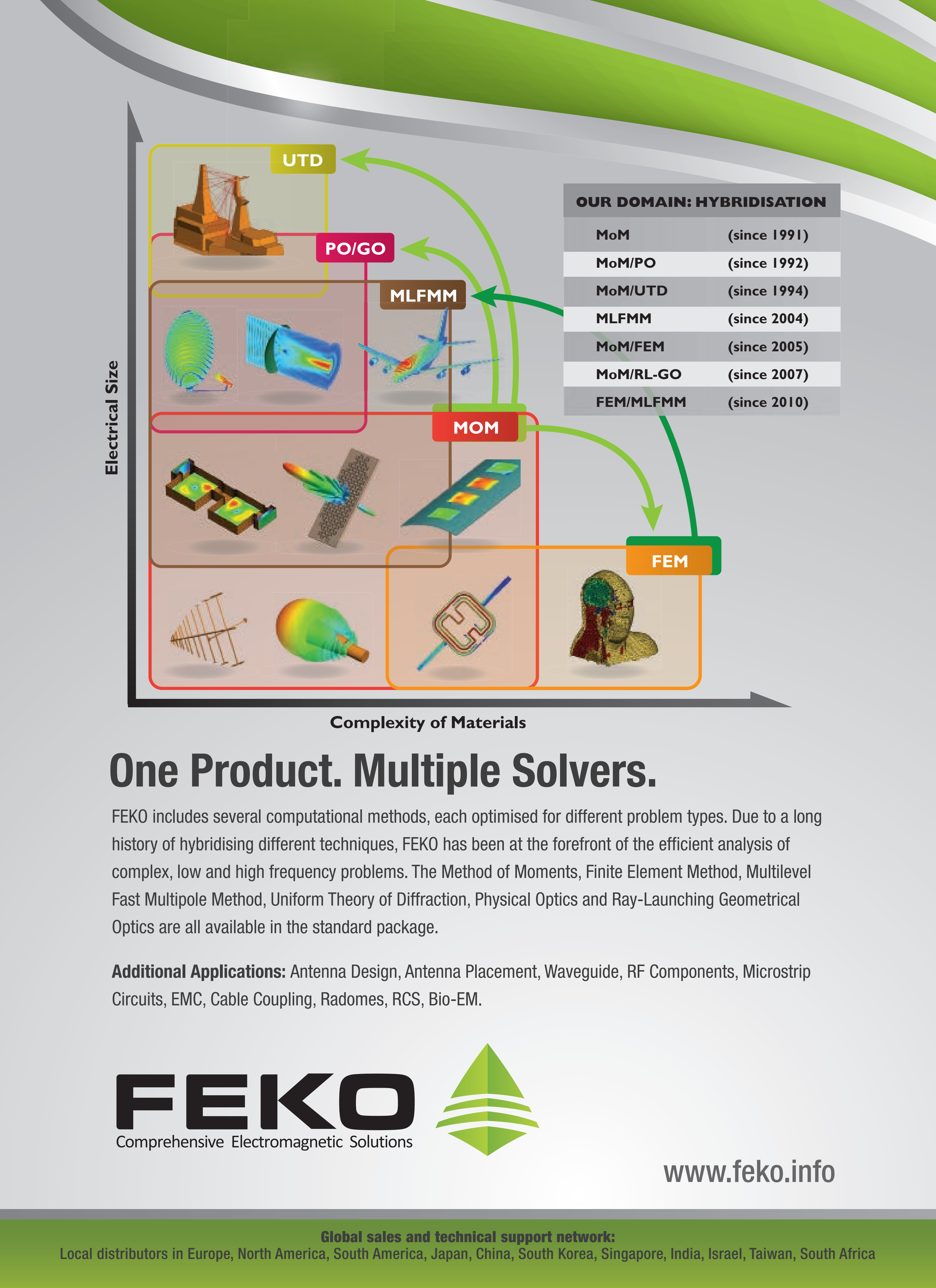
REGISTRATION AND UPDATES

Attendance is free and open to all EuMW 2013 conference delegates, exhibitors and visitors. However, to help with logistics and planning those wishing to attend the 2013 Defence and Security Forum are asked to pre-register. To do so, please visit www.eumweek.com/2013/special.asp and click on registration.

As information is formalized, the Conference Special Events selection of the EuMW website will give details of the speakers for all sessions and will be updated on a regular basis. ■



Photos courtesy of Shmuel Auster.


UTD
PO/GO
MLFMM
MOM
FEM
Electrical Size
Complexity of Materials

The 2013 Defence and Security Forum

At European Microwave Week

Tuesday 8th and Wednesday 9th October 2013

A one and a half-day Forum incorporating the *EuMIC Closing Session* and the *EuRAD Opening Session* and featuring the *EuMW Defence and Security Executive Forum*. Special emphasis will be on the differences and similarities between the two major radar applications today - defence and automotive.

Programme:

Tuesday, 8th October

Development and Production Requirements for Automotive and Military Radar
13:50 - 15:30

- Development and Production of Radar Modules for Automotive Applications
  Christian Frank, Innosent
- Packaging and Manufacturing Approach for Radar Applications
  Yves Mancuso, Laurent Pierre, Thales

EuMIC Closing Session
16:00 - 17:40

Wednesday, 9th October

Microwave Journal Industry Panel Session: Defence and Automotive Radar – Differences and Commonalities
08:30 - 10:10

- Test Challenges for Automotive Radars: a Compare/Contrast with Traditional Aerospace Radar Systems – *Richard Overdorf, Agilent Technologies*
- Defence and Automotive Radar – Differences and Commonalities – an ADI Perspective
  Patrick Walsh, ADI, representing Richardson RFPD
- Serving Defense Applications with Commercial 77/79 GHz Packaged Automotive Radar MMICs
  Dr. Mark R. Wilson, Freescale Semiconductor

Details in this programme are correct at the time of going to press – updates will be posted on eumweek.com

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- Defence and Automotive Radar – Differences and Commonalities: A Demanding Challenge to Measurement Techniques
  Steffen Heuel, Rohde & Schwarz
- MMIC Integration and Packaging for Defence and Automotive Radar: Size and Cost Reductions Create New Market Opportunities
  Dean White, TriQuint Semiconductor

EuRAD Opening Session
10:40 - 12:20

Lunch & Learn, Market Watch
12:30 - 13:30

- Future Technology Trends Bridging Automotive and Military Radar – *Asif Anwar, Strategy Analytics*

Experience and Future Expectations Regarding Automotive and Military Radars
13:50 - 15:30

- Future Developments of ADAS Systems – *Claudio Hartzstein, IAI*
- Comparative Test of Advanced Emergency Braking Systems
  Christof Gauss, ADAC, Holger Meinel, Daimler
- High Performance X-Band E-Scan Radar for Security Application – *Andreas Strecker, CASSIDIAN*
- Automotive Radar Application in Difficult Environments (e.g. Tunnel) – *Tom Schipper, KIT, Alicja Ossowska, Valeo*

EuMW Defence & Security Executive Forum
16:00 - 17:40

The Forum will feature executives from defence and security agencies and leading companies as well as experts and executives from companies involved in automotive radars. They will discuss the challenges and trends of the future and offer views regarding cross-fertilisation, in development and production, between different markets.

Cocktail Reception
17:40 - 19:00

The opportunity to network and discuss the issues raised throughout the Forum in an informal setting.

Organized by:

Microwave Journal

EuMA European Microwave Association

79 GHz High Resolution Short Range Automotive Radar Evolution

The 79 GHz band (77 to 81 GHz) was identified in Europe as the most suitable frequency band for long-term and permanent deployment of high resolution automotive radars due to its benefits. This article highlights the applications and benefits of 79 GHz, motivating a harmonized regulation for the 77 to 81 GHz band as a stable, permanent and globally harmonized frequency band for high resolution automotive radar equipment; and illustrates the status of allocation of the 77 to 81 GHz band in the key countries around the world and the current on-going initiatives for regulation.

TABLE I

SHORT RANGE RADAR AUTOMOTIVE APPLICATIONS

Applications	*Sensor location: Front/rear or side?*	*Comfort or safety?*
Adaptive Cruise Control (ACC)	Front	Comfort/Safety
Collision Warning System (CWS)	Front/Side	Comfort
Collision Mitigation System (CMS)	Front/Side	Safety
Vulnerable Road User Detection (VUD)	Front	Safety
Blind Spot Monitoring (BSD)	Rear	Comfort
Lane Change Assistance (LCA)	Rear	Comfort
Rear Cross Traffic Alert (RCTA)	Front/Rear	Comfort

AUTOMOTIVE SHORT RANGE RADAR APPLICATIONS

The last 10 years have shown a big revolution regarding automotive radar applications. The automotive industry's long-term goal is accident-free driving that can be achieved due to 360° surround vision or semi-autonomous/fully autonomous driving. As a matter of fact, automotive radars are one of the main tools to achieve these visions. As a consequence, evolution of automotive radar applications followed two ways: from only front side looking to rear/side looking up to 360° vision and from comfort functions that only give indications to the driver (e.g., sound alert or visual warning) to safety functions that will automatically control the vehicle (i.e., act on the brakes or the steering).

To support this evolution, the 79 GHz band is an ideal choice for every radar supplier for next-generation sensors that need to meet

Davide Brizzolara
ERTICO - ITS Europe, Belgium


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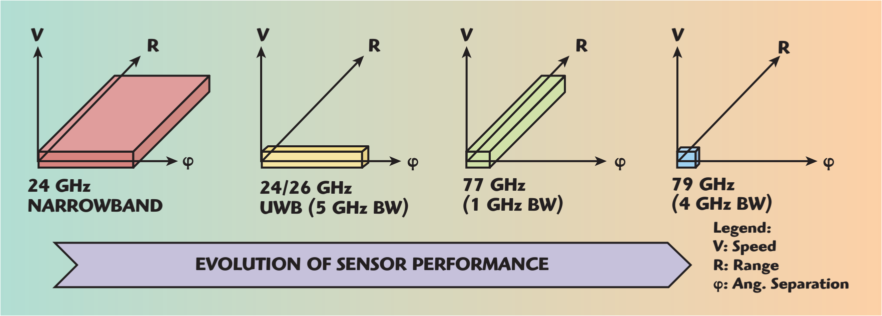
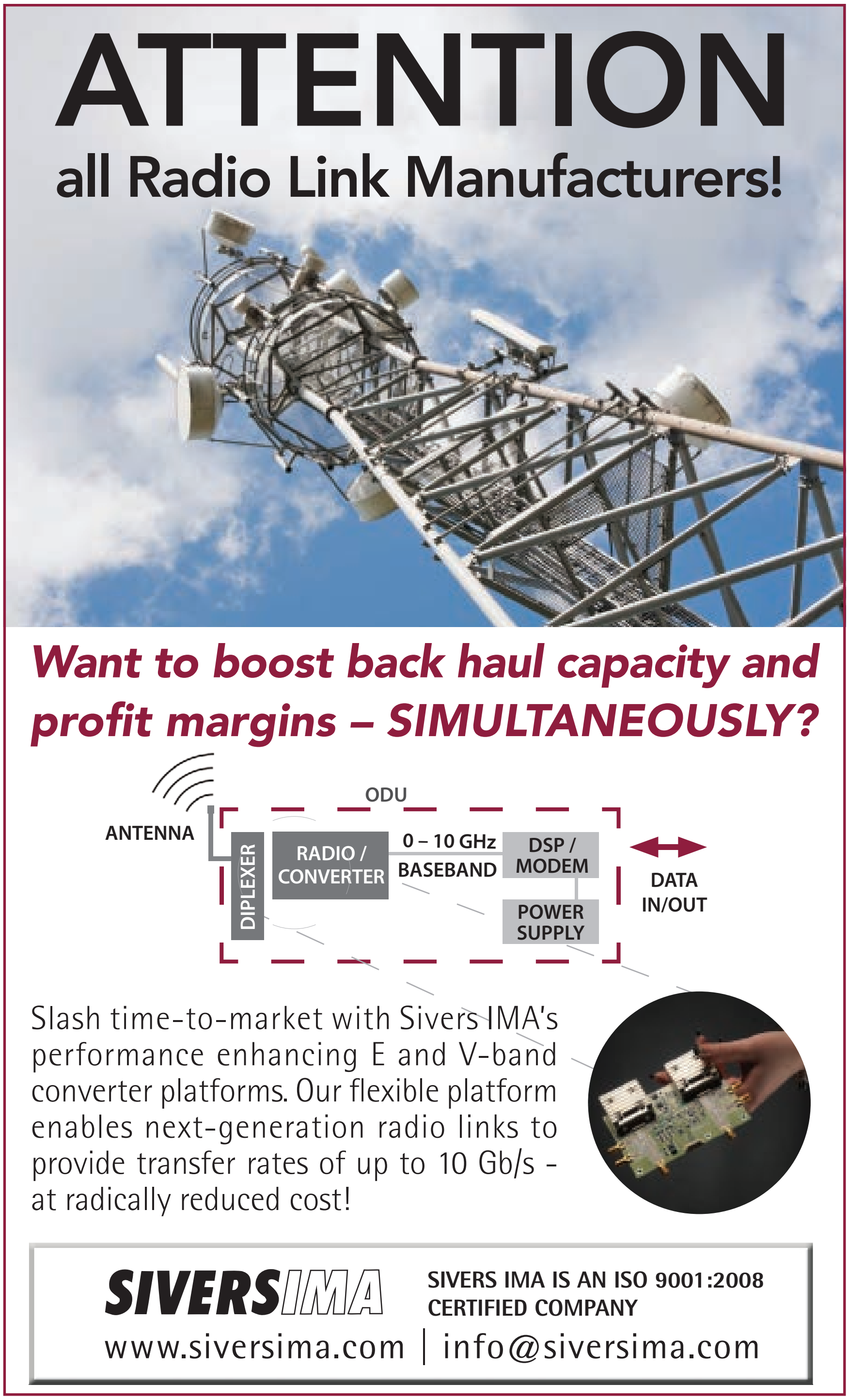


▲ *Fig. 1 Evolution of sensor performance for short range applications.*

high-level requirements. A wide range of applications will benefit from the use of the 79 GHz band (see ***Table 1***): the adaptive cruise control (ACC) whose principle is the acceleration/deceleration of the vehicle to keep a constant distance to the vehicle in front or stop behind a stopped vehicle and follow the vehicle when it drives on (requires driver input); the collision warning system (CWS) which provides an acoustic and/or optical warning to the driver and may prepare the braking system by building up pressure and increases the braking force if the driver does not generate the necessary deceleration to avoid the collision; the collision mitigation system (CMS) which provides optical and acoustic warning and prepare the braking system by building up pressure including eventually autonomous braking if the driver does not generate the necessary deceleration to avoid the collision; the vulnerable road user detection (VUD) which supports the detection of vulnerable road users (cyclists or pedestrians) in front (potentially also on the side of the vehicle) in order to enable warning or assist brake functions; the blind spot monitoring (BSD) function which observes adjacent lane in the area next to the host vehicle, in order to avoid lane change collisions with traffic at approximately the same velocity autonomous steering controllability might be an evolution of this function; the lane change assistance (LCA) radar which observes the adjacent lane in the area behind the host vehicle, in order to avoid lane change collisions with traffic approaching with a higher velocity from the rear; and the rear cross traffic alert (RCTA) sensors observing the area behind the host vehicle, in order to avoid collisions with crossing traffic when reversing, e.g., in a parking lot.

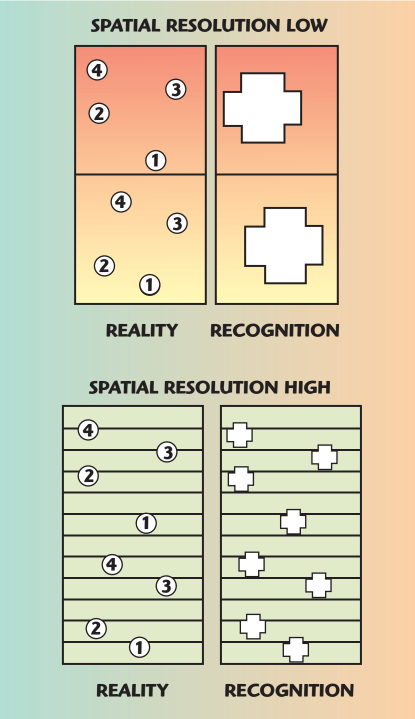
BENEFITS OF 79 GHz BAND

Several studies, for instance those carried out in the activity of the EU founded project MOSARIM (https://assrv1.haw-aw.de/), have shown that higher frequency radar systems tend to be more reliable, with better performance and accuracy (see ***Figure 1***). There are different advantages in the use of 79 GHz band. For instance, multiple objects cannot be distinguished if they appear in the same



range gate and are fused to one virtual object. The possibility of having a large bandwidth of 4 GHz, available at 79 GHz, allows a better target discrimination capability. Spatial resolution capability is directly linked to the available bandwidth. The higher the used bandwidth, the better the spatial resolution will be, as shown in ***Figure 2***. For safety-critical applications, an exact location determination is very important to reduce unjustified system responses or false alarms.

Radar devices are much smaller at 79 GHz compared to 24 GHz: HF-circuit structures and antenna sizes directly depend on the used wavelength. The higher the operational frequency is, the smaller the total size of the radar device. The relationship is of linear character and results, when comparing 24 GHz with 79 GHz, in a ratio-factor of 3. Common usage of one technology concept for all applications (currently automotive radar applications use different frequency ranges for the different applications); by using a common 76 to 81 GHz technology platform a holistic and flexible system concept can be established. This results in advantages regarding system development and multi-functional use of individual sensors. Mutual interference risk is low due to the smaller emission power: since compared with the 77 GHz long range radar (and also the 24 GHz narrowband devices) the average emission power of 79 GHz is three orders of magnitude lower, the interference distance is more than one order of magnitude lower, resulting in more robustness and interference margin.



▲ *Fig. 2 Comparison of spatial resolution of low and high bandwidth sensors.*

RESEARCH AND DEVELOPMENT PROJECTS

Various projects have been initiated since the European Decision in 2004 to open the 79 GHz band for automotive SRR. This includes, for instance, the above mentioned EU-founded project MOSARIM whose main objectives are the investigation in mutual vehicular radar interference and the definition and elaboration of

effective counter-measures and mitigation techniques focusing on automotive radar operation frequencies from 24 to 79 GHz. In addition, the Radar on Chips for Cars (RoCC) project, involving Daimler, BMW, Bosch, Infineon and Continental (financed by the German government), targets to further advance silicon-based radar technology in the 76 to 81 GHz band with special emphasis on SRR with the final goal to bring down the cost of 79 GHz automotive radar sensors significantly and make them cost-competitive.

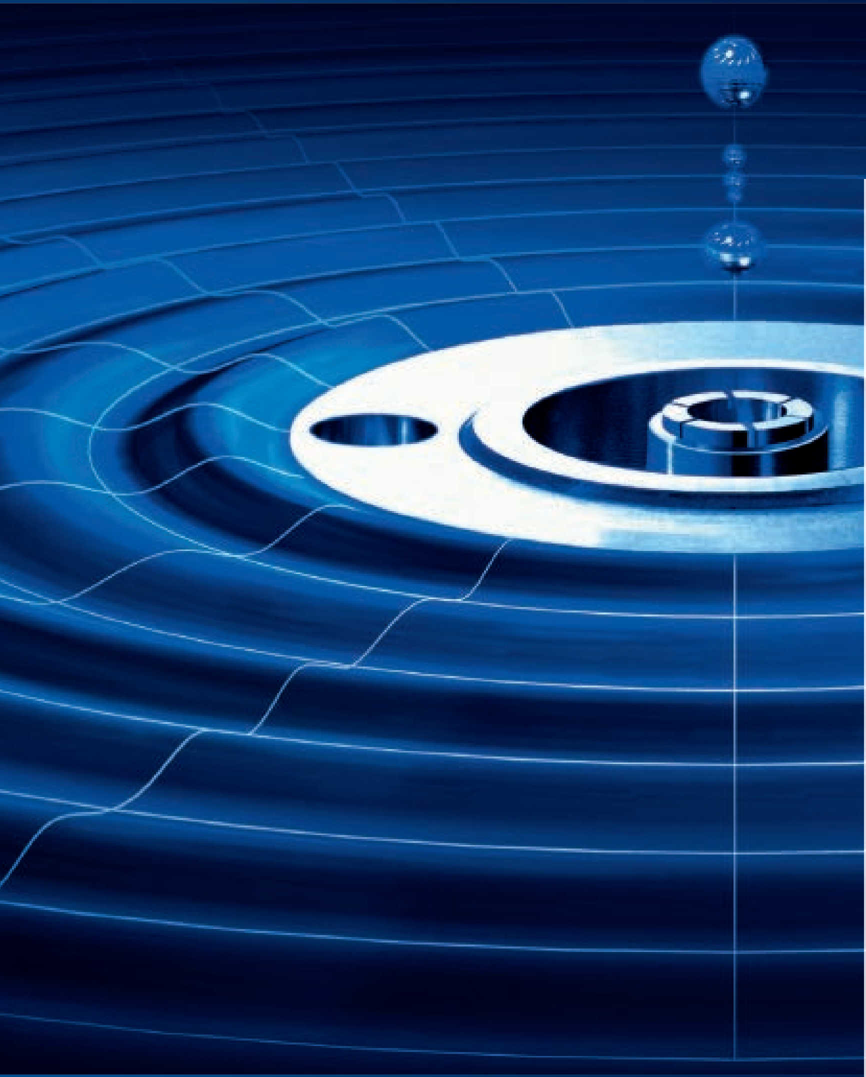
In France, research and development work has also been undertaken for 79 GHz UWB SRR technology mainly within the framework of three projects (RADAR ACC, ARPOD and RASSUR 79), financed by the general delegation of the French equipment (DGE), in complement to internal PSA Peugeot Citroën Automobile works. The RADAR ACC project is focused in developing a sensor capable of answering at the same time the specifications of the ACC, the pre-crash and the collision mitigation with the 76/79 GHz UWB technology. The ARPOD project focused in answering to the peripheral performances of the vehicle (example LCA, BSD, side FCW, pre-crash) by mean of the development of sensors with the 76/79 GHz technology and materials bumper adapted; the RASSUR79 project focused on the development of low cost high resolution radars operating within 77 to 81 GHz, for applications such as ACC and AEBS.

79 GHz FREQUENCY ALLOCATION

Taking into account the benefits of the 79 GHz band and the current status of the regulation in Europe (defined by the European Commission in 2004) and in others countries in the world (Russia, Singapore, etc.), the EU-founded project 79 GHz (www.79ghz.eu), supported by different companies, is currently operating to establish and speed up the worldwide harmonized frequency allocation for vehicular radars in that frequency range and to avoid jeopardizing the implementation of the previous described high performance radar applications.

At the beginning of the project, the 79 GHz radar equipment was only authorized in the 27 EC member states, in most of the further 21 CEPT countries, in Singapore and Australia. In all other countries, the operation of 79 GHz radar devices was not possible due to the lack of any regulatory framework for this frequency band.

Various actions have been taken by the 79 GHz project partners. In the USA, there have been extensive discussion and several meetings with Federal Communications Commission (FCC) and tests have been carried out to evaluate the interference with radio astronomy sites equipped with radar operating at the same frequencies. A petition to adopt and release the 77 to 81 GHz band is expected by midyear 2013. Canada's decision regarding 79 GHz partially follows the U.S. FCC rules due to the cross-border situation and direct neighborhood to the USA.



In Japan, the 79 GHz band is now regulated while the 500 MHz allocation in frequency band 77 GHz is still in discussion. A positive outcome is expected from countries like Hong Kong and Korea, where the Korea's National Radio Research Agency (RRA) is preparing to amend the legislation procedure to accept 79 GHz. 79 GHz project had a successful meeting with Thailand's National Broadcasting and Telecommunication Commission (NBTC): the Thai Automotive Industry Association (TAIA) is expected to submit a petition to NBTC with requests to regulate 79 GHz.

Several Gulf States are preparing for the introduction and in Brazil, where the regulation process started the process in 2012, there are on-going activities between ANATEL (the frequency authority in Brazil) and AEA (Associação Brasileira de Engenharia Automotiva) with the aim to analyze and review the European and U.S. studies for 79 GHz. In Argentina, CSA79GHz project is in contact with CNC (Comisión Nacional de Comunicaciones) and SECOM (Secretariat of Communications). In Chile, SUBTEL (Subsecretaría de Telecomunicaciones) has now regulated the 79 GHz band. China and India have currently no regulation for 79 GHz but initiatives are currently on-going promoted by the CSA 79 GHz project.

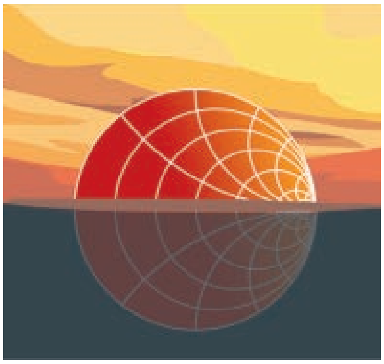
In the context of the 79 GHz project, the CLEPA (the European association of automotive suppliers) and OICA (the International organization of motor vehicle manufacturers) organizations decided (October 2012) to create a joint task group called GARREG, the International Automotive Radio Regulations Expert Group.

Radio communication systems are more and more used by the automotive industry to equip cars. Radar, keyless entry, tire pressure monitoring system (TPMS) and car-to-car communications are among all of these systems. Global harmonization is the key for car manufacturers to install such systems in the car and there is a crucial need for a global automotive group with legitimacy to support and drive the automotive frequency regulations on a worldwide level, a group that must be at the same level as other organizations (e.g., ITU-R) or interest groups (e.g., CRAF).

The creation of the GARREG group is in line with the above mentioned objectives and it will support the promotion of the interests of the Worldwide Automotive Industry regarding the Regulatory issues on radio based automotive systems and components, the use of the appropriate harmonized frequency bands for radio based automotive application within the existing and future regulatory environment and, finally, the maintenance of appropriate existing frequency bands. ■

This article is based on contributions from the activities of the partners of the European Commission founded 79 GHz project: Robert Bosch GmbH, TRW, ERTICO — ITS Europe, Continental and Renault.


NRP
FAMILY



Microwaves in Europe: What's on the Horizon?

As the roadmap for research and innovation in Europe transfers from FP7 to Horizon 2020, can this 2020 vision bring the strategies, investment and commitment needed to ensure that the European RF and microwave industry's future is bright and focused?

The end of 2013 will see the curtain fall on the Seventh Framework Programme for Research (FP7) and the conclusion of its seven year run as a key driver for development, innovation and collaboration, when it will be superseded by Horizon 2020. Despite the inroads that the initiative has made, the cross-border, cross-discipline cooperation it has generated, the streamlining of finance and bureaucracy it has achieved and the significant and influential results that its projects have yielded, European research and innovation hasn't quite been delivered to FP7th Heaven yet. There is a lot of work to be done and serious issues to be addressed before the prospect of European industrial Nirvana appears on the skyline.

"...European research and innovation hasn't quite been delivered to FP7th Heaven..."

When FP7 was launched in 2007 very few, if any, would have envisaged that just one year later the 2008 financial crisis would trigger the economic downturn, spark recessions of varying degrees across Europe and significantly change the political, industrial and economic landscape.

It is an ongoing process but Europe is slowly but surely recovering from the downturn and needs to play to its strengths for that to continue. It is a world leader in many strategic sectors such as automotive, aeronautics, engineering, space, chemicals and pharmaceuticals. Industry still accounts for 80 percent of Europe's exports, while 80 percent of both Europe's exports and private sector R&D investment comes from manufacturing.

Also, despite the continuing economic crisis, innovation performance in the EU has improved year on year but, as the European Commission Innovation Union Scoreboard 2013, a ranking of EU member states, points out, the innovation divide between member states is widening. While the most innovative countries have further improved their performance, others are failing to do so. The overall ranking within the EU remains relatively stable, with Sweden at the top, followed by Germany, Denmark and Finland. And, although coming from a relatively low base, it is the Eastern European counties of Estonia, Lithuania and Latvia that have most improved since last year.

"...the innovation divide between member states is widening..."

Scoreboard 2013 reports that drivers of innovation growth in the EU include small and medium sized enterprises (SME) and the commercialisation of innovations, together with excellent research systems. However the fall in business and venture capital investment from 2008 to 2012 has negatively influenced innovation performance.

Although the EU is a global leader in many technologies and its innovation performance has held up, it now faces increasing competition from traditional competitors as well as

Richard Mumford
Microwave Journal *International Editor*

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emerging economies and must strive to progress.

Research and innovation helps to deliver prosperity, employment and investment and also leads to business opportunities by creating innovative products and services. Consequently, it has been placed at the forefront of the Europe 2020 strategy by setting the objective to increase spending on R&D to 3 percent of GDP by 2020.

The European RF and microwave industry has the distinct advantage that it is at the forefront of key technologies such as mobile communications and wireless technologies that are sought after commodities and play a significant role in modern life. It can provide solutions to safer and efficient road transport, safeguard national and international borders, provide security and help explore new frontiers. Through R&D and industrial activities, the RF and microwaves sector is tackling technological challenges and creating business opportunities.

In particular, the hunger for higher data rates to sate the appetite of the 'smartphone generation' is challenging design concepts and stimulating innovation. For instance, in the battle to support LTE devices with multimode, multiband PAs, front ends have entered the frontline as the players in the GaAs, CMOS and envelope tracking camps fight to establish their position in the marketplace.

"...increase spending on R&D to 3 percent of GDP."

Like their counterparts in North America and Asia, European companies and engineers continue to make significant progress in the development of semiconductor power devices and integrated circuits, alongside the evolution of packaging solutions, which enables complex chip-level system integration at ever increasing frequencies. Indeed, higher frequencies are being developed for short-range, high capacity communications as well as high resolution imaging radar.

With reduced investment in defence, companies traditionally serving this sector are looking to augment their order books by addressing applications which increasingly stem from civil requirements. For instance, radar technology is expanding in areas such as road traffic safety, civil aviation/runway detection, homeland security and space/earth observation. In the field of civil radar, Europe remains strong even in terms of high volume production, especially in automotive radar, which will be demonstrated at EuMW 2013, where it will be a major theme.

With the industry focus primarily on product development, it is easy to forget the importance of developing the 'instruments' vital to support R&D and bring the latest technology to market. Europe continues to develop advanced modeling and simulation tools, alongside high performance, high speed RF test and measurement equipment that serves the global market.

As well as the tools to test and evaluate design and performance, the European RF and microwave industry needs the right tools to enable industry, research bodies and academia receive financial support, pool resources and build on expertise to bring research faster to market and stimulate demand for European products and services. Following is an overview of the initiatives and funding that the EU has put in place with particular emphasis on the objectives and operation of Horizon 2020 and the focus on SMEs.

EUROPEAN INITIATIVES

The final calls under the 7th Framework Programme for Research went out in the middle of 2012, with the successful projects now underway and due to run their course in the next few years. Some of those specific to the RF and microwave, semiconductor/IC and radar sectors of our industry are highlighted in Sector Overviews & Initiatives later in this report.

"...Horizon 2020 will run from 2014 to 2020 with a budget of €80 billion."

FP7 has played a significant role in bringing structure, direction and stimulus to European research and innovation projects and Horizon 2020 is set to build on its successes and benefit from the lessons learned. In particular, the FP7 interim evaluation

report concluded that further simplification was needed. Therefore, Horizon 2020 will have three main goals: to reduce administrative costs of participants, to accelerate all processes of proposal and grant management and to decrease the financial error rate.

Major simplification will be facilitated by a single set of rules and Horizon 2020 will amalgamate all research and innovation funding currently provided through the Framework Programmes for Research and Technical Development, the innovation related activities of the Competitiveness and Innovation Framework Programme (CIP) and the European Institute of Innovation and Technology (EIT), which has a vital role to play by integrating research, education and innovation. The EIT will do so primarily through the Knowledge and Innovation Communities (KIC).

With the aim of creating growth and employment across Europe through research and innovation, Horizon 2020 will run from 2014 to 2020 with a budget of €80 billion. The first calls are expected at the end of 2013/early 2014. Significantly, its approach to innovation will not be limited to just bringing new products to market. It will also encompass processes, systems or other approaches, including recognising and exploiting European strengths in design, creativity and services.

> **"...increase in funding of 77% for the European Research Council..."**

Horizon 2020 will focus resources on three priorities: Excellent Science, Industrial Leadership and Societal Challenges. Although all three priorities are relevant to the RF and microwave industry, it is the first two, especially Industrial Leadership, which have the potential to make the most impact. Excellent Science seeks to raise the level of excellence in Europe's science base and ensure a steady stream of world-class research to secure Europe's long-term competitiveness. In order to strengthen the EU's position in science, a dedicated budget of €24,598 million will provide a boost to top-level research, including an increase in funding of 77 percent for the European Research Council (ERC).

The stated aim of Industrial Leadership is to make Europe an attractive place to invest in research and innovation by promoting activities where businesses set the agenda. Investment of €17,938 million in industrial leadership in innovation includes significant investment in key technologies, greater access to capital and support for small and medium-sized enterprises.

SMEs are the backbone of the RF and microwave skeleton in Europe, supporting the larger operations and international conglomerates. Their potential for innovation, stemming from their inherent agility and flexibility needs to be exploited and the Innovation Union flagship initiative includes a commitment to ensure strong participation by SMEs in Horizon 2020.

Simplification is seen as being the key for SMEs, whose limited resources should not be stretched by having to deal with unnecessary red tape and high administrative burdens. To this end there will be a single entry point for small and medium-sized enterprises wishing to participate in Horizon 2020 and a dedicated activity for research-intensive SMEs will support the next stage in the Eurostars scheme implemented in partnership with member states.

As has been touched on in this annual Report in previous years, the Eurostars Programme is a European joint initiative dedicated to SMEs performing R&D, and co-funded by the European Communities and EUREKA member countries. Within the programme, small businesses lead international research projects where they partner with other small companies, universities and big companies. Eurostars funding is used for the development of new technological products and purely academic projects are not eligible for funding. Being tailored specifically for SMEs, the application and reporting processes are simplified.

> **"...promoting activities where businesses set the agenda..."**

While it supports the Eurostars Programme, EUREKA has a larger

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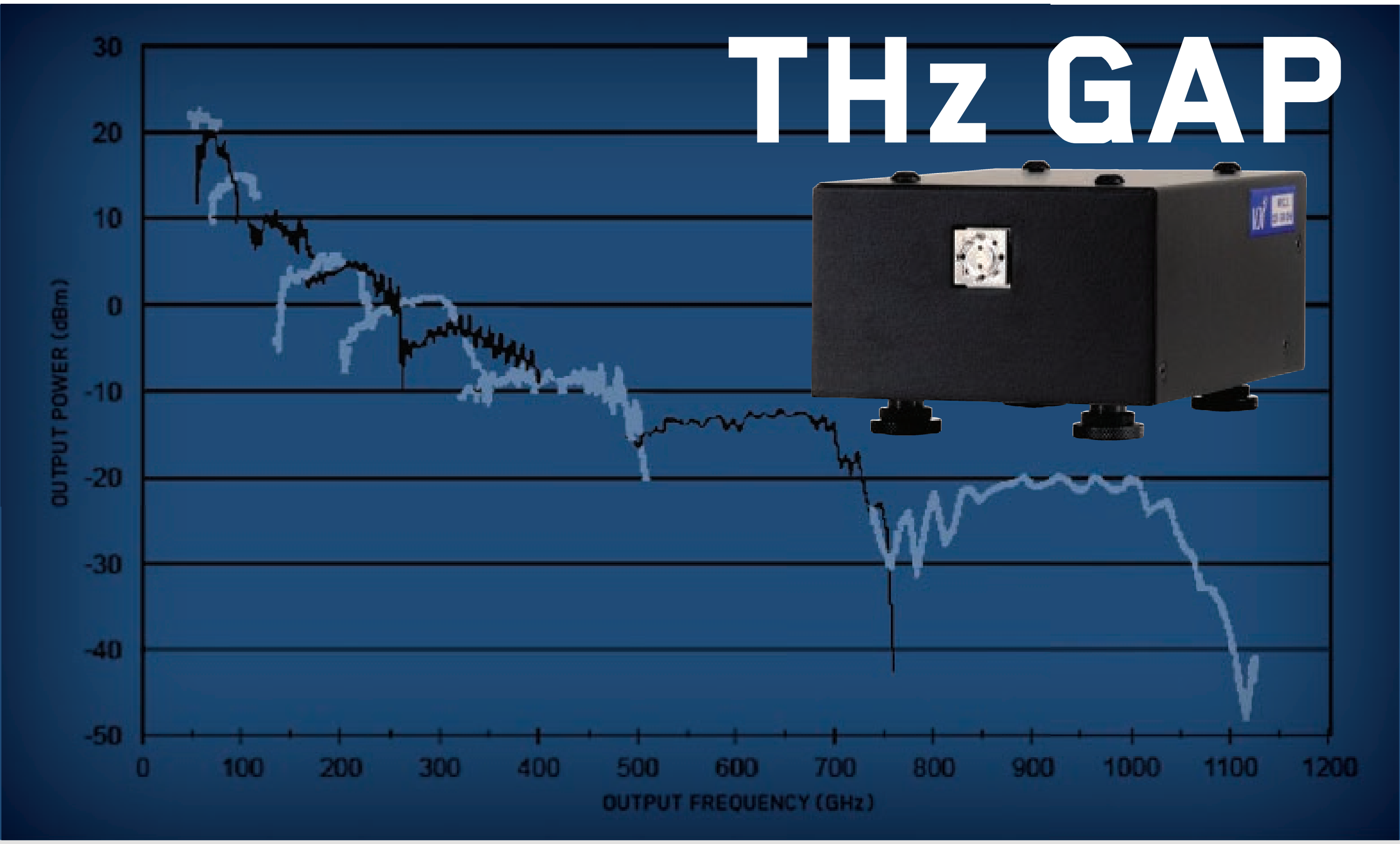
BRIDGE THE THz GAP



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Multiplication Factors	4	6	12	12	12	18	36	54	81
Input Frequencies (GHz)	12.5 - 18.8	12.5 - 18.3	7.5 - 11.7	9.2 - 14.2	11.7 - 18.3	12.2 - 18.3	9.0 - 13.9	9.3 - 13.9	9.3 - 13.6
Alternate Multiplication Factors	2	3	6	8 or 4	6	9	24 or 12	36 or 18	54 or 27
Typical Output Power (dBm)	20	14	9	8	4	-2	-10	-21	-25/-35
Minimum Output Power (dBm)	17	10	3	2	0	-8	-18	-30	-33/-40

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remit. Founded in 1985 to challenge the increasing migration of R&D and industrial innovation to Asian and North American countries, EUREKA now unites 40 member countries and counts the European Union as its 41st member. Together, they promote international, market-oriented research and innovation through the support they offer to SMEs, large industry, research institutes and universities.

Also of interest to the RF and microwave industry are EUREKA Clusters. They are public-private partnerships uniting major companies and national innovation agencies to complete pre-competitive technological research projects, setting standards for entire markets. Clusters projects are initiated through calls for funding application, where SMEs and universities are invited to join projects, thus directly linking them to large companies and multinationals.

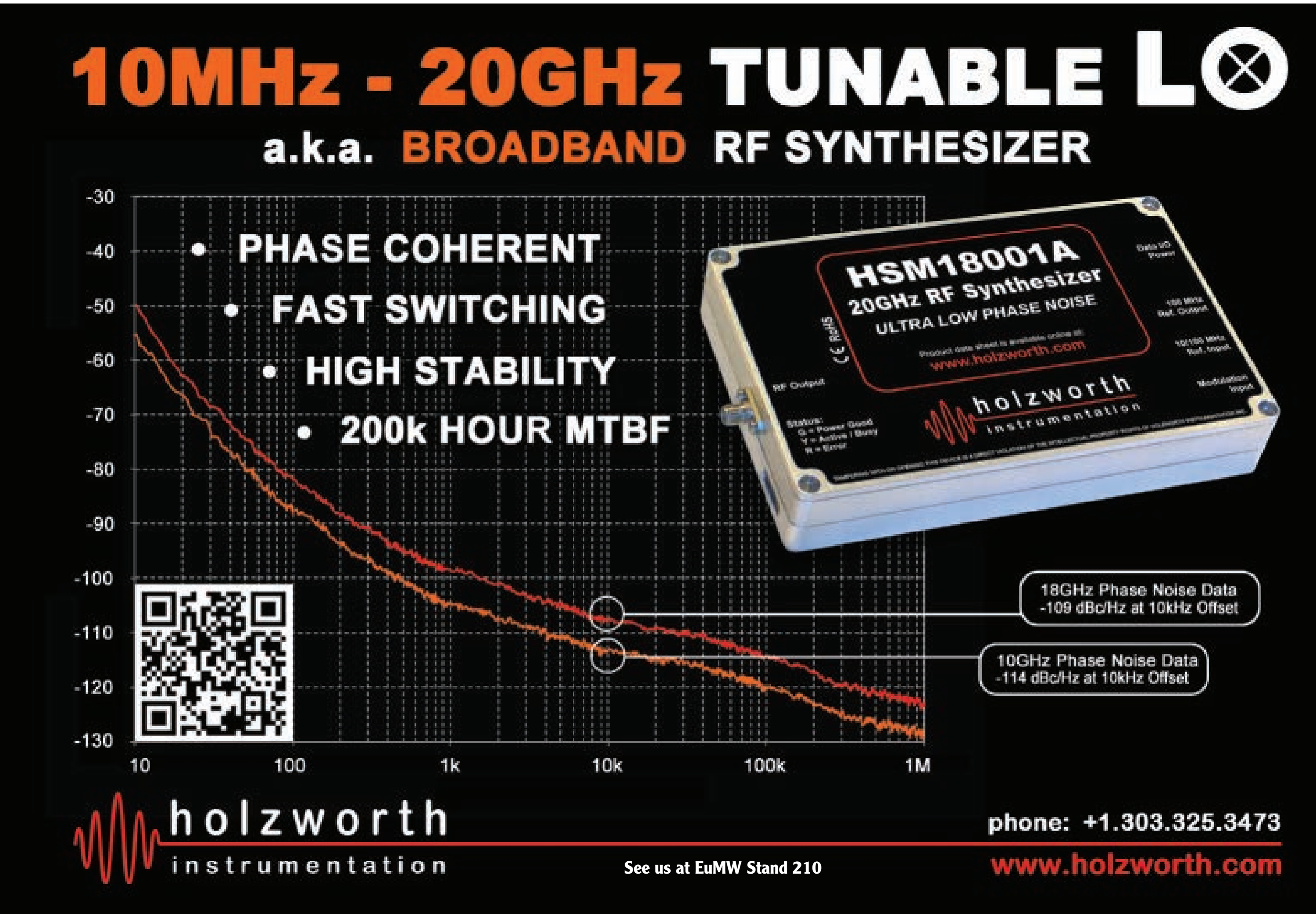
Each Cluster covers one specific industry sector. Those of particular interest to the RF and microwave community are: CATRENE – the Cluster for micro and nano-electronics, EURIPIDES, which specialises in smart systems and CELTIC Plus that focuses on telecommunications, including smartphone and other Internet-based services.

Although Horizon 2020 and associated initiatives are, of course, Europe-centric, it is also recognised that European industry does not operate in a vacuum and has to complement and function within the global marketplace. Activities at the international level are equally important to enhance the competitiveness of European industry by promoting the take-up and trade in novel technologies, e.g., through the development of worldwide standards and guidelines, and by promoting the acceptance and deployment of European solutions to the wider world. In particular, international cooperation with third parties is necessary to effectively address specific objectives defined within Horizon 2020.

The general principles of Horizon 2020, like FP7 before it, and other EU initiatives are far reaching and all encompassing. Emanating from them are specific initiatives that are of significance to the RF and microwave industry.

For instance, to reverse the decline of the EU's global share in the electronic components and systems market and build on areas of strength such as embedded systems, semiconductor equipment and materials supply and the design of complex electronic systems, the European Commission has proposed the new Electronic Components and Systems for European Leadership (ECSEL) Joint Technology Initiative (JTI). This is a merger of the ARTEMIS initiative on embedded systems and the ENIAC initiative on nano-electronics that were both launched in 2008; it also incorporates research and innovation on smart systems.

The ECSEL JTI is likely to have a budget of €4.8 billion, with an EU contribution up to €1.2 billion, matched by the contribution from member states. It is expected to start in early 2014 and run for 10 years, bringing together large and small companies, world-class European research and technology organisations and academia.



"I want 5G to be pioneered by European industry..."

Also, the mobile communications industry, fuelled by the 'smartphone revolution,' may have posed technological challenges but it has also created potentially game changing opportunities. While many of us have still to embrace 4G, the European Commission has announced €50 million for research to deliver 5G mobile technology by 2020, with the aim of putting Europe back at the forefront of the global mobile industry. When announcing the initiative, EC vice president Neelie Kroes said, "I want 5G to be pioneered by European industry, based on European research and creating jobs in Europe – and we will put our money where our mouth is."

Europe also intends to take greater ownership of its military communications capability and harmonise wireless communications, with EU member states having tended to address this issue in a piecemeal manner, through various developments and standards that are not always compatible. This has made it increasingly difficult for forces to cooperate on multinational operations and resulted in reliance on third-party nations, particularly the United States, for certain interoperable assets or resources.

Therefore, the European Defence Agency (EDA) has commissioned Thales to conduct a study of the main terrestrial and satellite communication network Programmes in European Union countries under the Future Communications (FUCOM) project. The project will compile an inventory of the main member states' existing and future assets, including military satellite communication systems, terrestrial tactical communications (software-defined radio), professional mobile radio (PMR) and LTE capabilities.

Such initiatives will offer momentum and direction to our industry and complement the individual and collective efforts of those at the forefront of research and innovation. The next section of this report offers a perspective of current activity and identifies future trends.

SECTOR OVERVIEWS & INITIATIVES

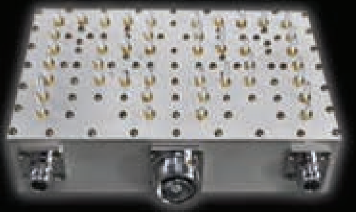
The chairmen of the three 2013 European Microwave Week conferences – the European Microwave Conference (EuMC), the European Microwave Integrated Circuits (EuMIC) Conference and the European Radar (EuRAD) Conference – offer an insight into key areas of development and identify future trends. To illustrate specific European activity in these sectors, examples of current FP7 initiatives that will continue after 2013 are highlighted.

RF & MICROWAVES

Sector overview by Lorenz-Peter Schmidt, EuMC 2013 chair

(In collaboration with Thomas Zwick, TPC chair and Yoke Leen Sit, secretary)

The RF and microwave sector in Europe is steadily developing despite increasing worldwide competition, especially since the high volume business in fields such as mobile communication devices manufacturing,

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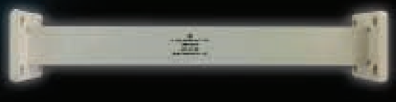
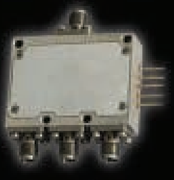
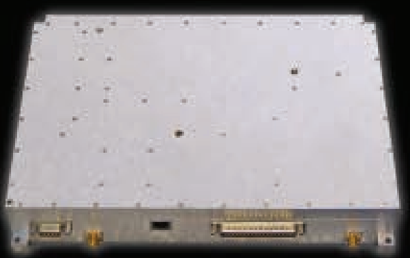






including specific Research & Development activities, are increasingly being shifted to Asia. In the field of civil radar, especially automotive radar, the European position is still going strong even in terms of high volume production. However, the military business and partly also the space business are suffering from budget cuts in European countries, only partly compensated by their worldwide export business success. Currently the European Union is preparing new frameworks to strengthen the competitiveness of the micro- and nanoelectronics activities in Europe in order to preserve Europe's strong position in these high-tech fields.

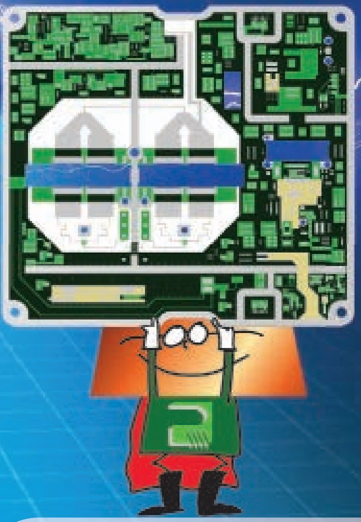
In the RF and microwave sector, rapid technological progress is underway towards the design and production of devices of higher complexity, higher flexibility, lower power consumption and better performance at lower prices. Examples are the reconfigurable, fully software-controlled communication and radar front ends in flexible MIMO systems. This is rendered possible by novel system concepts, higher levels of device integration, intensive use of switching or tuning elements such as MEMS switches and wide swing varactors, which are currently available with extended lifetime and high reliability.

Enormous advances have been achieved in the semiconductor world, where III-V semiconductors are being entirely replaced by highly advanced Silicon-based circuits for low to medium power applications. There is also ongoing dynamic competition between CMOS and bipolar SiGe circuits with changing priorities, depending on performance and cost issues. The rapid progress of the GaN technology on the other hand enables higher output power per device as well as significantly increased supply voltages, which then reduces supply currents, and this benefits power transmitters and flexible multi-element active phased array transmitter front ends. Highly advanced linearization concepts and sophisticated modulation schemes further increase the levels of available power from solid-state power amplifiers at microwave to millimetre-wave frequencies.

> **"…integrated circuits in smart packages at reasonable costs…"**

Currently there is also the trend to evaluate and develop the utilization of the frequency range beyond 100 GHz. The work focuses on specific applications in the fields of short-range, high capacity communications as well as high resolution imaging radar for security applications and non-destructive testing of materials. These systems are supported by a novel class of integrated circuits in smart packages at reasonable costs.

Coming up are the challenges for the system development and mass production of devices in the fields of car-to-car and car-to-infrastructure communication. Furthermore, the 360° coverage of the car environment by smart radar sensors as well as smart home and smart city applications of

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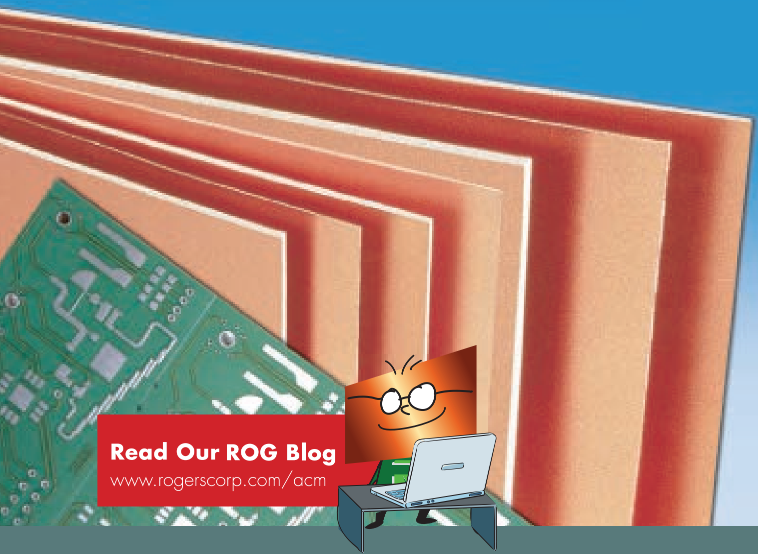
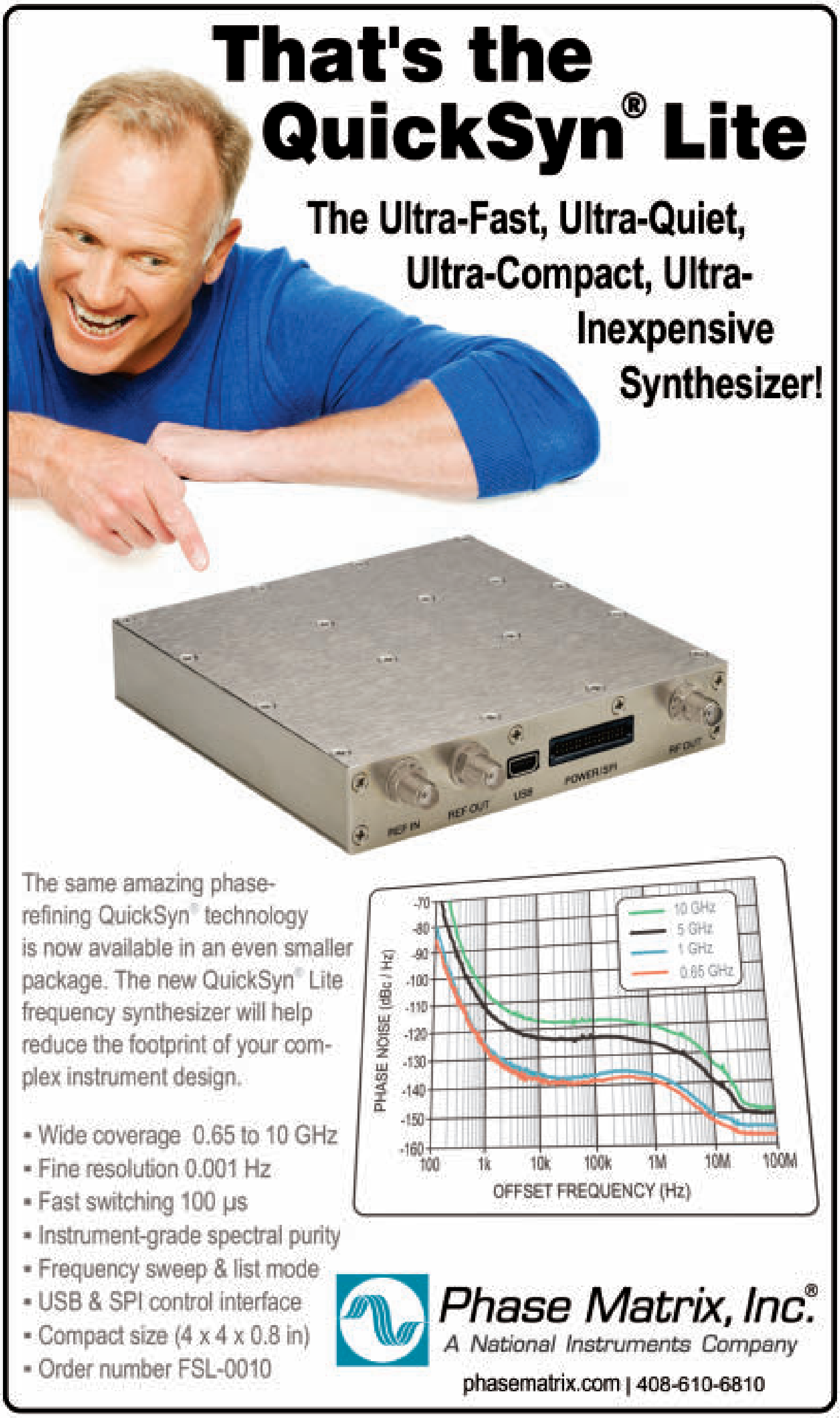


low-cost microwave short-range communication devices, smart sensors and RFID equipment is of rapidly growing interest. Actual developments such as devices that require very low supply power, energy harvesting, wireless power transmission and UWB technologies are further extending the range of applications for RFID and smart sensor systems.

These systems have now matured into versatile, highly mobile platforms combining identification and precise localization with a wide variety of sensing capabilities for industrial, medical, smart home and other applications. Moreover, the microwave range has proven to be ideally suited to a variety of sensor and communication systems for natural or manmade disaster management support, which includes highly flexible, UAV or satellite based SAR and environmental monitoring systems, where Europe traditionally has a strong position.

Microwave R&D and also low to high volume production enterprises are becoming excellently supported by highly advanced commercial modeling and simulation tools as well as by dedicated, high performance, high speed RF test and measurement equipment. Hence, a lot of scientific and technological challenges and business opportunities are keeping the European RF and microwaves sector on a very attractive level for increased or new R&D and industrial activities.



FP7 PROJECTS

One of the most important developments in communication microelectronics was the invention and popularization of digital RF. It is best realized in mainstream nanometer-scale CMOS technologies and easily integrated with digital processors. Consequently, RF transceivers based on this architecture are now the majority of the 1.5 billion mobile handsets produced annually. Unfortunately, that low-cost low-data-rate market segment has already reached saturation and now the fastest growing segments of the wireless communications market are: high-data-rate smartphones, ultra-low-power wireless sensor network devices, antenna-array and millimetre-wave transceivers, where the original digital RF approach could not be readily exploited.

Therefore, the goal of the Time-Domain RF and Analog Signal Processing (TDRFSP) project is to revisit and exploit the fundamental theory of the time-domain operation of RF and analogue circuits. This way, the broad area of the wireless communications, as well as analogue and mixed-signal electronics in general, can be transformed for the ready realization in the advanced CMOS technology. This project will receive just under €1.5 million in funding and has a finish date of 31 August 2017.

With a total budget of around €2.87 million, the Quantum Propagating Microwaves in Strongly Coupled Environments (PROMISCE) project aims to provide the foundations for a novel research field: propagating quantum microwave technologies in strongly and ultra-strongly

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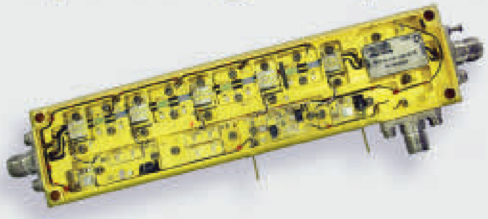

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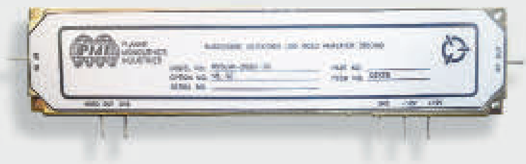

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- Log Slope: 25mV/dB
- 11nS Video Rise Time
- 60nS Recovery Time
- 12nS Delay Time
- TSS: -65dBm
- 30nS to CW Pulse Width
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- Hermetically Sealed
- Military Quality

SDLVA-212-65-010891SA
SDLVA-418-65-010891SA

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- Log Slope: 16mV/dB
- Limited Output: +12dBm
- 10nS Video Rise Time
- 12nS Video Fall Time
- 30nS Recovery Time
- 25nS to CW Pulse Width
- TSS: -64dBm
- 4.25" X 1.00" X 0.38"
- Hermetically Sealed
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coupled environments. In particular, it has potential for scalable quantum information and communication technology (Q-ICT) applications. It combines two major innovative and interdisciplinary components. The first, propagating quantum microwave photonics, focuses on the generation, control and detection of quantum microwave beams and photons using superconducting quantum circuits. The second aims at exploring propagating quantum microwave interactions. Both components are intimately connected: technological and conceptual achievements in one component will immediately trigger progress in the other one. Together they will provide, integrated on a chip, the equivalent of optical Q-ICT experiments in the microwave regime. The project is scheduled to run until 31 March 2015.

ICS & SEMICONDUCTORS

Sector overview by Manfred Berroth, EuMIC 2013 chair (In collaboration with Andreas Thiede, vice-chair and Alexander Bräckle)

The state of the art in integrated circuits, covering frequencies from microwaves to the submillimetre-wave region, will be presented and discussed at the 8th European Microwave Integrated Circuits Conference. One of the main applications for RF integrated circuits is mobile communication, where the industry faces an ever-increasing demand for higher data rates, resulting from the widespread use of smartphones.

Apart from classical mobile communication, there are several challenges which can also be solved by RF integrated circuits. Many research activities focus on technologies to enable data rates up to 1 Tbit/s. This can be achieved by wireless communication systems operating at millimetre-wave frequencies as well as by optical data transmission.

In industry, there is a clear trend towards self-organization of machines requiring communication within the factory environment. The main challenge is a highly rugged communication link, which is achieved by communication links at high frequencies up to 60 GHz. Thus, RF integrated circuits enable low cost communication systems in industrial environments.

> **"…energy efficiency will become a dominating design challenge…"**

Universally, energy efficiency will become a dominating design challenge. As most of the power in a communication system is dissipated in the power amplifier, this continues to be a hot topic of research. Gallium nitride offers new opportunities for RF power amplifier design, but CMOS circuits are also being investigated due to their integration capabilities. For example, nanoscaled CMOS allows power amplifiers at 60 GHz and by the use of BiCMOS technologies, amplifiers in the higher millimetre-wave region are being reported.

Further research to achieve technologies beyond 100 GHz is being carried out in universities, research facilities and several foundries in Europe. The importance of this topic is reflected in the fact that a focused session on high frequency technologies will be a highlight of EuMIC.

The spectrum of RF integrated circuits is completed by RF micro-electromechanical systems (MEMS) and ferroelectric materials. These allow the design of tunable and switchable filters, offering attractive markets for multiband and multistandard terminals.

Last but not least, the advances in RFICs require better theoretical understanding as do the increasingly cheaper and easier-to-use simulation and test capabilities available. As well as advancements in mobile radio communication, sensing and imaging offer interesting applications at microwave and millimetre-wave frequencies.

FP7 PROJECTS

Current applications of microwave technologies in communications, remote sensing and in industry are based on the properties of the interaction of microwaves with matter at supra-wave length scales (above centimetres). The developments performed in nanotechnology in recent years now make it conceivable to explore the interaction of microwaves with matter at much smaller scales, from micrometres to nanometres.

Being an emerging technology, there is a need for training early stage researchers in this field of research so that enough critical mass can be achieved. The main objective of the Microwave Nanotechnology for Semiconductor and Life Sciences (NANOMICROWAVE) network is to train a whole generation of researchers in the field of nanoscale microwave technologies and related emerging applications in the fields of semiconductor industry and life sciences. The final aim of the network is to help to position and consolidate Europe as a leader in the field of nanoscale microwave technologies and related applications. The project will receive over €4 million of EU funding and will extend until 31 December 2016.

Technology requirements for future IC systems include low power computing and communication, sensing capabilities and energy harvesting. These will unlikely be met with silicon technology alone. Therefore, the Integrating Graphene Devices (INTEGRADE) project investigates graphene as a potential alternative technology. The proposal focuses on the experimental exploration of novel (opto-) electronic devices and systems based on graphene. Strong emphasis is put on integration, defined as an interdisciplinary approach combining graphene manufacturing, graphene process technology, device engineering and device physics as well as system design. The project will receive €1.5 million of funding and will extend until 31 August 2017.


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RADAR

Sector overview by Arne Jacob, EuRAD 2013 chair (In collaboration with Reinhard Knoechel, TPC-chair and Christian Friesicke, secretary)

As one of the major international conferences in the field, the 10th European Radar Conference, reflects well the current developments in the radar sector, both in industry and in academia. The sector benefits at the system level from technological progress realized at the component and the subsystem level. Today's radars thus incorporate increasingly sophisticated features emerging from a wealth of technological areas. This trend is driven by applications which increasingly stem from civil needs. Besides the traditional military markets, radar technology is expanding more and more in areas such as traffic safety, homeland security, or space/earth observation to name only a few. The observed system advancements rely both on improved analog and digital hardware technologies and on enhanced software possibilities.

At the component and subsystem level obviously the antennas play an important role. The progress realized in this field substantially contributes to the versatility of modern radars. This is illustrated by the numerous conference reports on MIMO radars. The trend is supported by the tremendous progress in semiconductor power devices and integrated circuits development as well as in packaging solutions, which allows for high complexity chip-level system integration at ever increasing frequencies and boosts Active Electronically Scanning Arrays (AESA) for application in multifunctional radar systems.

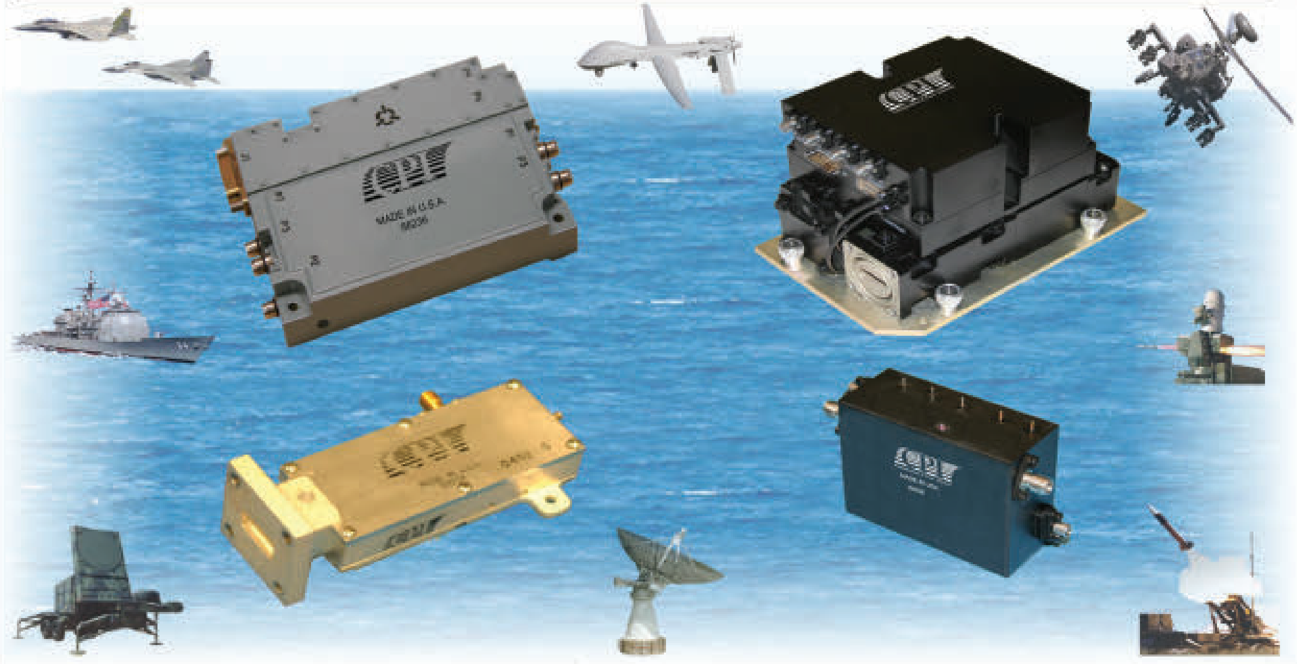
A clearly noticeable trend is the progress realized in the rapidly evolving area of target classification. On the hardware side, it is fostered by the evolution of polarimetric radar. In addition, advanced signal analysis as well as sophisticated post-processing methods allow for precise feature extraction. The effort in this area is clearly demonstrated by the conference reports on human motion recognition via micro-Doppler signature extraction or on concealed object detection and classification.

> **"Target classification...is fostered by the evolution of polarimetric radar."**

These technological trends as well as the cost reductions realizable, e.g., because of the progress in semiconductor processing, open up a wealth of opportunities for improved or even new and, in particular, civil applications. Much effort is devoted to extending the performance range of automotive radar, pedestrian and cyclist protection as well as current advances in active avoidance techniques. Fast and reliable imaging in difficult environments is also an issue in security applications.

In industrial environments, one can notice the development of precise localization schemes and the implementation of dependable level mea-

Integrated Microwave Assemblies



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surements, e.g., in silos. Radars also find their way into microwave medical applications where vital sign detection is a strongly growing field. Finally, a constant driver of innovation is the space sector. The multitude of surveillance and mapping tasks has been – and still is – leading to a wealth of challenging new developments, especially of SAR technology.

In summary of this partial overview, the radar sector is a more than healthy and rapidly expanding field, which is heavily impacted by the latest technological developments.

FP7 PROJECTS

EISCAT_3D is a next generation incoherent scatter radar system for high-latitude atmosphere and geospace studies that will be built in northern Fenno-Scandinavia. The first phase of the project is: EISCAT_3D: A European three-dimensional imaging radar for atmospheric and geospace research (Preparatory Phase), which will run until 30 September 2014 with a total cost of €6 million. The facility will consist of multiple large phased-array antenna transmitters/receivers in three countries, comprising tens of thousands of individual antenna elements. The new radars will collect data from the upper stratosphere to the magnetosphere and beyond, contributing to the basic, environmental and applied science that underpins the use of space by contemporary society.

Also, the International automotive 79 GHz frequency harmonization initiative and worldwide operating vehicular radar frequency standardization platform (79 GHz) project is set to conclude on 30 June 2014. Its intention is to establish and speed up the worldwide harmonized frequency allocation for automotive radar systems in the 77 to 81 GHz (79 GHz) frequency range.

CONCLUSION

The technologies outlined in this report have the potential to stimulate activity, fuel growth, combat the lingering effects of the economic downturn and withstand competition from both traditional and emerging markets. Together, new technologies, new materials and the expertise of skilled designers and engineers, backed up by the streamlined structure, focus and financial support of Horizon 2020 and associated EU initiatives can be a potent force.

The promise is there but will it become a reality? There is no doubting the EU's commitment to stimulating research and innovation and growing European industry. Although the EU is providing financial stimulus that is the envy of others around the world, the money has to be spent wisely and focused on developing new technologies, improving the business environment and offering easy and simple access to markets and finance, particularly for SMEs, in order to ensure that skills meet industry's needs and products satisfy demand.

The name of the EU's new funding programme for research and innovation – Horizon 2020 – reflects the ambition to deliver ideas, growth and jobs for the future. If confidence returns, and with it new investments, Europe's industry, including the RF and microwave sector, can perform better, continue growing and widen its horizons. ■

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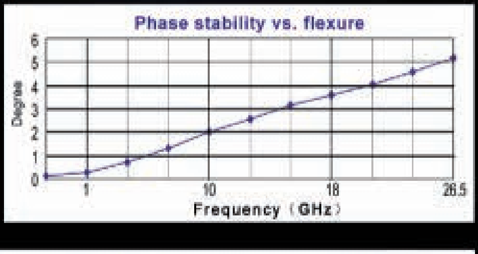
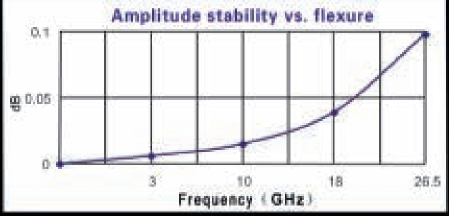
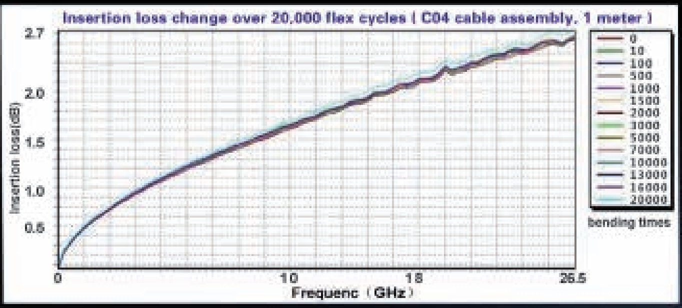


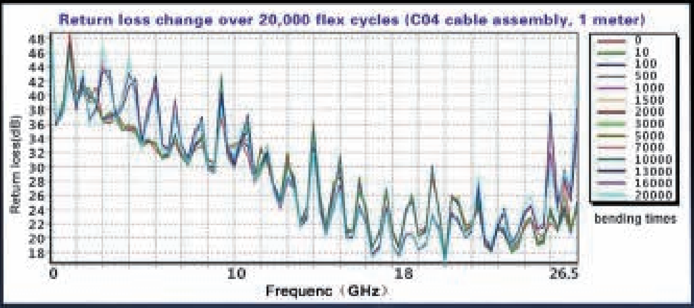
Phase stability vs. flexure



Amplitude stability vs. flexure



Insertion loss change over 20,000 flex cycles (C04 cable assembly, 1 meter)



Return loss change over 20,000 flex cycles (C04 cable assembly, 1 meter)

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Editor's note from Harlan Howe Jr.:
Pulse width modulation (PWM) has been the preferred method for control of electric automobiles as well as speed control for robot motion, because of its very high efficiency. However this is the first time that I have seen it applied to a power amplifier. The authors have presented a design that provides improved PAE efficiency at peak power and almost double the PAE at the 6 dB back-off point compared to previous works. While this amplifier is an RF design, there is no reason why PWM could not be applied to a microwave power amplifier.

High Efficiency Pulse Width Modulation Transmitter

This article describes a high efficiency Class E transmitter that produces variable output power using pulse width modulation (PWM) to maintain high efficiency. The system consists of a Class E power amplifier and a PWM generator. To reduce matching losses, high-Q inductors are used in the resonator. Low second and third harmonic distortion is achieved with a harmonic filter in the output matching network. It exhibits high power added efficiency (PAE) of 90.5 percent at an output power of 10.1 W. PAE at a low output power of 1.5 W is greater than 80 percent. The second and third harmonic distortion levels are as low as –35.1 and –44.0 dBc, respectively, at an output power of 10.1 W.

For efficient RF power transmission, transmitters need to have high efficiency. For power amplifier components, this reduces maintenance costs and cooling system requirements. Extensive research has been carried out using switching mode power amplifiers (SMPA) to improve power amplifier efficiency.[1-7] Class D and Class E amplifiers are representative SMPAs. The Class E power amplifier considered here has a simpler circuit design and a higher operational frequency range than its Class D counterparts.[8-10]

For many applications, and especially for adaptive wireless power transmission systems, power transmitters are required to have variable output power to maintain high efficiency over a wide output power range. Typical power amplifiers, however, have a significant efficiency drop as the output power level becomes lower. In order to overcome this limitation, a bias modulation technique can be employed.[11-13] This requires a DC-DC converter that has a variable output voltage. The output of the DC-DC converter is applied to the power amplifier as a drain bias, making the system more complex and expensive.

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JEONGBAE JEON, HYUNGCHUL KIM,
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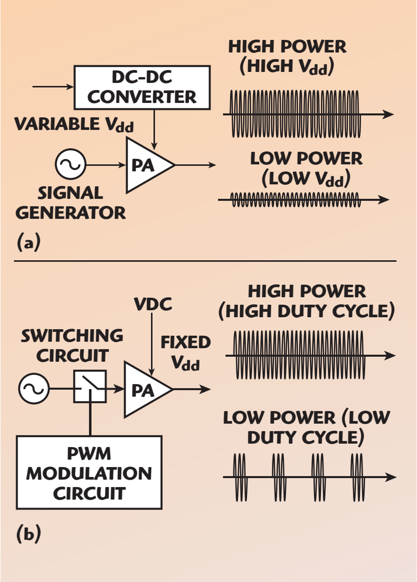
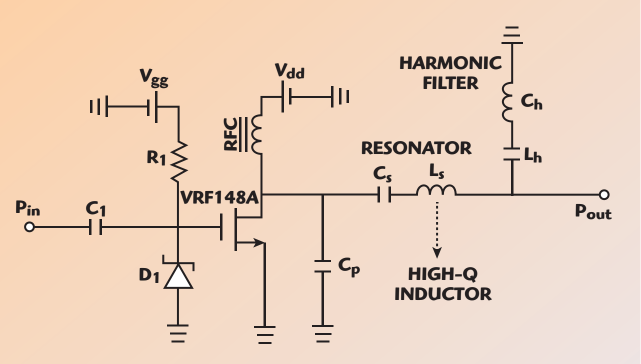


▲ *Fig. 1 Transmitter block diagrams based on: bias modulation (a), PWM (b).*

In this article, we propose a high efficiency power transmitter that has variable output power. It is based on a Class E power amplifier using a pulse width modulation (PWM) technique. It also includes harmonic filtering. As the duty cycle of the PWM signal decreases, the average output power of the transmitter is also reduced while theoretically maintaining efficiency as high as its peak value. By avoiding the need for a DC-DC converter, the circuit becomes significantly simpler. To verify this technique, a Class E transmitter with an output power of 10 W at 13.56 MHz was built and tested.



▲ *Fig. 2 Schematic diagram of the 10 W Class E power amplifier with harmonic filter.*

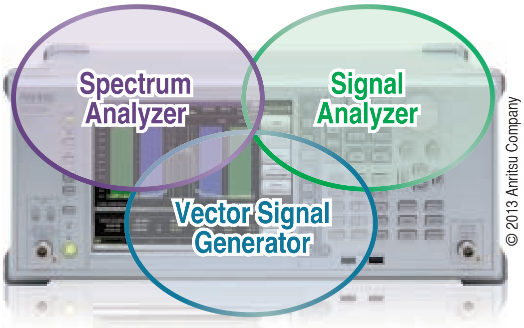
PRINCIPLE OF OPERATION AND CIRCUIT DESIGN

Figure 1 shows block diagrams of the conventional and proposed transmitters. The conventional transmitter employs an adjustable DC-DC converter to provide the power amplifier with variable bias to change its output power level. Figure 1a shows that the peak output signal level is reduced as the drain bias voltage is decreased. The DC-DC converter should have high efficiency throughout its range, but the amplifier may not.

Figure 1b shows a PWM generator providing a pulse-width modulated sinusoidal signal at the input to the power amplifier driving it from zero to its peak output amplitude. As the duration of the PWM output is decreased, the average output power level of the amplifier decreases as well. Hence, the power amplifier has either a peak or zero-amplitude output signal. The amplifier is always driven to a region in which it operates most efficiently.

A schematic diagram of the Class E power amplifier with a harmonic filter is shown in ***Figure 2***. The output network of the amplifier consists of a shunt capacitor (Cp), a series resonator using capacitors and inductors for proper Class E operation and a shunt harmonic filter to remove the second and third harmonics. The inductance and the harmonic filter also provide fundamental matching. A Zener diode, D1, protects the circuit by clipping excessive input voltage to the transistor.

An ideal Class E power amplifier can achieve an efficiency of 100 percent based on its zero voltage switching (ZVS) characteristics. This means non-zero voltage and current waveforms of the transistor are shaped to not overlap each other. Non-ideal switching operation and insertion loss of the output network for practical Class E power amplifiers, however, cause efficiency degradation. The Q-factor of the resonator's series inductor has the largest impact.[14] We used a custom designed high-Q inductor to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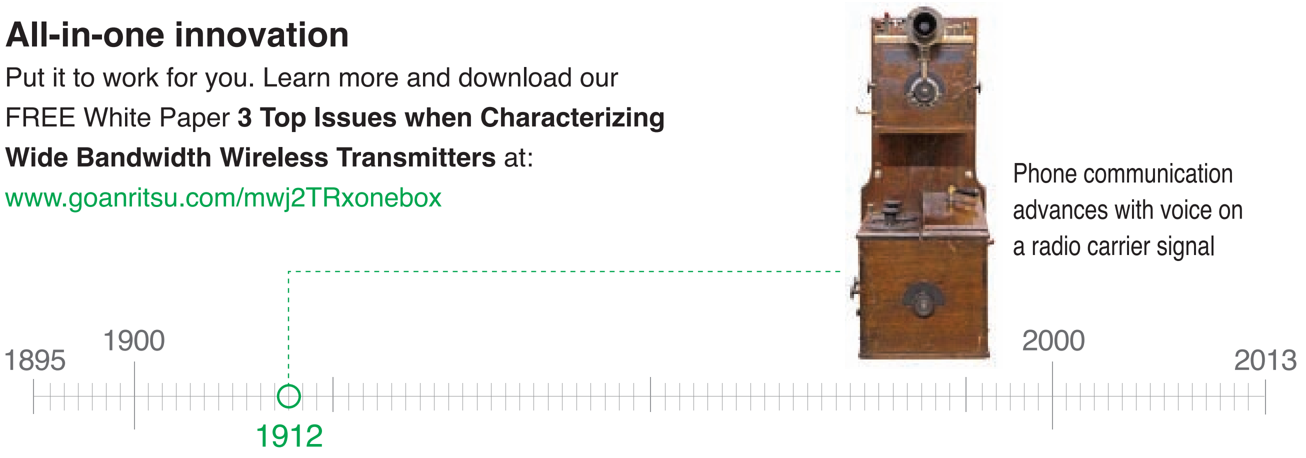
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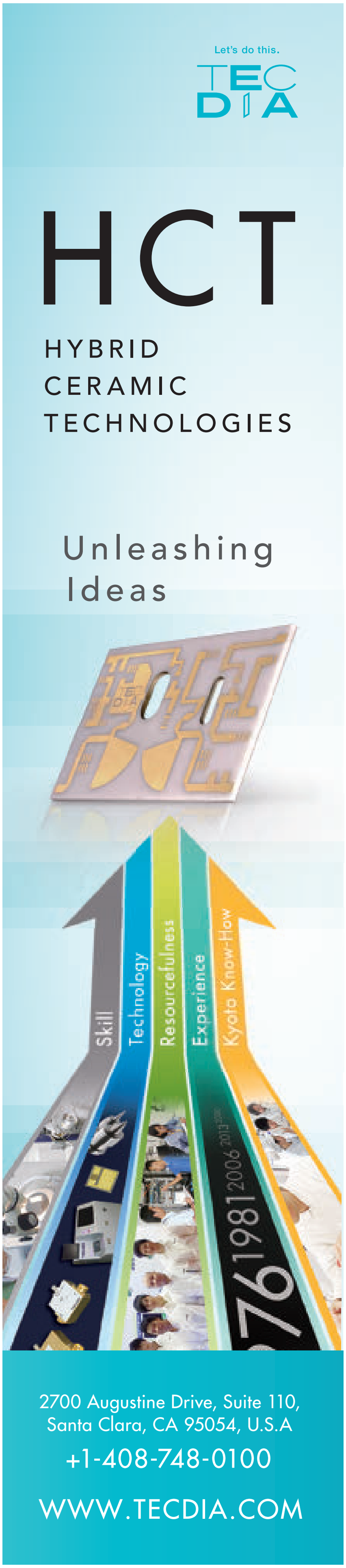
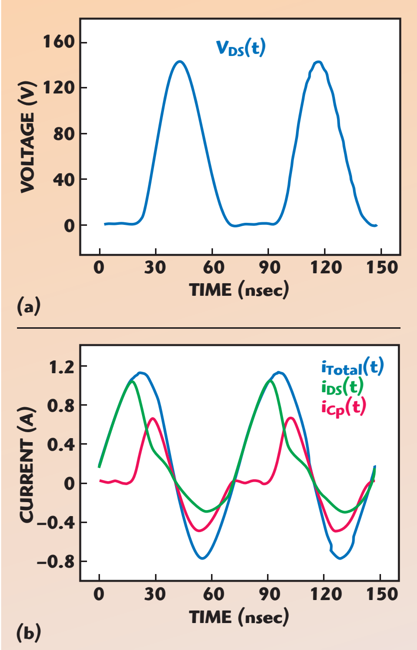
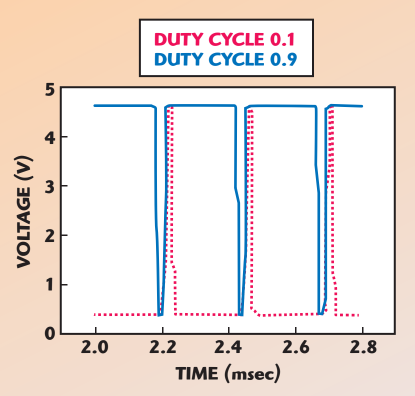




▲ *Fig. 3 Simulated voltage and current waveforms: drain voltage and current (a), current to the shunt capacitor and total current (b).*

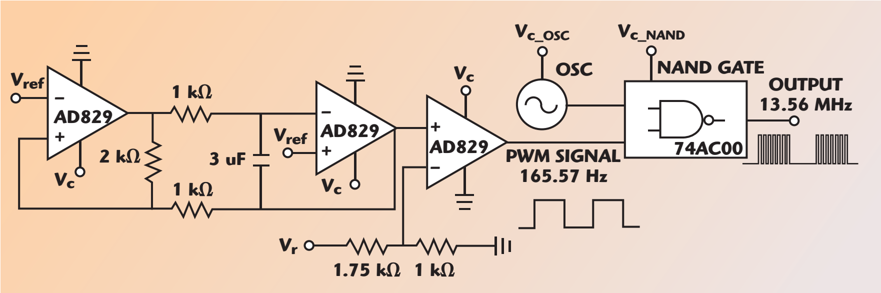


▲ *Fig. 5 Simulated signals of the pulse generator.*

make the output power loss, i.e., efficiency degradation, as low as possible.

Agilent's Advanced Design System (ADS) was used to design the Class E power amplifier. ***Figure 3*** shows the simulated drain voltage and current waveforms for a drain bias voltage of 50 V and an output power of 40 dBm. A peak voltage of 142 V is approximately 2.8 times larger than the drain bias voltage. Due to the internal parasitic capacitance, the waveforms exhibit some non-zero overlapping. Each component in the output network has been fully optimized to have high efficiency, so we are confident that non-zero overlapping at the internal current source of the transistor is minimized. The simulation results yield a power gain of 23.6 dB and a high power-added efficiency (PAE) of 93.7 percent at an output power of 40 dBm using a 13.56 MHz continuous wave (CW) signal.

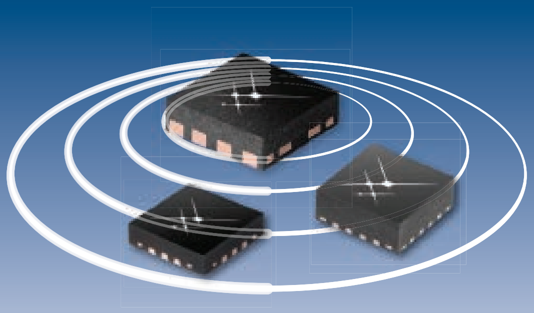
To change the average output power, the RF signal is repeatedly turned on and off using the variable PWM generator to adjust the duty cycle. ***Figure 4*** shows a schematic diagram of the PWM generator. It consists of a three-stage OP amp which generates a 165.57 Hz pulse signal whose duty cycle can be adjusted using a tuning voltage (V_r). The 165.57 Hz pulse signal and 13.56 MHz oscillator output signal are fed to the NAND gate to form the PWM signal. ***Figure 5*** shows the simulated output waveforms of the pulse generator with duty cycles of 0.9 and 0.1. By changing V_r, the duty cycle can be changed from 1 to 0.



▲ *Fig. 4 Schematic diagram of the PWM generator.*

IMPLEMENTATION AND EXPERIMENTAL RESULTS

A photograph of the 10 W Class E transmitter using the PWM technique is shown in ***Figure 6***. Using FR4 substrate, which has a relative permittivity of 4.6, the circuit is approximately 115×36 mm^2. Microsemi's VDMOS FET, VRF148A, which has a breakdown voltage of 170 V, is used as the active transmitter device. To reduce matching losses, high-Q passive components are used in the matching



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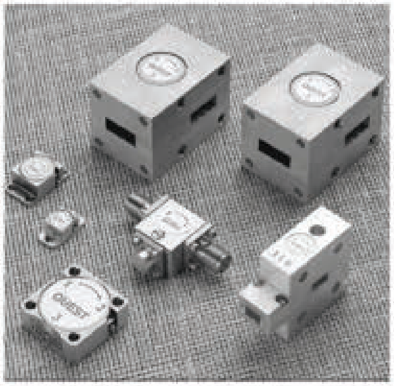
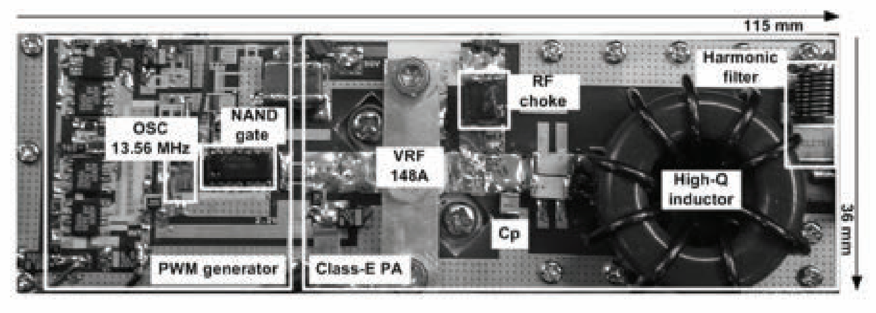




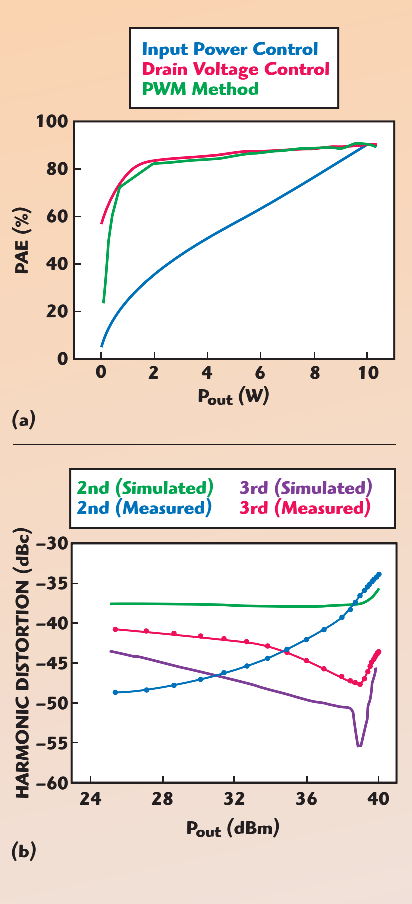
▲ *Fig. 6 Photograph of the implemented 10 W Class E power transmitter based on the PWM method.*

▲ *Fig. 7 Measured output waveforms of the PWM generator at various duty cycles.*

network. The measured inductance and Q-factor of the custom-made series inductor at the output matching network are 1.3 and 300 uH, respectively. The NAND gate is a Fairchild 74AC00. An EXA XC300H13563TEH is used for the 13.56 MHz crystal oscillator. The PWM generator uses Analog Device's AD829. ***Figure 7*** shows the measured output waveforms of the PWM generator at various duty cycles. The duty cycle can be adjusted from 0 to 1 using V_r, which ranges from 5.5 to 3 V.

Figure 8a shows the measured PAE for three conditions: (1) input power control, (2) drain bias control using the conventional bias modulation method with a fixed input power, and (3) duty cycle control for the proposed PWM method with a fixed input power. When the input power is used to change the output power from approximately 10 W to almost 0, the efficiency drastically decreases. PAE based on the PWM technique, however, has a very similar trend as the conventional drain bias control method even without considering losses due to the conversion efficiency of the DC-DC converter. At a low output power of 1.5 W, the efficiency using the PWM technique is roughly 80 percent.

Figure 8b shows simulated and measured harmonic distortion levels of the Class E transmitter as a function of output power level. Both second and third harmonic distortion levels are lower than –34 dBc for all output power levels due to the harmonic filter in the output matching network.



▲ *Fig. 8 Measured performance of the Class E power transmitter: efficiency (a), second and third harmonic distortion (b).*

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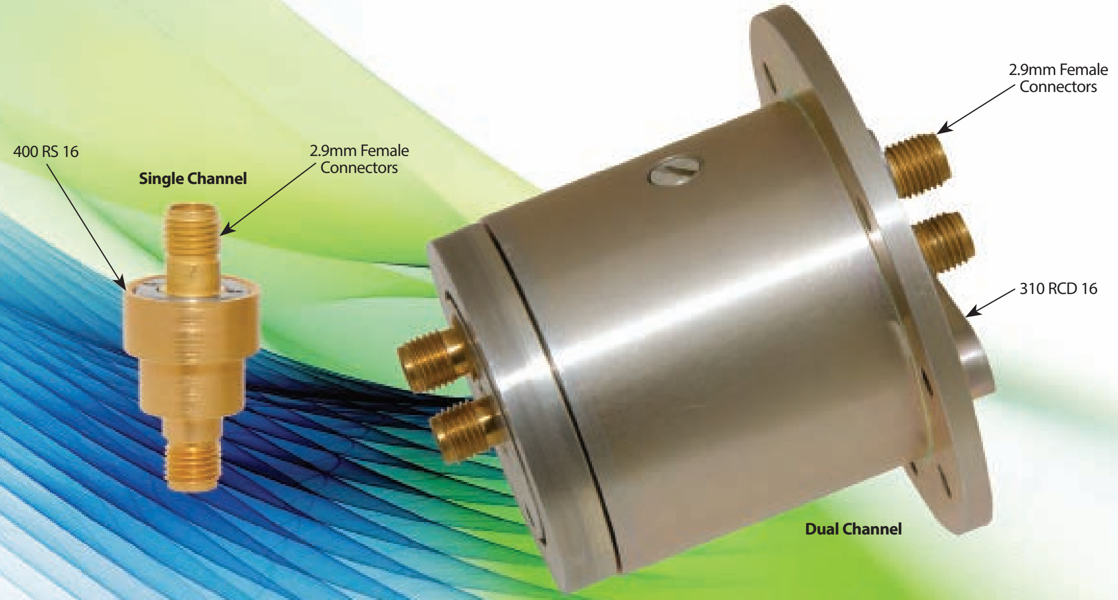

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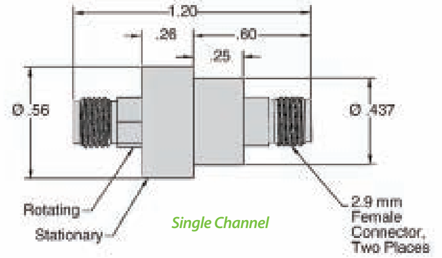

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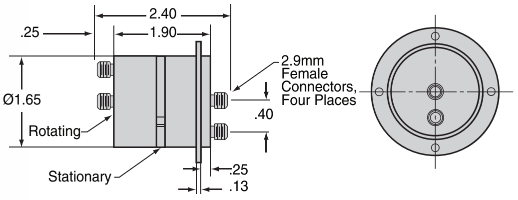

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	10 - 26 GHz	1.35 : 1 MAX.
	26 - 40 GHz	1.75 : 1 MAX.
WOW	1.05 MAX.	
INSERTION LOSS	DC - 10 GHz	0.2 dB MAX.
	10 - 26 GHz	0.4 dB MAX.
	26 - 40 GHz	0.6 dB MAX.
PEAK POWER	Equal to connector rating	

310 RCD 16

DUAL CHANNEL SPECIFICATIONS:

ELECTRICAL	Channel 1	Channel 2
FREQUENCY	7.0 - 22.0 GHz	29.0 - 31.0 GHz
VSWR	1.50:1 MAX.	1.70:1 MAX.
WOW	0.15	0.25
INSERTION LOSS	0.5 dB MAX.	1.0 dB MAX.
ISOLATION	Channel to Channel	50.0 dB MIN.

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TABLE I

PERFORMANCE COMPARISON TO THE PREVIOUS WORKS

Reference	[1]	[2]	[3]	[13]	This Work
Transistor Type	LDMOS FET	LDMOS FET	LDMOS FET	LDMOS FET	VDMOS FET
Class	E	E	D	AB	E
Technique	N/A	N/A	N/A	Bias modulation	PWM control
Frequency (MHz)	13.56	13.56	13.56	420-440	13.56
Output Power (W)	15.7	10	27.5	6.5	10.1
PAE (%) at Peak Power	84.6	80.1	84.6	44	90.5
PAE (%) at 6 dB Back-off	N/A	36	47	45	83
Harmonic Distortion (dBc)	N/A	N/A	2nd: -50.3, 3rd: -46.4	N/A	2nd: -35.1, 3rd: -44.0

Second and third harmonic distortion levels are –34 and –43.6 dBc, respectively, at an output power of 10.1 W. ***Table 1*** compares the results obtained from this work with those from other published works, showing significant improvement in efficiency at peak and 6 dB backed-off power levels.

CONCLUSION

In this article, we propose a high efficiency Class E variable output power transmitter using a PWM technique. The PWM generator in the transmitter modulates the input signal of the amplifier with pulses of various duty cycles, allowing the power amplifier to have high efficiency at a low average output power level. This method is simpler than that of a transmitter based on the conventional bias modulation technique, which requires a DC-DC converter having a variable output voltage.

The Class E power amplifier in this work employs a harmonic filter in its output matching network. The high-Q inductor in the series resonance circuit and the shunt harmonic filter also provide matching at the fundamental frequency. The second and third harmonic distortion levels are significantly suppressed. Based on the proposed PWM and harmonic filtering methods, a 10 W power transmitter was designed and implemented for the 13.56 MHz band. It exhibited a high PAE of

90.5 percent at an output power of 10.1 W and 80 percent at a low output power of 1.5 W. ■

ACKNOWLEDGMENT

This work was supported by Future IT Research Center, Samsung Advanced Institute of Technology.

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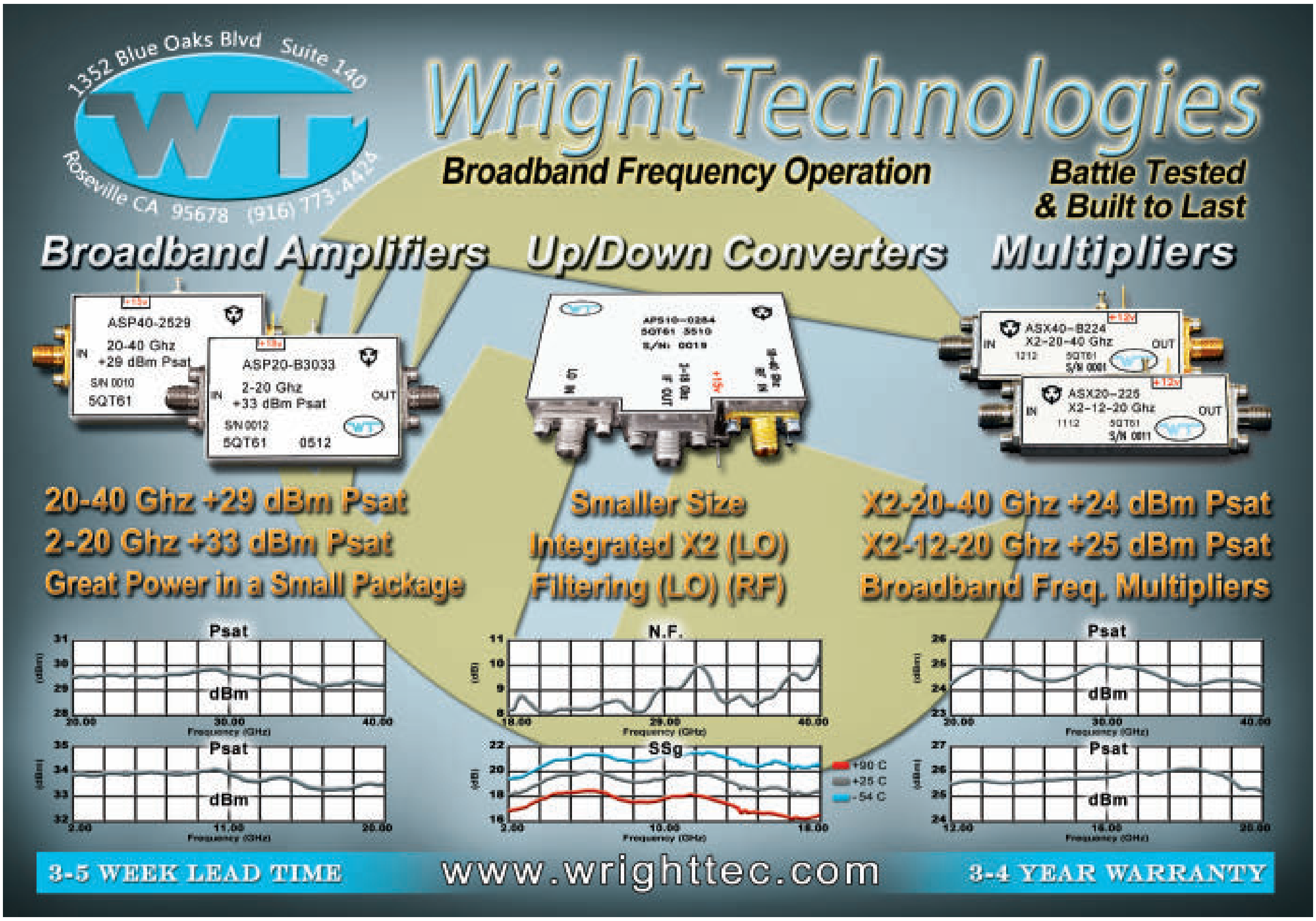


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Tri-Band Bandpass Filter Using Shorted Stub-Loaded Dual-Mode Resonators

A compact tri-band bandpass filter (BPF) using three shorted stub-loaded dual-mode resonators (SSLDMR) is presented. The center frequency and bandwidth of all three passbands can be flexibly controlled by tuning the electrical length of the corresponding resonators and shorted stubs, respectively. Moreover, each passband can be independently adjusted without affecting the other two. A prototype of a tri-band BPF centered at 2.4, 3.5 and 5.2 GHz has been designed and fabricated with six transmission zeros. Good agreement can be found between measured and simulated results.

Modern wireless communication systems such as GSM (0.9/1.8 GHz), W-CDMA (2.1 GHz), WiMAX (3.5 GHz) and WLAN (2.4/5.2 GHz) are widely used in people's daily lives. High performance multiband bandpass filters (BPF) have become indispensable in the RF front ends of communication systems designed to work across all of these bands. To address this need, a variety of multiband bandpass filters designs have been recently proposed. Stepped-impedance resonators (SIR) are utilized to construct the dual-band and tri-band BPFs.[1-3] A two-section SIR can achieve a dual-band response by tuning its geometric parameters,[2] and determining the resonant frequencies of a tri-band filter is straightforward.[3] It is difficult, however to control the passbands independently, and these structures are relatively complicated. Stub-loaded resonators (SLR), which can be analyzed by the odd and even-mode method, are widely used structures in the design of dual-band[4-7] and tri-band filters.[8,9] An open stub-loaded resonator (OSLR) has been presented and analyzed and a dual-band BPF was designed.[4] A shorted stub-loaded resonator (SSLR) had been analyzed[7] and a tri-band filter using both shorted and open stub loaded resonators has also been presented.[9]

The OSLR and SSLR have been analyzed by odd- and even-mode methods.[4,5] Both the OSLR and SSLR have demonstrated that the fundamental even-mode resonant frequency can be shifted by changing the stub length, whereas the fundamental odd-mode resonant frequency is preserved. The odd-mode and even-mode resonant frequencies, however, are used in two different passbands. Thus the bandwidths of the passbands mainly depend on

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W.T. Joines[2], Q.H. Liu[2] and Y. Fan[1]
University of Electronic Science and Technology of China[1], Chengdu, China
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the coupling coefficients, which can only be adjusted over a relatively narrow range.

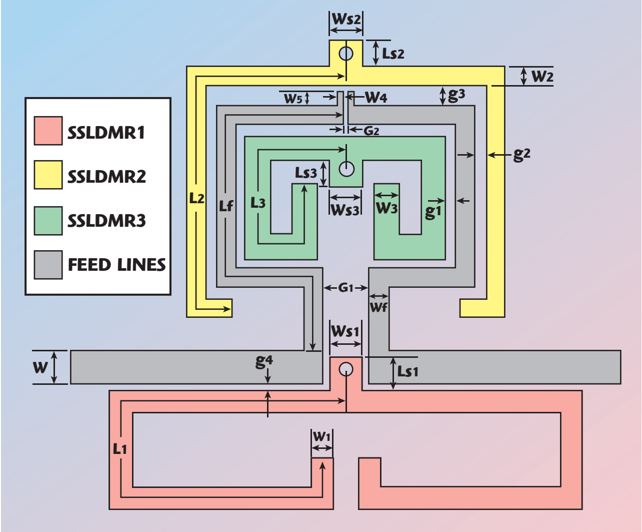
In this article, the odd and even-modes of the SSLR are used to generate only one passband as long as the fundamental even-mode resonant frequency is close to the fundamental odd-mode resonant frequency. We call this the short-circuited stub-loaded dual-mode resonator (SSLDMR). Thus the bandwidth is determined primarily by the distance between the fundamental even-mode resonant frequency and the fundamental odd-mode resonant frequency. Our analysis shows that the bandwidth of the passband can be controlled by changing the shorted stub length. We propose a compact tri-band BPF using three different sizes of half-wavelength SSLDMRs that can have independently controllable bandwidth for each of three passbands by properly selecting the length of the shorted stubs. A tri-band BPF for WiMAX (3.5 GHz), and WLAN (2.4/5.2 GHz) applications was fabricated and measured.

FILTER DESIGN

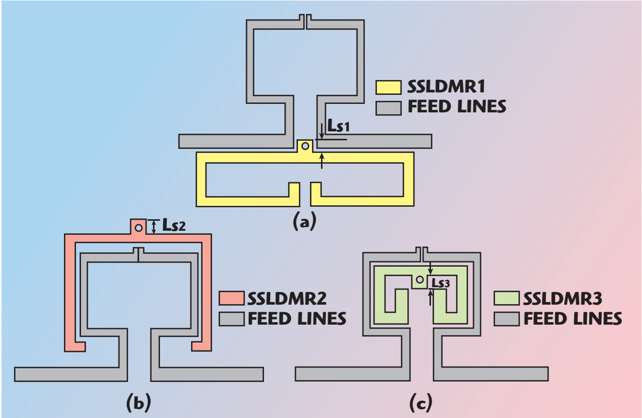
The structure of the proposed compact tri-band BPF is shown in ***Figure 1***. It consists of a pair of meandering feed lines and three sets of folded half-wavelength SSLDMRs with frequencies at 2.4, 3.5 and 5.2 GHz. A pair of vertical parallel coupling lines at the end of each feed line is used for increasing source-load coupling. This structure enables each passband to be independently designed since there is no mutual coupling among the three sets of SSLDMRs.

To verify the approach, three single-band filters with only one folded SSLDMR and the same pair of meandering feed lines are each simulated by using the Ansoft HFSS simulator. All the other dimensions are fixed except the stub lengths (L_{S1}, L_{S2} and L_{S3}) shown in ***Figure 2***. From ***Figure 3***, we can conclude that the bandwidth of each passband can be adjusted over a wide range by changing the shorted stub lengths (L_{S1}, L_{S2}, L_{S3}) respectively.

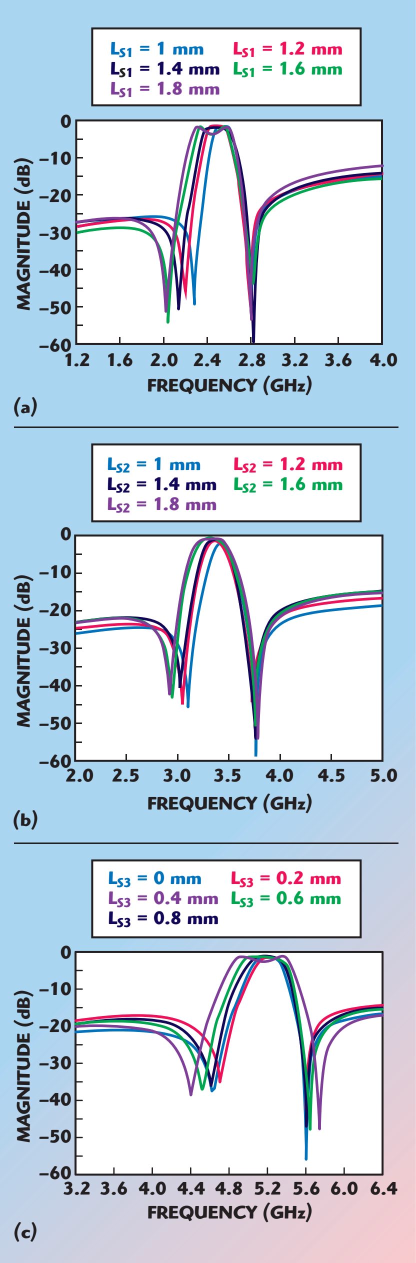
Shown in ***Figure 4*** are the simulated results of the single-band and tri-band filters. It demonstrates that any single passband can be independently designed and adjusted while the other two are not affected. The proposed filter achieves tri-band performance using three parallel transmission paths for the three individual passbands. The feed



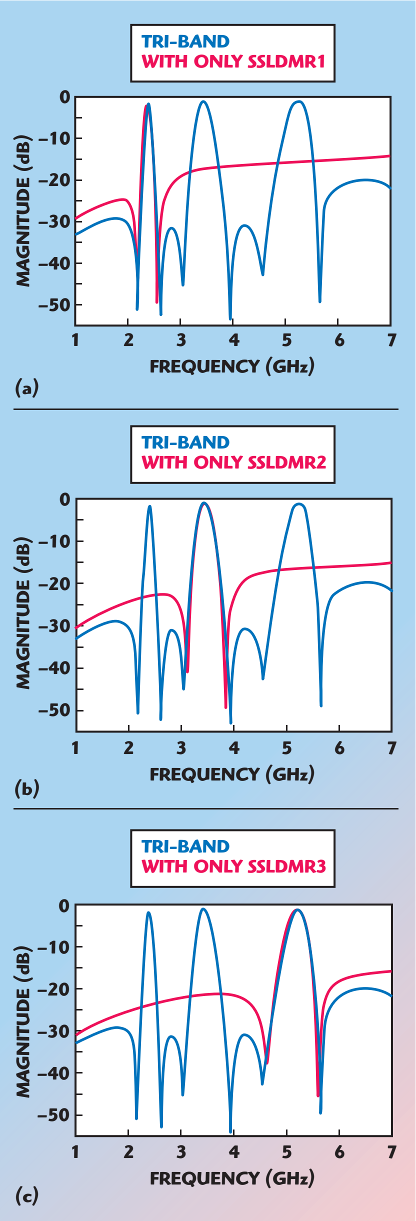
▲ *Fig. 1 Schematic diagram of the proposed tri-band BPF.*



▲ *Fig. 2 Structures of three single-band filters with only SSLDMR1 (a), SSLDMR2 (b) and SSLDMR3 (c).*



▲ *Fig. 3 Frequency response versus stub length for the filters in Figure 2 - L_{S1} (a), L_{S2} (b) and L_{S3} (c).*



▲ *Fig. 4 Tri-band/single-band simulation results of the proposed filter. With three SSLDMRs/with only SSLDMR1(a), with three SSLDMRs/with only SSLDMR2 (b), and with three SSLDMRs/with only SSLDMR3 (c), (dimensions of the structure are the same).*

design provides sufficient isolation for the three specific passbands, and the bandwidth of each passband can be adjusted independently by changing the shorted stub length of the corresponding SSLDMR without affecting the other two passbands. Also verified are the responses of four filters with the same feed line structure, i.e., three dual-band filters using any two SSLDMRs and a combined tri-band filter using three SSLDMRs (see ***Figure 5***).

Since the coupling paths of the three passbands are isolated, the center frequency and bandwidth of all three passbands are independently controlled by adjusting the electrical length of each resonator and each shorted stub, respectively. Source-load coupling is utilized to improve selectivity with six transmission zeros on either sides of all three passbands; therefore, any single-band, dual-band, or tri-band microstrip BPF with good frequency selectivity can be designed using the proposed structure by changing the number and position of the SSLDMRs. To obtain a

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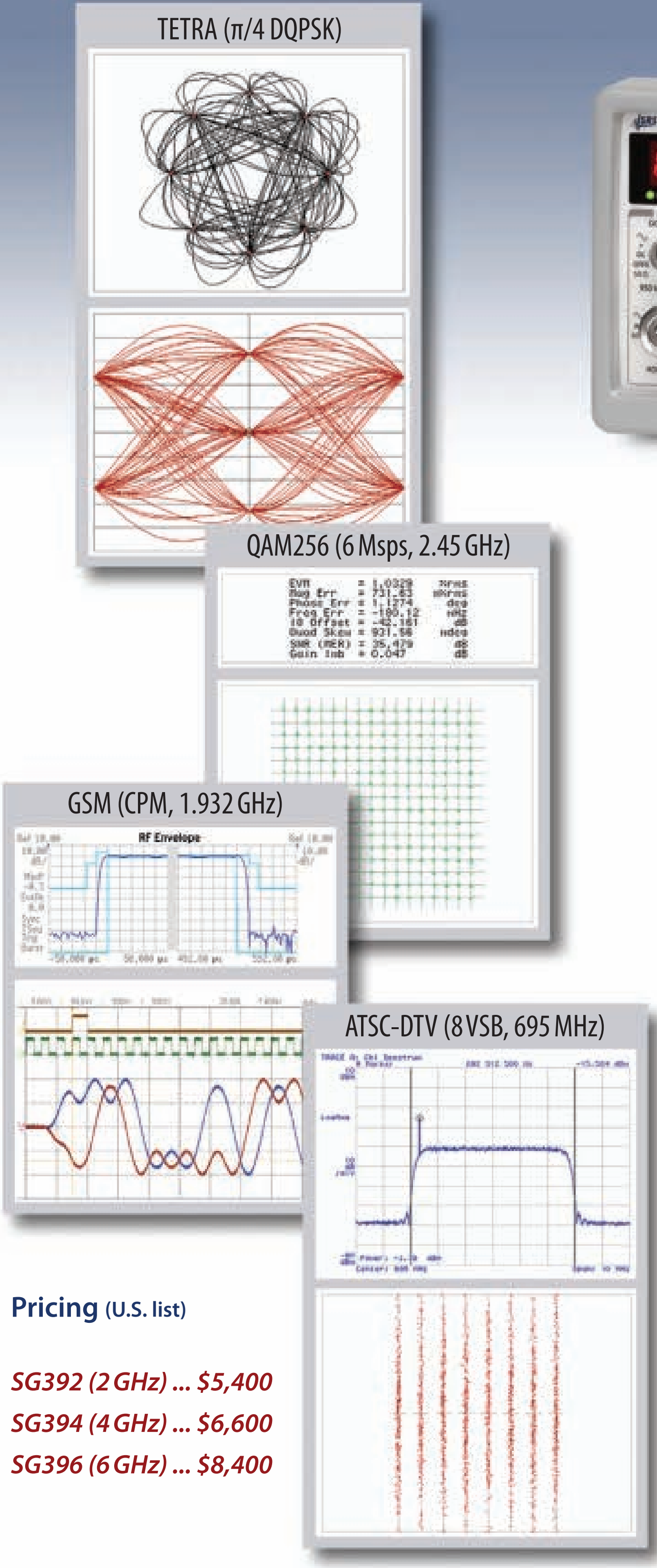

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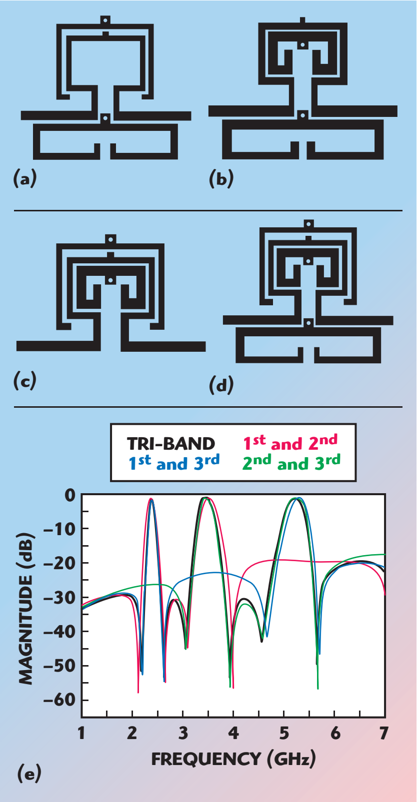
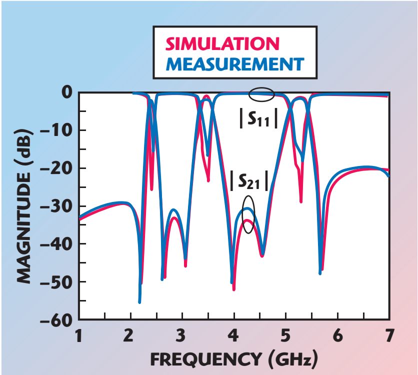


▲ *Fig. 5 Topology of three dual-band filters and a combined tri-band filter – dual-band filter using 1st and 2nd passbands (a), dual-band filter using 1st and 3rd passbands (b), dual-band filter using 2nd and 3rd passbands (c), tri-band filter (d); simulated frequency responses of the four filters (e).*

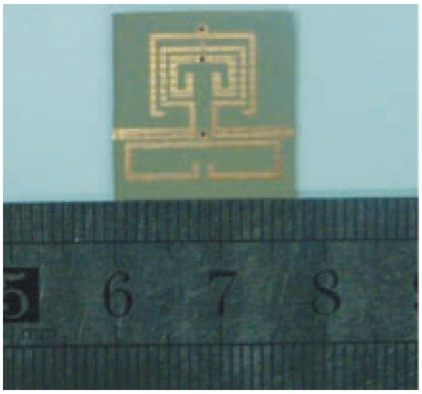
more compact structure, three sets of SSLDMRs are folded and are located in close proximity to the pair of meandering feed lines.

EXPERIMENTAL RESULTS

The prototype tri-band BPF with center frequencies at 2.4, 3.5, 5.2 GHz was fabricated on an RF-35 substrate with a relative dielectric constant of 3.5 and a thickness of 0.508 mm. The dimensions (units: mm) of the filter are: $L_1 = 17.9$, $L_2 = 13.2$, $L_3 = 9.5$, $L_{S1} = 1$, $L_{S2} = 0.8$, $L_{S3} = 0$, $L_f = 13.9$, $W = 1.1$, $W_{S1} = W_{S2} = W_{S3} = 1$, $W_1 = 0.7$, $W_2 = W_f = 0.6$, $W_3 = 0.8$, $W_4 = 0.2$, $W_5 = 0.45$, $g_1 = 0.3$, $g_2 = 0.35$, $g_3 = 0.65$, $g_4 = 0.18$, $G_1 = 1.5$, $G_2 = 0.1$. Via diameters are all 0.5 mm. The distances between the centers of each via and the end of each stub are all 0.4 mm. The stub lengths of SSLDMR1, SSLDMR2 and SSLDMR3 are 1, 0.8 and 0 mm, respectively. A comparison of the simulated and measured frequency responses is shown in



▲ *Fig. 6 Simulated and measured results of the prototype tri-band BPF.*



▲ *Fig. 7 Photograph of the fabricated tri-band BPF.*

TABLE I

PERFORMANCE COMPARISON OF SOME DUAL-BAND BANDPASS FILTERS

Reference	Substrate Height (mm)/ ε_r	Overall Size	Center Frequencies of the Three Passbands (GHz)	Numbers of Transmission Zeros	3 dB Bandwidth of the Three Passbands (%)
8	0.8/2.55	$0.08\ \lambda_g \times 0.15\ \lambda_g$	2.41/3.56/5.29	5	6.2/12.2/11.8
9	0.8/2.55	$0.1\ \lambda_g \times 0.25\ \lambda_g$	1.57/2.4/3.5	4	11.46/17.5/5.71
10	1.0/2.65	$0.26\ \lambda_g \times 0.24\ \lambda_g$	2.45/3.5/5.25	0	13.5/7/3.5
11	0.8/2.55	$0.26\ \lambda_g \times 0.16\ \lambda_g$	2.45/3.5/5.25	5	12.6/8.8/6.4
This Work	0.508/3.5	$0.19\ \lambda_g \times 0.19\ \lambda_g$	2.4/3.5/5.2	6	5.0/7.7/7.3

λ_g is the guided wavelength of 50 Ohm microstrip at the center frequency of the first passband.

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Figure 6. The measured results are in good agreement with the full-wave simulation. Slight deviations are attributed to fabrication error. The measured 3 dB bandwidths for the three passbands (2.4, 3.5 and 5.2 GHz) are 5.0, 7.7 and 7.3 percent, respectively. Minimum insertion losses, including the losses from two SMA connectors, are 1.78, 1.63 and 1.72 dB, respectively. Six transmission zeros on either side of three passbands are located at 2.17, 2.62, 3.04, 3.94, 4.55 and 5.65 GHz. Its size is only 14.9 × 15 mm including the feed lines (see ***Figure 7***). ***Table 1*** summarizes some previously reported performance of tri-band bandpass filters for comparison, demonstrating that this work features reduced size and improved selectivity.

CONCLUSION

This article presents a tri-band BPF with three different sizes of SSLDMRs. The bandwidths of the three passbands can be all independently controlled. It has high isolation in a compact size. The design procedure is simple and it can be easily and inexpensively fabricated using common printed circuit board technology. Moreover, any single-band, dual-band, or tri-band microstrip BPF with good frequency selectivity can be designed using this structure. ■

ACKNOWLEDGMENT

This work was supported by the China Scholarship Council (CSC).

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Wideband BSF Using Coupled Stepped Impedance Hairpin and Interdigital Capacitor

A compact bandstop filter (BSF), using a coupled stepped impedance hairpin unit and an inner interdigital capacitor, is presented in this article. Detailed theoretical analysis reveals that the filter's bandwidth and stopband rejection level can be controlled by the upper transmission line's characteristic impedance, the capacitance or the coupling strength of the coupled line. Based on this theory, a proposed BSF centered at 2.22 GHz with a bandwidth of 81.08 percent has been designed, fabricated and measured. The implementation area is 0.141 λg × 0.158 λg, where λg is the guided wavelength of a 50 Ω transmission line at the center frequency. Good agreement between measured and simulated results is obtained.

Bandstop filters (BSF), important components in the process of sending and receiving signals in telecommunication, play a key role in suppressing noise and spurious signals, which results in a great demand of BSFs with wide stopband and compact size. Conventional BSFs, using series and shunt stubs, exhibit narrow stopband and large size.[1,2] Recently, to meet the stringent requirements of wide stopband and compact size BSFs, several methods and structures have been proposed. A wideband BSF, using a tight-coupled hairpin unit, has been presented.[3] A dual band BSF, with a dual-mode loop resonator and a cross-coupled capacitor, has been described.[4] It achieved a high rejection of the stopband and the 20 dB fractional bandwidth are over 100 and 10 percent, respectively. But because of the parasitic effect of the lumped element, the precise capacitance is hard to control. Another compact BSF, composed of a single quarter-wavelength resonator and anti-coupled lines, was proposed,[5] which show the characteristics of wide bandwidth and low in-

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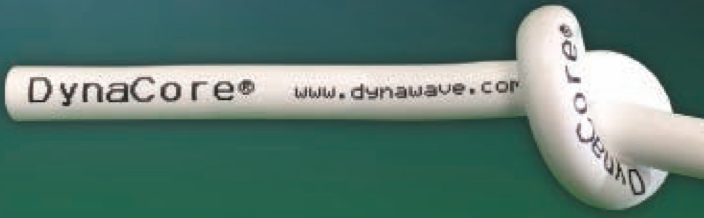
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sertion loss. The signal interference technique has been used to design wideband BSF with 40 dB fractional bandstop of 22.3 percent.[6,7] Parallel coupled transmission line units have been adopted to provide wide stopband characteristics with attenuation poles.[8] Meanwhile, the rejection depth and bandwidth of the filters can be controlled by the coupled-line parameters. Two transmission line configurations have been proposed to design sharp-rejection BSF.[9] The impedances of the transmission lines can easily control the rejection depth and bandwidth of the BSF.

Owing to the characteristic of simple structure and compact size, the coupled stepped impedance hairpin unit has been used to compose a proposed BSF.[10] The fabricated wideband BSF exhibits a measured bandwidth of 75 percent at the center frequency. However, the bandwidth characteristics are far from ideal, especially if the two transmission zeros confine the bandwidth of stopband for only 18 dB.

Here, for the sake of improving the bandwidth characteristics of the BSF, a modified structure, using a coupled stepped impedance hairpin unit and an interdigital capacitor, is presented to realize a higher rejection level. It can be seen that this modified structure can provide another transmission zero due to the introduction of an interdigital capacitor. Thus the additional zero improves the stopband attenuation level and results in a comparatively wider bandwidth, simultaneously.

FILTER ANALYSIS

Figure 1 shows the configuration of the proposed filter. The filter is composed of a coupled stepped impedance hairpin unit with an inner capacitor of Cg. As the model is symmetrical, it is useful to simplify the analysis by odd- and even-mode networks.

When the circuit is excited in the odd-mode, the corresponding equivalent circuit shown is obtained. The input admittance of the odd-mode is:

$$Y_{odd} = Y_{o1} + Y_{o2} + Y_{o3} \tag{1}$$

where

$$Y_{o1} = j\frac{Z_1 \tan\theta_3 + Z_{0o}\tan\theta_1}{Z_1\left(Z_{0o3} - Z_1\tan\theta_1\tan\theta_3\right)} \tag{2}$$

$$Y_{o2} = -j\cot\left(\frac{\theta_2}{2}\right)/Z_2 \tag{3}$$

$$Y_{o3} = \frac{jwCg}{2} \tag{4}$$

Similarly, when the circuit is excited in the even-mode, the corresponding equivalent circuit is obtained. The input admittance for the even-mode is:

$$Y_{even} = Y_{e1} + Y_{e2} \tag{5}$$

where

$$Y_{e1} = j\frac{Z_1 \tan\theta_3 + Z_{0e}\tan\theta_1}{Z_1\left(Z_{0e3} - Z_1\tan\theta_1\tan\theta_3\right)} \tag{6}$$

$$Y_{e2} = j\tan\left(\frac{\theta_2}{2}\right)/Z_2 \tag{7}$$

The scattering parameters S_{21} and S_{11} of the filter are given by

$$S_{11} = \frac{Y_0^2 - Y_{even}Y_{odd}}{\left(Y_0 + Y_{even}\right)\left(Y_0 + Y_{odd}\right)} \tag{8}$$

$$S_{21} = \frac{Y_0\left(Y_{odd} - Y_{even}\right)}{\left(Y_0 + Y_{even}\right)\left(Y_0 + Y_{odd}\right)} \tag{9}$$

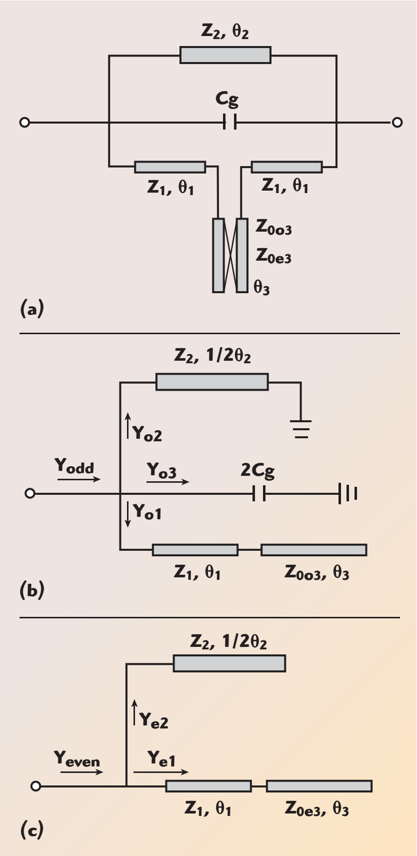
When setting $S_{21} = 0$ in Equation 9, the equation can be simplified as:

$$\frac{\tan\theta_3\left(Z_{0e3} + Z_{0o3}\right)\left(1 + \tan^2\theta_1\right)}{\left(Z_{0e3} - Z_1\tan\theta_1\tan\theta_3\right)\left(Z_{0o3} - Z_1\tan\theta_1\tan\theta_3\right)} = \frac{wC_gZ_2\sin\theta_2 - 4}{2Z_2\sin\theta_2} \tag{10}$$

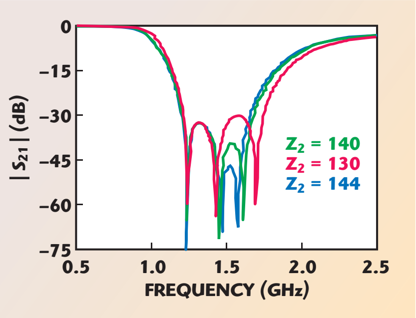
Based on the theoretical analysis,[3] the transmission zeros can be derived from Equation 10. Since the bandwidth of the stopband is mainly dependent on the positions of the transmission zeros which are derived from Equation 10, the bandstop feature can be proved by simulating the same model with diverse parameters.

As illustrated in ***Figure 2***, the stopband rejection depth can be upgraded by the increase of Z_2, when $Z_1 = 120\ \Omega$, $Z_{0e3} = 50\ \Omega$, $Z_{0o3} = 49\ \Omega$, $\theta_1 = 45°$, $\theta_2 = 35°$, $\theta_3 = 30°$, Cg = 1.1 pF, while two of the transmission zeros move back to the edges of the stopband, leading to a narrower bandwidth and slower attenuation. To observe the effects of the capacitance Cg on the filter response, the theoretical transmission responses of the BSF with different capacitance values are analyzed in ***Figure 3***. In all of the three cases, $Z_2 = 140\ \Omega$, $Z_1 = 120\ \Omega$, $Z_{0e3} = 50\ \Omega$, $Z_{0o3} = 49\ \Omega$, $\theta_1 = 45°$, $\theta_2 = 35°$, $\theta_3 = 30°$. Based on the similar analysis above, a lower Cg creates a higher-level stopband rejection. However, an extremely low Cg may lead to the deterioration of the number of the transmission zeros. After taking the actual circumstance and layout into consideration, a moderate Cg is the best choice to balance the rejection performance and the number of the transmission zeros.

From Equations 8 to 10, it can be seen that the transmission lines of the coupled stepped impedance hairpin unit play a key role on deciding the transmission zeros, which are affected by the coupling factor defined by $M = (Z_{0e3}-Z_{0o3})/(Z_{0e3}+Z_{0o3})$.



▲ *Fig. 1 Equivalent circuit of the BSF (a), odd-mode equivalent circuit (b), even-mode equivalent circuit (c).*



▲ *Fig. 2 Computed responses of the BSF with different Z_2.*

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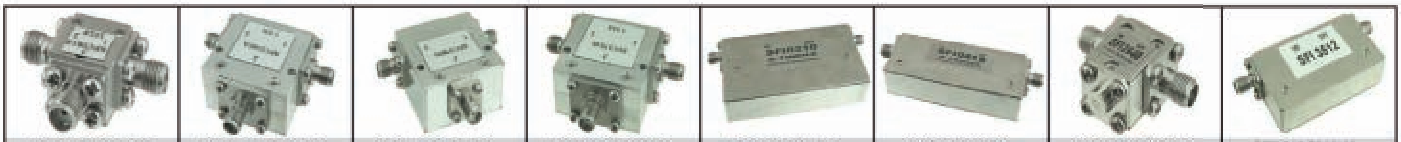

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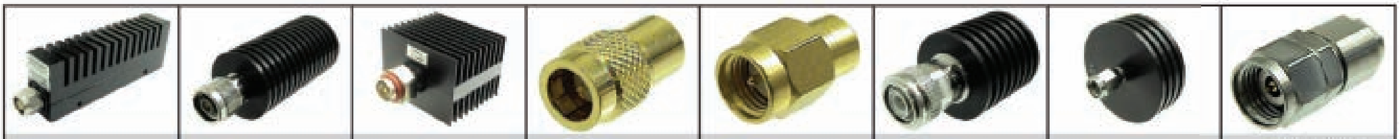

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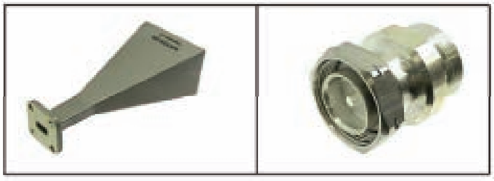

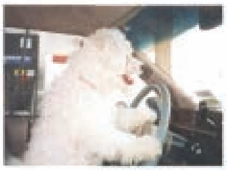

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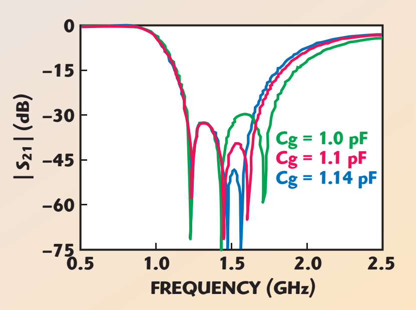
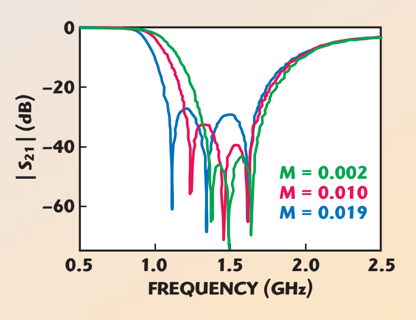


▲ *Fig. 3 S_{21} parameter as a function of C_g for fixed Z_2.*

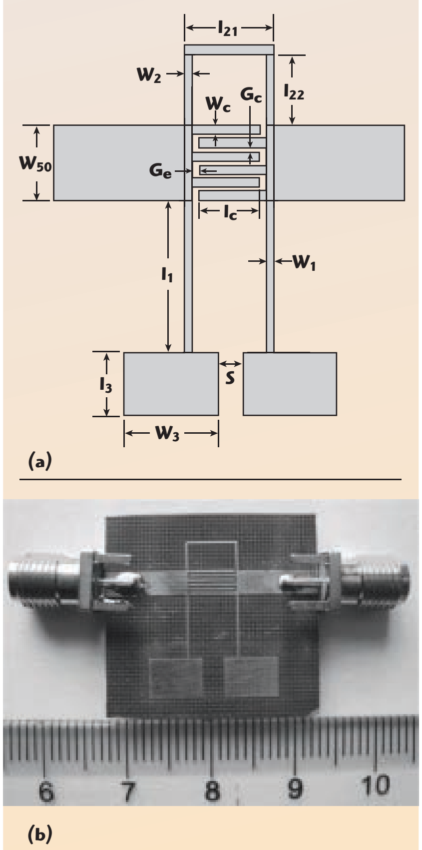


▲ *Fig. 4 Theoretical transmission responses for different values of M.*

To observe the practical and exact effects of M, ***Figure 4*** shows the S_{21} of the proposed structure with different coupling factors M, when $Z_2 = 140\ \Omega$, $Z_1 = 120\ \Omega$, Cg = 1.1 pF, $\theta_1 = 45°$, $\theta_2 = 35°$, $\theta_3 = 30°$. It has been found that as M increases from 0.002 to 0.019, the rejection level decreases, while the transmission zeros move toward the edges of the bandstop, creating a wider bandwidth and sharper skirts.

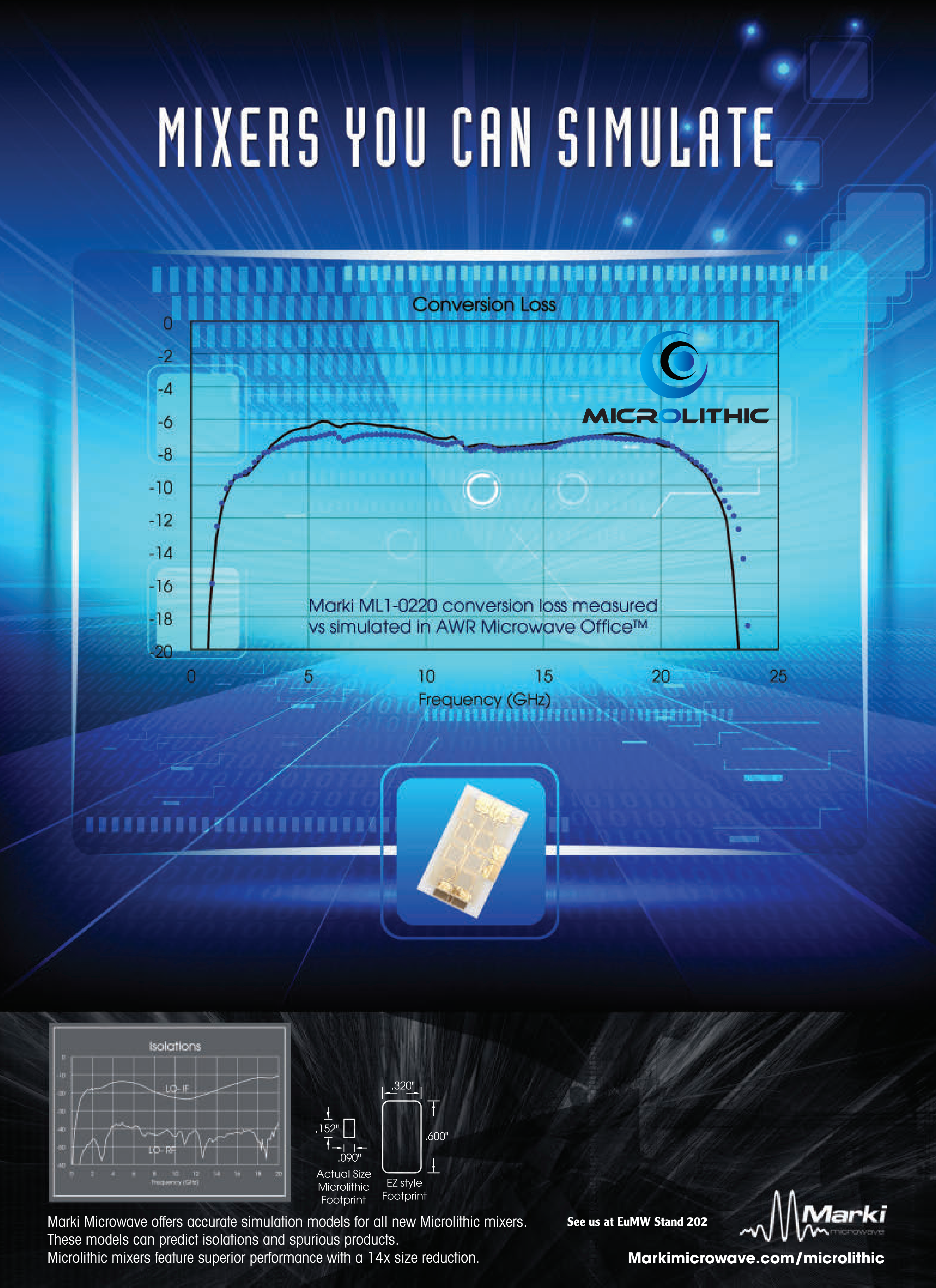
SIMULATED AND MEASURED RESULTS

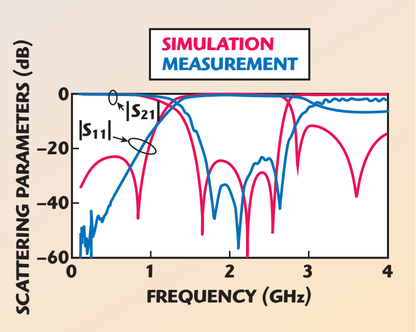
To verify the above design methodology, a bandstop filter, derived from the prototype, is designed on a 1 mm thick substrate, with a relative dielectric constant of 2.5, for experimental demonstration. After taking the stopband ripple, passband match and the layout into consideration, the impedances of the configuration are set to be: $Z_1 = Z_2 = 156.70\ \Omega$, $\theta_1 = 23.46°$, $\theta_2 = 39.54°$, $Z_{0o3} = 27.23\ \Omega$, $Z_{0e3} = 29.54\ \Omega$ and $\theta_3 = 16.12°$. The interdigital structure is employed to realize the required capacitor Cg. The optimized layout and photograph of the fabricated filter are shown in ***Figure 5***. The parameters of the stubs are selected as follows: $W_1 = 0.2$ mm, $l_1 = 7$ mm, $W_2 = 0.2$ mm, $l_{21} = 5.8$ mm, $l_{22} = 3$ mm, $W_3 = 6$ mm, $l_3 = 4.42$ mm, $S = 2.4$ mm, $W_c = 0.2$ mm, $G_c = 0.2$ mm, $G_e = 0.2$ mm, $W_{50} = 2.7$ mm and $l_c = 5.2$ mm.



▲ *Fig. 5 Fabricated wideband BSF (a) layout and (b) photograph.*

The simulated results obtained with Ansoft HFSS and the measured results are displayed in ***Figure 6***, where the two curves show good agreement. From the results, the attenuation rates at the passband transition knees are 71.42 dB/GHz (measured attenuations are 5 and 30 dB at 1.38 and 1.73 GHz, respectively) and 78.13 dB/GHz (measured attenuations are 5 and 30 dB at 2.99 and 2.67 GHz, respectively) on the lower and upper side of the stopband, respectively. The BSF aims to provide three different stopband centers at 1.65, 2.22 and 2.54 GHz. Because of the joint effect and unexpected couplings between the stubs, three transmission zeros located at 1.79, 2.09 and 2.63 GHz appear in the measured S_{21} response as expected. In addition, with the aid from introducing a transmission zero, the bandwidth of the BSF at 3 dB and 20 dB is increased. The measured lower and upper 3 dB cut-off frequencies are 1.30 and 3.10 GHz, representing a 3 dB FBW of 81.08 percent centering at





▲ *Fig. 6 Simulated and measured responses of the fabricated BSF.*

2.22 GHz and the rejection below –20 dB is extended from 1.64 to 2.72 GHz. Furthermore, the measured insertion loss (including the loss of the SMA connectors) is from 2.94 dB to 0.001 dB in the lower passband from DC to 1.3 GHz, whereas in the upper passband, from 3.2 to 4 GHz, the insertion loss is from 2.81 to 1.52 dB.

In addition, the filter occupies a compact size of 12.82 × 14.4 mm, corresponding to 0.022 λg^2 (0.141 λg × 0.158 λg), where λg is the guided wavelength of a 50 Ω transmission line at 2.22 GHz.

CONCLUSION

A compact wideband BSF, using a coupled stepped impedance hairpin unit and an inner interdigital capacitor, is designed in this article. By tuning the upper transmission line's characteristic impedance Z_2, the capacitances of Cg or the coupling strength of the coupled line, the bandwidth and rejection level of the stopband can be easily controlled. Based on the proposed structure and theoretical analysis, the proposed wideband BSF exhibits three transmission zeros, resulting in a sharp-rejection stopband filtering response. Implementation and test of a microstrip wideband BSF shows a very compact size of 0.022 λg^2. ■

ACKNOWLEDGMENT

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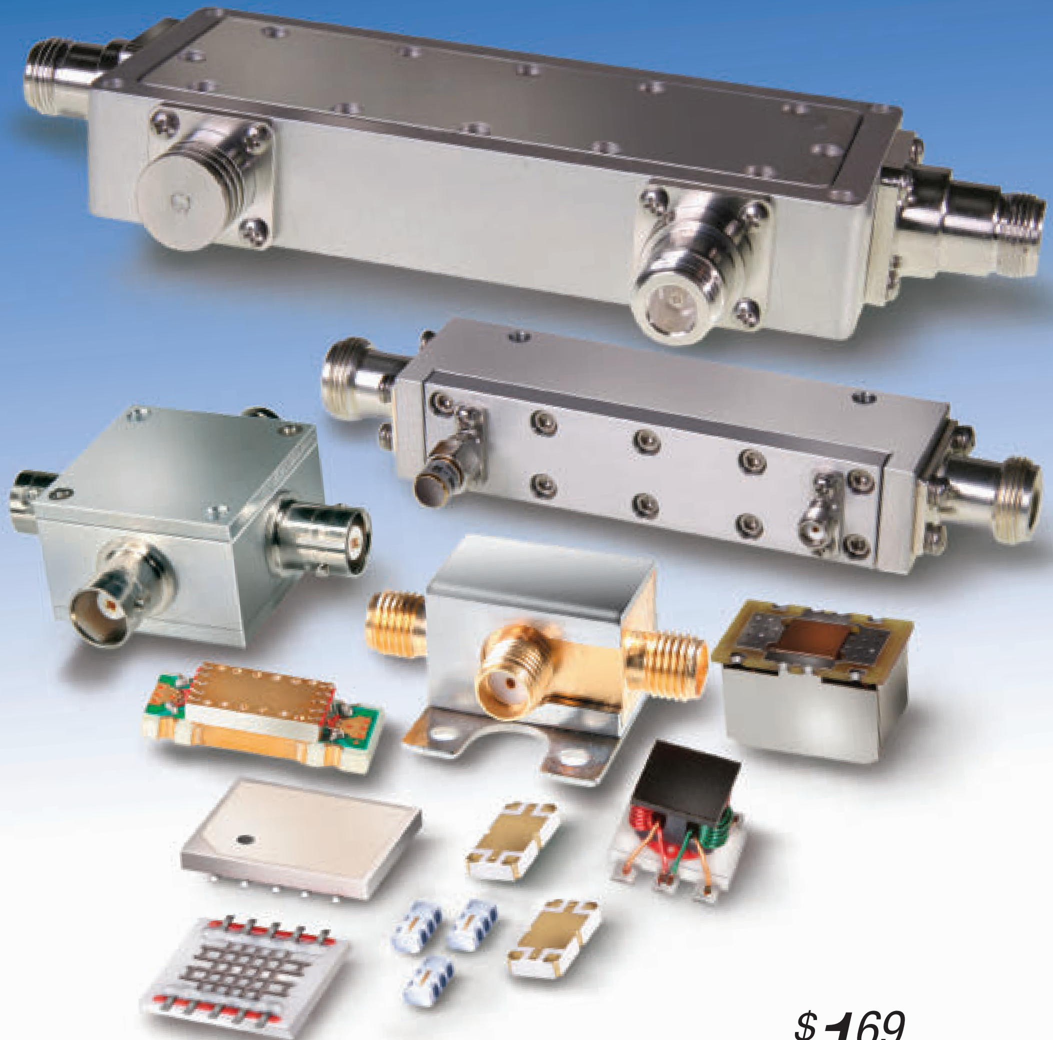

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SP8T, 50 to 1000 MHz, 20 W Switch Design Using PIN Diodes in Plastic

Since their introduction more than 50 years ago, PIN diodes continue to be the technology of choice for the switching of medium to high power RF and microwave signals simultaneously with high linearity and fast switching speeds. Although transistor switches are able to perform switching functions with reasonably good RF performance, they often come up short compared to a PIN diode based design.

This article demonstrates the simplicity of designing what may be considered a complex single-pole-eight-throw (SP8T) switch using PIN diode SPICE models along with commercially available microwave CAD tools. Design principles highlighted include the use of EM simulations for developing an optimum center junction, the use of a nonlinear PIN diode model and a method for modeling the PIN diodes in a 2012 surface mount plastic package mounted on a substrate. The design is validated by comparing RF measurement to simulation. The results show that the PIN diode SPICE model provides a good fit to measured data and, therefore, minimizes the risk and potential additional costs associated with multiple design turns.

DESIGN AND MODEL

The application is a mobile transceiver that requires quick transitions between different RF channels along with good isolation. Size, cost and RF performance are all important considerations in the design of the switch that has the following goals:

- SP8T switch
- 1.2" × 1.2"
- 50 to 1000 MHz
- 1 dB insertion loss
- 30 dB isolation
- 15 dB IRL and ORL
- 20 W CW power
- 100 nSec RF switching speed with 500 nS pulse width and 10 percent duty cycle.

Figure 1 shows the circuit schematic. For this example, an Aeroflex / Metelics MSWSS-040-30 series-shunt PIN diode switch element (see ***Figure 2***) is selected since it can

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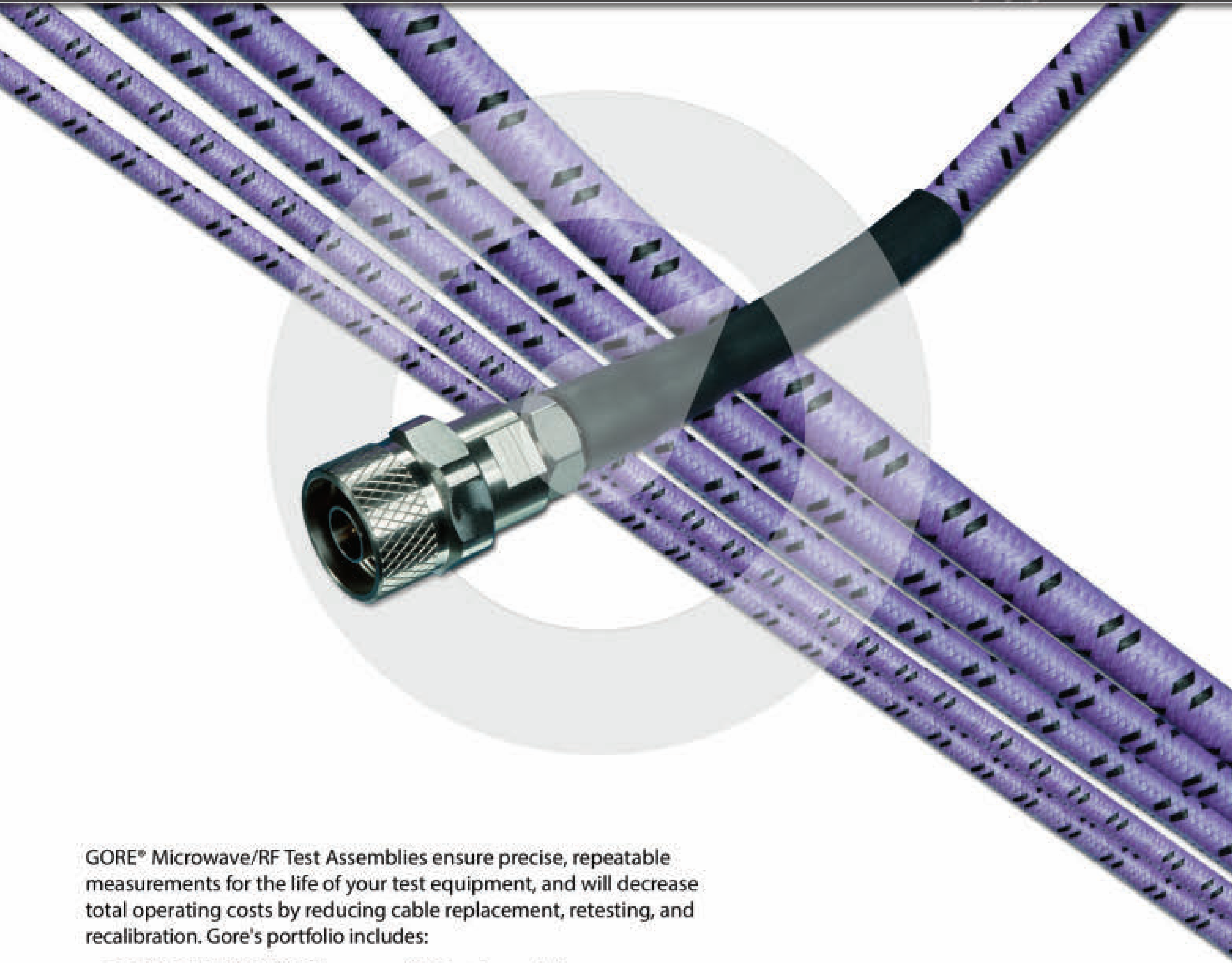

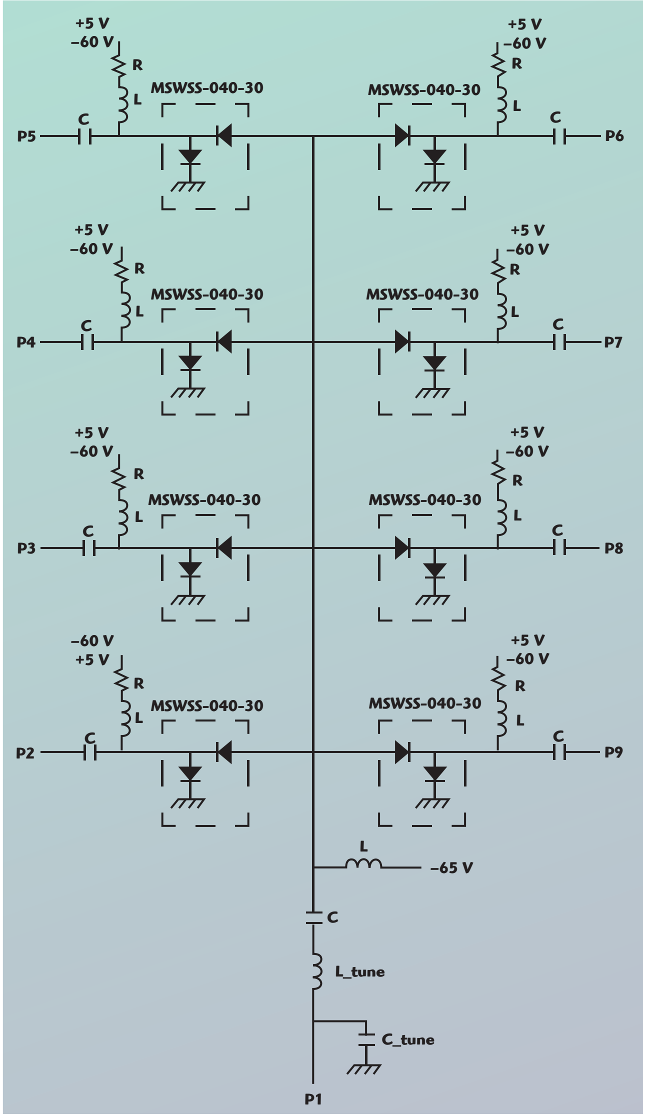

Fig. 1 SP8T switch schematic.

TABLE I

COMPONENTS

Item	Value	MFG	PN
RFC	510 nH	Coilcraft	0402HL-511XJR
L_{tune}	5.1 nH	Coilcraft	0402HP-5R1XJR
DC BLK	360 pF	ATC	700A361KT150XT
C_{tune}	2.0 pF	ATC	600F2R0BT250XT
R_{bias}	75 Ohm	KOA	RK73B2BTTD750J

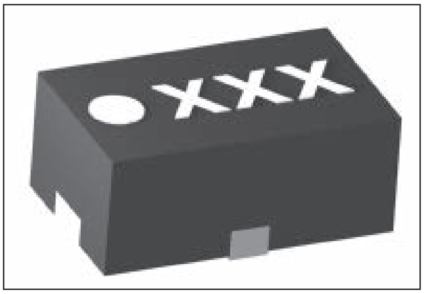

Fig. 2 MSWSS-040-30 series-shunt PIN switch element with high isolation in a low cost 2012 surface mount plastic package.

handle the power and provides high linearity and high isolation in a small low cost 2012 surface mount package. The rest of the design uses a low cost FR-4 substrate, chip inductors and capacitors. The component values are given in ***Table 1***.

The objective for the first part of the design is a center junction that presents an impedance as close as possible to 50 Ω at the input port with seven of the output ports turned off (capacitive loads) and only one of the output ports switched to a 50 Ω load. The structure, see Gardiol[1], is modified for nine ports. When in operation, most of the ports look like capacitors (reverse biased series diodes). The port feeds are narrowed to make them look inductive; thus compensating for the capacitive loads. EM simulations were carried out while making iterative dimensional adjustments to the center junction to bring the input impedance as close as possible to 50 Ω (blue trace in ***Figure 3***); then the input port was tuned with a series inductor and a shunt capacitor (green trace in Figure 3) to bring the in-

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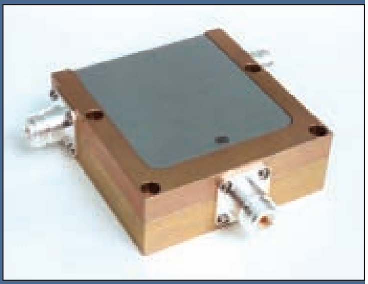

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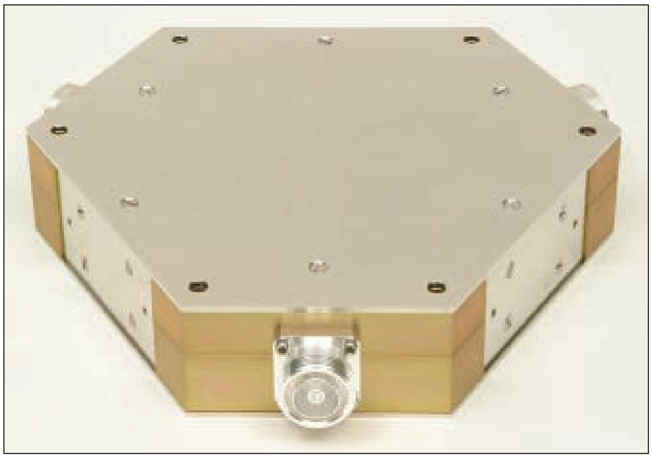

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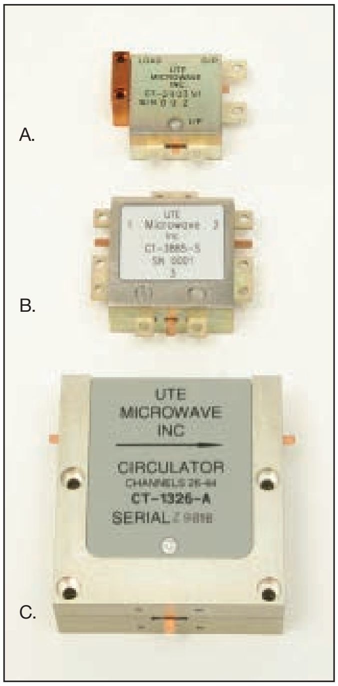
C) UHF TV Band 5 kW pk, 500 W av



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CT-3838-N	5 Kw Pk 500 W Av	N Conn.	2.7–3.1 GHz
CT-1645-N	250 W Satcom	N Conn.	240–320 MHz
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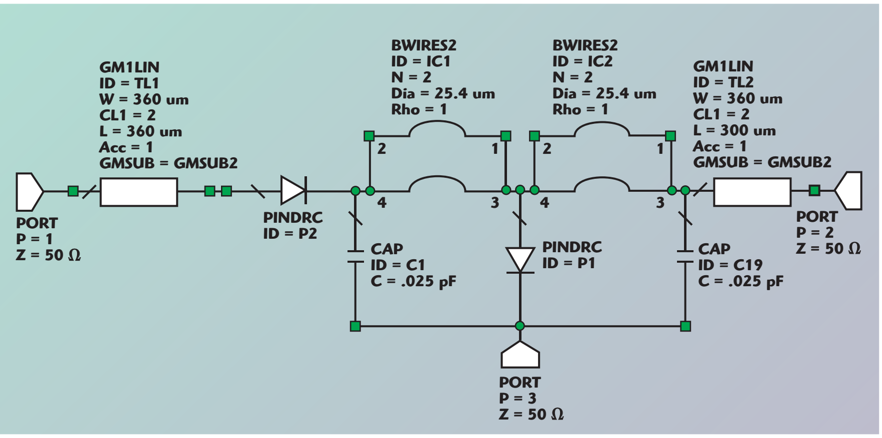
Contact us for more information on our extensive product line and current catalog. We accept Visa, MC, Amex put return loss (IRL) to more than 15 dB. The final center junction design is shown in ***Figure 4***.

An important factor in the center junction design is its dimension relative to a quarter wavelength (1/4 λ). At 1 GHz, ¼ λ on FR-4 material (dielectric constant of 4.35) is equal to 1.4 inches, while the length across the final junction is only 0.295 inches (much less than a ¼ λ). If the frequencies were higher, and the wavelengths within the operating band were to approach the center junction dimension, then the center junction would need to be reduced in size to avoid transmission line effects that would make it more difficult to tune.

The second part of the design is the modeling of the PIN diode switch elements on the FR-4 printed circuit board substrate. The building blocks include the EM simulated center junction sub-circuit, the PIN Diode SPICE Models, the 2012 plastic package model, the Coilcraft inductor models and the ATC capacitor models. ***Table 2*** provides the PIN diode parameter values and ***Figure 5*** shows the 2012 package model with bond wires, transmission lines (for the package leads) and stray capacitance. The package leads are modeled as transmission lines sandwiched between two substrates — the plastic molding compound on top and the FR-4 below.



▲ *Fig. 5 2012 package model with PIN diodes, bond wires, package leads and stray capacitance.*

TABLE II

NONLINEAR SPICE MODEL[2]

Parameter	Series NIP	Shunt PIN
I_s (mA)	3.10E-06	2.20E-06
I_{knee} (mA)	15	15
N	1	1
R_{lim} (Ω)	0.345	0.6
R_{epi} (Ω)	1000	1000
C_j (pF)	0.14	0.12
C_{pkg} (pF)	0	0
Tau (ns)	2600	3000
W (μm)	75	75
B	3	3
L_{bond} (nH)	0	0

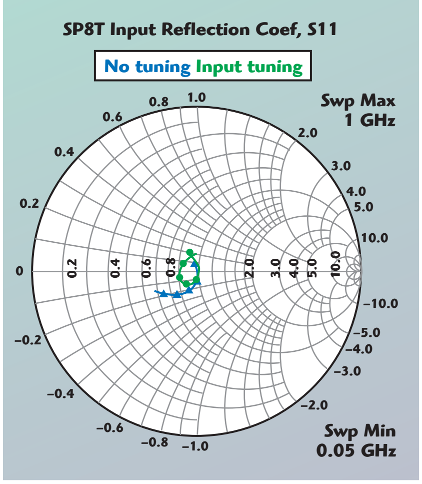
Representing one arm of the switch, ***Figure 6*** shows the PIN diode switch element mounted on an FR-4 substrate with three vias to ground. To provide bias for the diodes, there is a discrete bias tee consisting of an RFC inductor, a DC blocking capacitor, a bypass capacitor and a bias resistor connected to a DC power supply.

The SP8T switch is less than 1 inch in diameter meeting the design goal of 1.2 × 1.2 inches; however, a final printed circuit board size of 2.37 × 2.58 inches (see ***Figure 7***) is required to provide enough room for the bias terminals and RF SMA edge connectors.

RF SIMULATION VERSUS MEASUREMENT

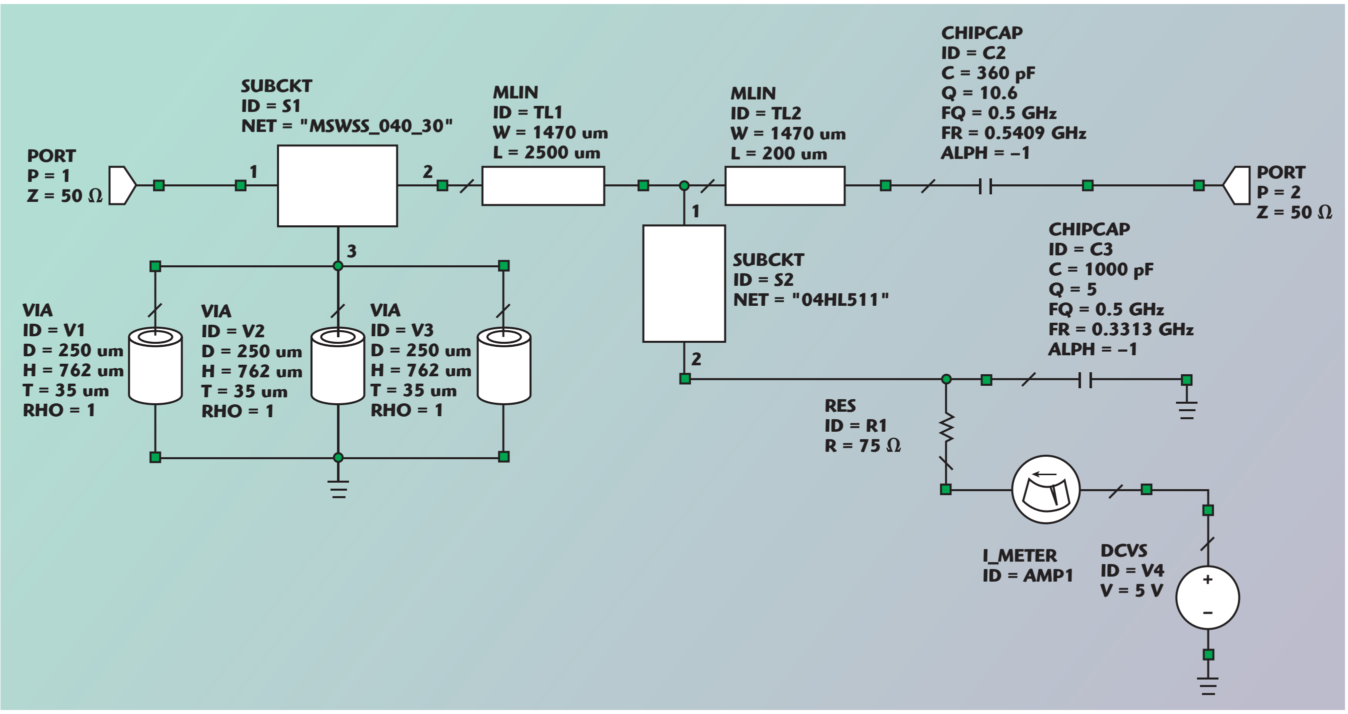
The complete RF performance is summarized in ***Table 3***. Overall, it is accurately predicted by the model. After subtracting out through losses, actual and modeled insertion loss agree to within 0.06 dB (see ***Figure 8***). Isolation between non-adjacent channels agrees closely with the model at low frequencies and to within about 5 dB at the high frequency end. The deviation at higher frequencies is due to capacitive coupling. Isolation between adjacent channels — Port 1 to port 2 with port 3 turned on does not agree as closely. This is due to adjacent channel coupling not included in the model. Co-planar or ground metal between channels would improve this. The typical difference between simulated and measured results for this case is 15 dB (see Figure 8); however, the design still meets the 30 dB goal, because the series-shunt switch element provides a large amount of isolation.

The modeled values of input and output return loss (see ***Figure 9***), excluding the low frequency deviation due to the broadband capacitor used, are within 2.3 dB of measured. The



▲ *Fig. 3 Center junction input impedance.*

▲ *Fig. 4 Final nine port center junction.*



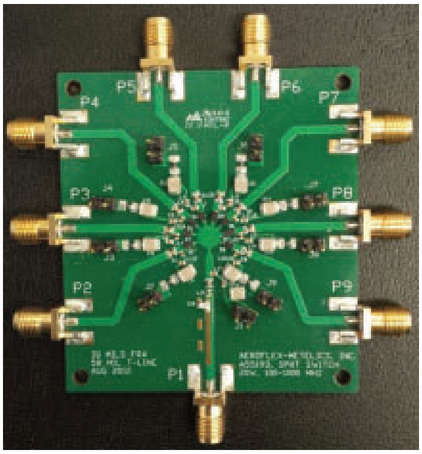
▲ *Fig. 6 Package on PCB with RF choke, DC blocking capacitor, bypass capacitor, resistor and power supply.*

worst case measured value of 17.1 dB is better than the 15 dB design goal.

Often overlooked is one of the PIN diode's biggest value propositions — linearity. In this case, the PIN diode's 73 dBm third order intercept point (IP3) is higher than the measurement capability of the test system used. For this reason, the IP3 was calculated analytically using equation 1.[2]

$$IP3 = 24 + 15\log(Q_{nc} f_{MHz} / Rs)\text{dBm} \qquad (1)$$

Another advantage of PIN diodes, as compared to other types of switch elements, is the ability to switch large RF and microwave signals extremely fast. Using the Aeroflex / Metelics' A55196 (rev -) driver circuit as an example, measured RF rise and fall times are 20 nSec and 15 nSec respectively, for a 500 nSec pulse width, 250 KHz repetition frequency and 20 W



▲ *Fig. 7 RF board actual size (2.37 × 2.58 inches).*

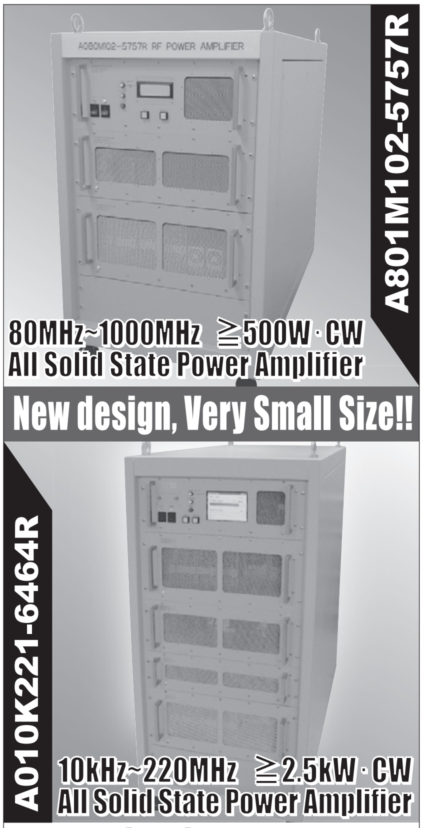
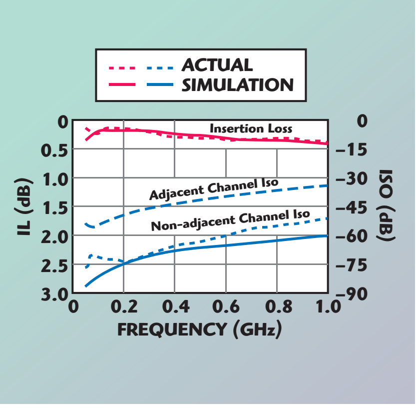


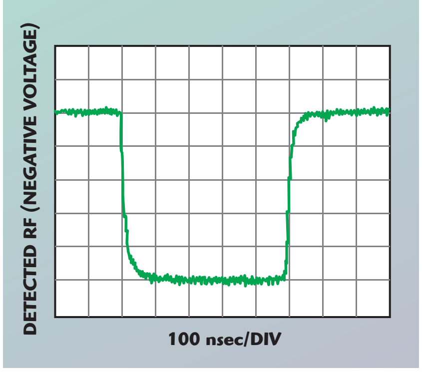
TABLE III

RF PERFORMANCE SUMMARY

Freq. (MHz)	IL (dB)	IRL/ORL (dB)	Isolation (dB) Adjacent	Isolation (dB) Non-Adjacent
50	0.15	21	54	76
100	0.24	28	54	71
200	0.20	23	49	74
300	0.22	20	46	70
400	0.30	18	44	66
500	0.32	17	42	63
600	0.35	18	40	60
800	0.36	22	37	55
1000	0.40	20	34	52



▲ *Fig. 8 Insertion loss and isolation modeled (solid) vs. measured (dashed).*

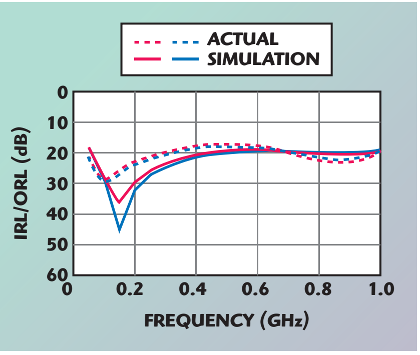


▲ *Fig. 10 Detected RF switching speed with 20 ns rise time and 15 ns fall time.*

input power hot switched (see ***Figure 10***). This is 44 times faster than the 450 nSec lifetime of the PIN diode and easily meets the 100 nSec design goal.

CONCLUSION

A design methodology is presented which uses the PIN diode SPICE model and commercially available EM CAD tools for designing a SP8T switch. The model predicted IL to within 0.06 dB, IRL to within 2.3 dB and isolation between non-adjacent channels to within about 5 dB. Using a driver circuit, a switching speed of 20 nSec is achieved. The SPICE model combined with the EM simulation tool accurately predicts RF performance, minimizing the time and cost associated with multiple design turns. In this case, only a single design and fabrication turn was needed. ■



▲ *Fig. 9 IRL and ORL modeled (solid) vs. measured (dashed).*

ACKNOWLEDGMENTS

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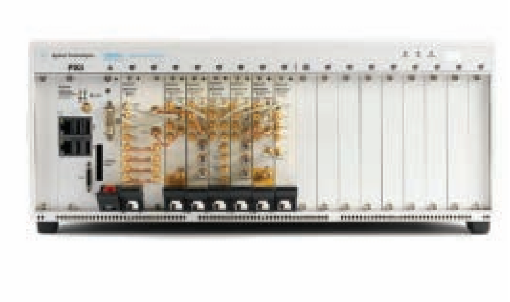


PXI Vector Signal Analyzer and Generator

For those who develop wireless devices, the following refrain will be familiar: "I have to test twice as much in half the time, we're selling the product for half its previous price, and volume keeps growing." As devices become increasingly dense with integrated capabilities, testing "twice as much" includes not just "more things" but also "new things."

Satisfying this "twice/half" dynamic requires three essential attributes in the test solution: speed, continuity and longevity. Speed is needed in two dimensions: shorter development time and faster test times. Continuity comes from consistent test results across R&D, design verification (DV) and manufacturing: apples-to-apples comparisons of measurement results reduce uncertainty, delays and finger-pointing. Longevity refers to flexible capabilities in signal analysis and signal generation that enable system creators to handle expanding test requirements.

In the evolution of RF test solutions, a new and logical step forward is the Agilent M9391A and M9381A PXI vector signal analyzer and generator (PXI VSA/G). For the testing of power amplifiers, front end modules and more, the PXI VSA/G offers fast, proven results through the combined benefits of raw hardware speed and standard-specific measurement applications. In addition, compatibility with Agilent 89600 VSA software enables deeper analysis and support for Agilent SystemVue electronic system-level (ESL) software provides links between design, simulation and measurements.

COMBINING VECTOR SIGNAL ANALYSIS AND GENERATION

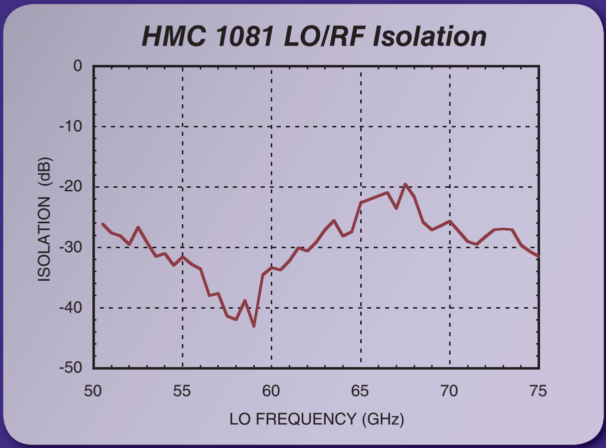
With today's complex modulation schemes, magnitude-only spectrum analysis lacks the phase information needed to demodulate and characterize standardized wireless signals such as LTE or 802.11ac. In contrast, vector signal analysis captures magnitude and phase information, demodulates the signal according to the relevant standard, and provides essential figures of merit such as error vector magnitude (EVM).

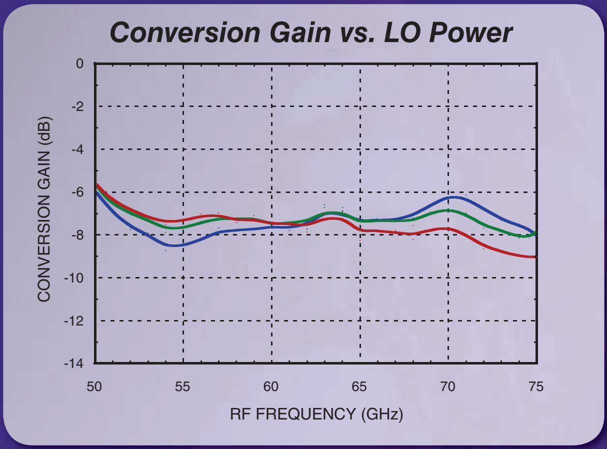
Agilent Technologies
Santa Clara, CA

E/V BAND MMIC MIXERS

Up & Downconversion for E/V Band Radios

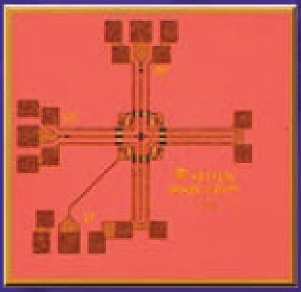
Analog, Digital & Mixed-Signal ICs,
Modules, Subsystems & Instrumentation





Features

- *High RF Frequency: 50 to 75 GHz*
- *Wide IF Bandwidth: DC to 26 GHz*
- *High LO/RF Isolation: 28 dB*
- *Low LO Power: +12 dBm*
- *Passive: No DC Bias Required*



HMC1081

E/V BAND MMIC MIXERS

Part Number	RF Frequency (GHz)	Function	IF Frequency (GHz)	Conversion Gain (dB)	LO / RF Isolation (dB)	IIP3 (dBm)
NEW HMC1081	50 - 75	Double Balanced Mixer	DC - 26	-7.5	28	+16
HMC-MDB218	54 - 64	Sub-Harmonic, I/Q Mixer	DC - 3	-12	30	+7
HMC-MDB169	54 - 64	Double Balanced Mixer	DC - 5	-8	30	+13
HMC-MDB277	70 - 90	Double Balanced Mixer	DC - 18	-12	—	—
HMC1057	71 - 86	Sub-Harmonic, I/Q Mixer	DC - 12	-12	30	+13
HMC1058	71 - 86	Sub-Harmonic Mixer	DC - 12	-11	28	+6

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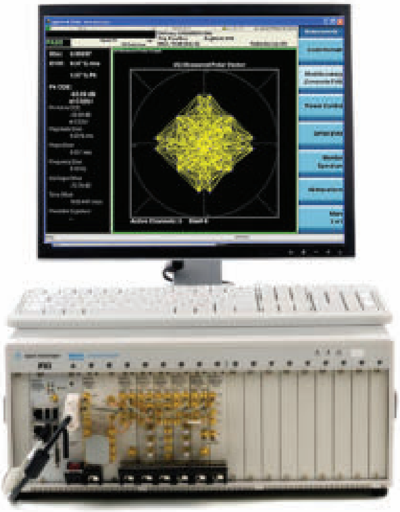


Fig. 1 Agilent PXI VSA/G configured with optional keyboard, monitor, embedded controller and software.

Similarly, analog signal generators are not able to simulate today's most advanced wireless signals—and the solution is a vector signal generator. These are equipped with the memory, signal processing and digital-to-analog conversion technologies needed to realistically simulate highly complex signals.

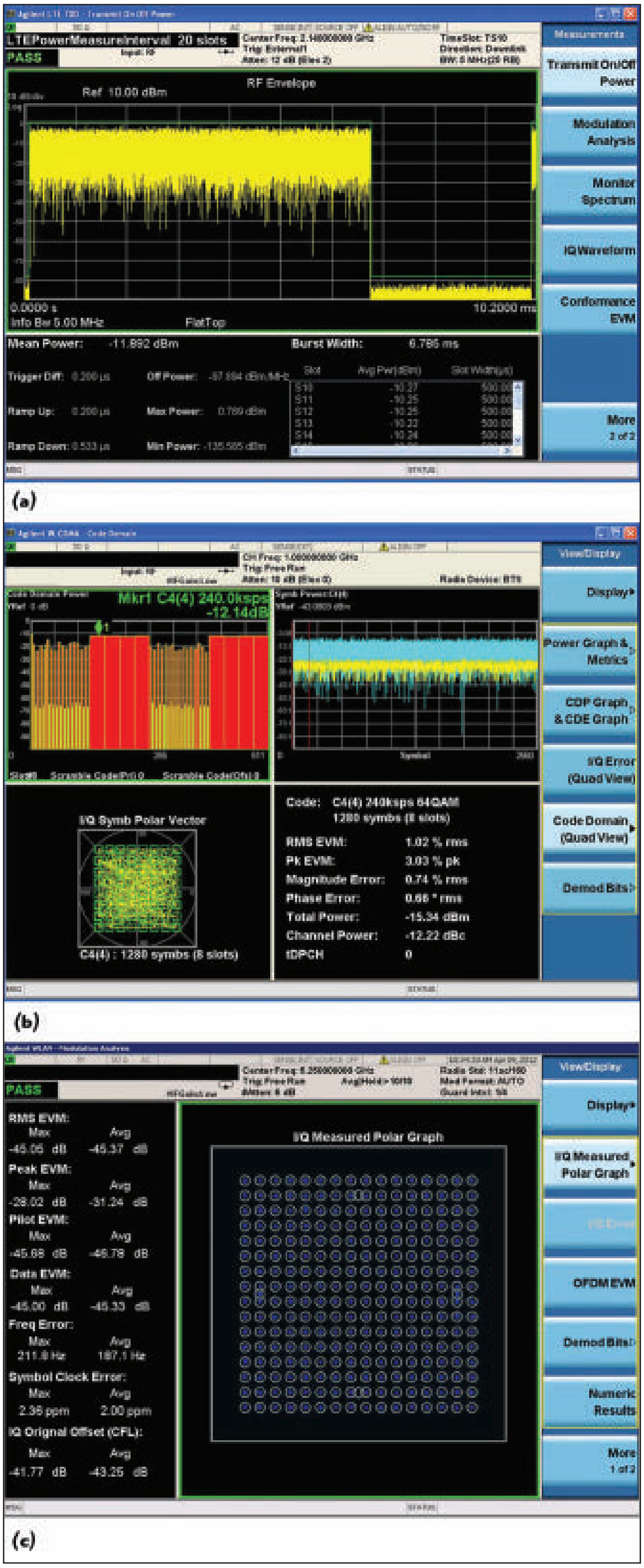
These signal-analysis and signal-generation capabilities are available in benchtop and modular form factors. When space and cost are at a premium, a modular solution such as the PXI VSA/G makes both capabilities available in a single PXI chassis (see ***Figure 1***). To enable closed-loop testing of power amplifier (PA) parameters such as gain compression, the PXI VSA/G provides internal connections between the analyzer and the generator. This combination of speed, capability and convenience is emerging as a highly effective way to address the "twice/half" dynamic in DV and manufacturing applications.

MEETING TECHNICAL REQUIREMENTS

To help accelerate system development and device testing, two key themes apply to the PXI VSA/G: raw hardware speed and RF parametric performance. On the production line, measurement throughput is a key metric. To help reduce test time, the PXI VSA/G provides extremely fast signal-analysis results enabled by a unique hardware mode dedicated to power measurements. This utilizes real-time hardware resampling, which enables high speed modulation analysis by reducing the amount of data sent across the bus and thereby accelerating measurement speed.

Measurement time can also be reduced with rapid switching of both frequency and amplitude, which comes from the innovative "fastune" baseband-adjustment capability built into the PXI VSG. In addition, the need for external hardware is reduced through capabilities such as the +19 dBm maximum power output of the PXI VSG.

When working together, the preceding capabilities can reduce test times by enabling power servos to converge faster while providing excellent linearity, repeatability and absolute amplitude accuracy. This is supported by a built-in RF calibration signal that covers the PXI VSA/G's entire frequency range of 3 GHz (standard) or 6 GHz (optional).



LTEPowerMeasureInterval 20 slots
PASS
Center Freq: 2.140000000 GHz
Trig: External1
Atten: 12 dB (Elec 2)
TimeSlot: TS10
Direction: Downlink
BW: 5 MHz(25 RB)

Mean Power: -11.892 dBm
Burst Width: 6.785 ms
Trigger Diff: 0.200 µs
Off Power: -97.894 dBm/MHz
Ramp Up: 0.200 µs
Max Power: 0.789 dBm
Ramp Down: 0.533 µs
Min Power: -135.585 dBm

Slot	Avg Pwr(dBm)	Slot Width(µs)
S10	-10.27	500.00
S11	-10.25	500.00
S12	-10.25	500.00
S13	-10.22	500.00
S14	-10.24	500.00

Ch Freq: 1.000000000 GHz
Trig: Free Run
Atten: 10 dB (Elec 0)
Radio Device: BTS

Code: C4(4) 240ksps 64QAM
1280 symbs (8 slots)
RMS EVM: 1.02 % rms
Pk EVM: 3.03 % pk
Magnitude Error: 0.74 % rms
Phase Error: 0.66 ° rms
Total Power: -15.34 dBm
Channel Power: -12.22 dBc
tDPCH 0

PASS
Center Freq: 5.250000000 GHz
Trig: Free Run
Avg|Hold:>10/10
Atten: 6 dB
Mod Format: AUTO
Guard Intvl: 1/8

RMS EVM:
Max -45.05 dB Avg -45.37 dB
Peak EVM:
Max -28.02 dB Avg -31.24 dB
Pilot EVM:
Max -45.68 dB Avg -46.78 dB
Data EVM:
Max -45.00 dB Avg -45.33 dB
Freq Error:
Max 211.8 Hz Avg 187.1 Hz
Symbol Clock Error:
Max 2.36 ppm Avg 2.00 ppm
IQ Orignal Offset (CFL):
Max -41.77 dB Avg -43.25 dB

Fig. 2 Example screens from Agilent modular X-Series applications: LTE-TDD (a), W-CDMA (b) and 802.11ac (c).

ADDRESSING BUSINESS REQUIREMENTS

To help ease business pressure, three more themes apply to the PXI VSA/G: faster development, longevity in ca-

Tuf-Flex™ Cables

When the going gets tough, the tough *get connected!*

TUF-FLEX offers an internal layer of silver plated copperweld protection that is crush resistant & offers exceptional resistance to kinking in lieu of external armor.

TUF-FLEX Cable Performance vs. Crush Force

Force (lbs)	Max VSWR	Max Loss (dB)
0	1.20	1.3
45	1.20	1.3
90	1.20	1.3
160	1.20	1.3
200	1.22	1.3
225	1.28	1.3

Results of crush and bend tests on IW's TUF-FLEX cable assemblies, using 2 ft long samples of our 1803 cable. Results show max VSWR and insertion loss over a frequency range of .04 to 18 GHz.

For crush force testing, the cable was placed between two 1 inch diameter plates with force applied to the top plate. The same cable was then tested using successively smaller bend radii to a minimum bend radius of 1.5".

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pability and total cost of ownership. The PXI VSA/G helps reduce development time with Agilent's X-Series applications for modular instruments, which are derived from those used with Agilent X-Series signal analyzers. Using the same algorithms across R&D, DV and manufacturing ensure continuity, which minimizes time spent reconciling inconsistent results. Currently, the available applications include those that support W-CDMA/HSPA/HSPA+, LTE FDD, LTE TDD, GSM/EDGE/EDGE Evo, TD-SCDMA/HSPA, 1xEV-DO, cdma2000 and 802.11 (a, b, g, n and ac) wireless LAN (see ***Figure 2***).

To reduce the time spent on signal creation, the PXI VSG is compatible with Agilent Signal Studio software. Its flexible suite of signal-creation tools provides standard-compliant, performance-optimized reference signals that enhance the process of characterizing and validating wireless devices. Fully defined signals—with or without impairments—can be downloaded and stored in module memory for rapid recall and playback.

With regard to longevity, optional and built-in capabilities allow the PXI VSA/G to evolve as requirements change. For example, the standard 40 MHz analysis bandwidth is upgradeable to 160 MHz analysis bandwidth (optional) through a software license key.

Finally, a variety of factors affect the total cost of ownership (TCO) for any solution. In the PXI VSA/G, the "whole product" envelope address TCO with a standard three-year warranty, one day of solution optimization with an Agilent application engineer and a built-in "calibration status manager" application. To help reduce TCO for global organizations, Agilent has 50 service and support centers located around the world.

LOOKING TO THE FUTURE

Ongoing industry trends suggest that RF requirements will keep growing while timelines keep shrinking. To help ease the pressure—technical and business—a test solution should provide speed in development, speed in measurements, continuity in measurements and longevity in capability. With raw hardware speed and standard-specific measurement applications, the Agilent PXI VSA/G is designed to meet these needs. Through its fully modular hardware, links to analysis and simulation software, and the ability to leverage proven measurement applications, the PXI VSA/G is a low-risk way to manage change and be ready today for what may come tomorrow.

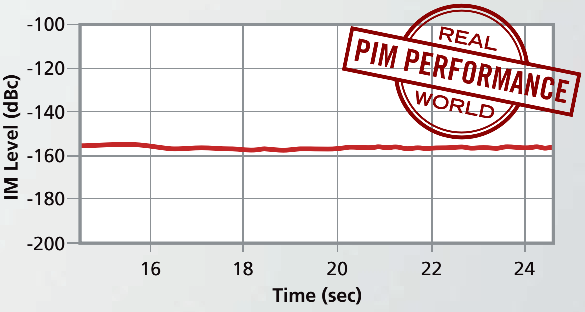
VENDORVIEW

Agilent Technologies,
Santa Clara, CA,
www.agilent.com/find/M9391A.

VIEW VIDEO

The perfect PIM cable assembly. For the not-so-perfect world.

Achieving flat PIM performance in the lab is hard enough. But in the real world, keeping PIM at bay is nearly impossible. Until now. SRX™ jumper cables from San-tron are the first and only flat PIM cable assemblies that stand up under tough conditions. They deliver impressive PIM performance of -158 dBc standing still and degrade just 2 dB under heavy vibration. Offering a bend radius of 2.5 inches, power handling of 160 W, and attenuation of 13 dB per 100 feet, you can snake them around anywhere.



Learn more about our complete line of SRX solutions by downloading our SRX brochure at **Santron.com**.

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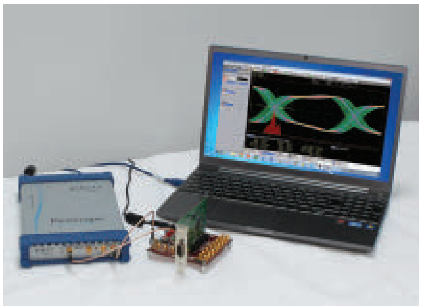
San·tron

Always Thinking

Affordable Analysis for Next-Generation High Performance Designs

Growing demand for high performance RF, microwave and serial communication devices (SERDES) has highlighted the need for good signal integrity (SI) in modern designs. Engineers need to accurately characterize timing, jitter and noise performance to determine the operating envelope of their designs and guarantee reliable operation once deployed.

Validating SI has traditionally been a specialist task requiring high-end oscilloscopes that can be both expensive and bulky. Real-time digital oscilloscopes, above 10 GHz, are suited to debug and troubleshoot tasks, and can be used to check signal integrity. However, they tend to be expensive and suffer from drawbacks – including limited 8-bit ADC resolution, reduced to 6 bits or less at high frequencies – and relatively high intrinsic jitter floor.



▲ *Fig. 1 The PicoScope 9302 set up to measure characteristics of a 2.5 Gbit/s PCI Express card using a 'break-out' box with SMA connectors to access clock and data channel.*

For cyclic signals, or repeating patterns, sampling scopes offer wide bandwidth for lower budgets and benefit from low intrinsic jitter and noise, and voltage resolution down to 100 μV or better. Those capabilities, combined with measurement analysis and visualization tools, make the sampling scope a potent tool for device characterization and identification of signal integrity issues.

Most sampling scopes employ a large mainframe with sampling heads on extender leads that can be placed close to the device under test. This complexity is not necessary with the PicoScope 9300 Series scopes, as their small size allows the user to position them right next to the device under test.

With 20 GHz bandwidth, the scopes can acquire signals with rise times down to 17.5 ps. Precise time-base stability and accuracy, and timing resolution as low as 64 fs, allow characterization of clock timing and jitter in demanding applications.

PicoSample 3 software gives control of the scope and numerous predefined trace, eye and statistical measurements. The software includes 167 standard serial data communications masks with user margin, editing and custom mask compilation. Advanced tools such as a color-graded persistence display, histograms and pattern-lock triggering give more insight into waveform characteristics plus jitter and noise distribution.

PICO TECHNOLOGY
St Neots, UK

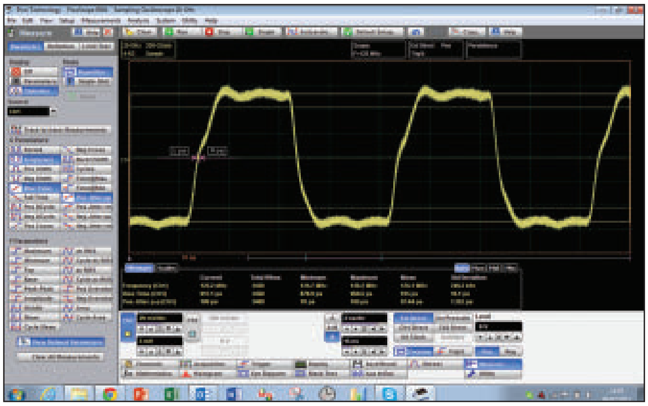


Fig. 2 Automated measurements show frequency, rise time and jitter (peak-to-peak).

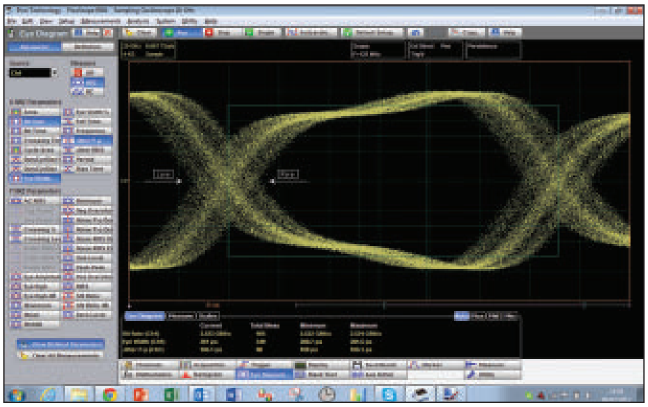


Fig. 3 An eye diagram can be used to construct the characteristics of the data channel.

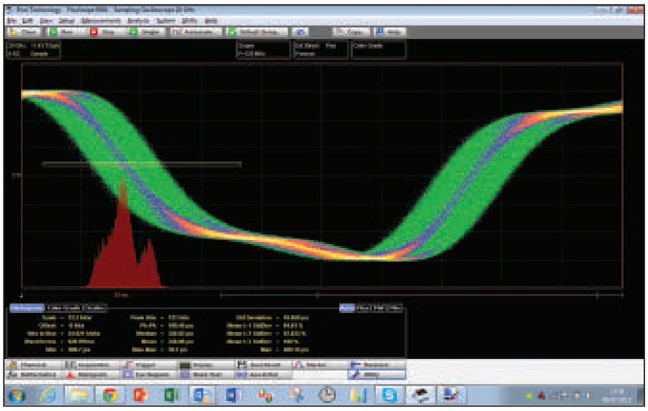


Fig. 4 The eye diagram has been complemented with a histogram of the waveform crossing points.

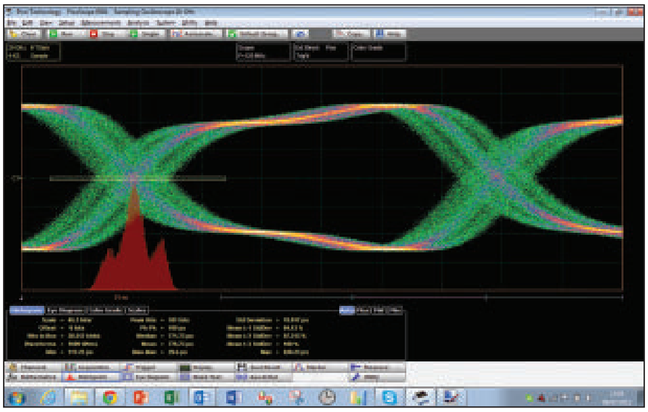


Fig. 5 The histogram can be used to 'slice' the waveform to reveal subtle details and offer an insight into the waveform behavior.

In the test setup shown in ***Figure 1***, a PicoScope 9302 has been set up to measure characteristics of a 2.5 Gbit/s PCI Express card using a 'break-out' box with SMA connectors to access clock and data channels. The PicoScope 9300 is small enough to be placed close to the device under test to ensure good measurement fidelity.

For the practical example, the first task is to characterize the clock signal. A dedicated frequency counter shows the trigger signal frequency at all times, regardless of measurement and time-base settings. Automated measurements have been enabled to show frequency, rise time and jitter (peak-to-peak) as shown in ***Figure 2***. Measurement statistics can be used to analyze long-term signal behavior as a predictor of system reliability.

Next, the characteristics of the data channel can be examined by building an eye diagram (shown in ***Figure 3***) and measuring key parameters such as the eye height and width, and jitter – a key parameter to control with designs operating in the Gbit/s range and higher. Note that the device under test has been programmed to output a pseudo-random bit pattern to represent real-world operating conditions. Eye diagram testing can be automated using masks defined for the transmission standard in question. Note also that a color-graded display is being used to give a visual indication of frequency of occurrence of waveform paths, which gives important clues about error types and their sources.

In ***Figure 4***, the eye diagram has been complemented with a histogram of the waveform crossing points. Histograms show distribution of jitter (or noise) in a high speed design, which give important clues about the jitter components and their source: pattern-dependent (bounded) and random components can be isolated and tackled in the design.

If a design appears susceptible to error under certain bit sequences, the pattern lock trigger can be used to isolate only the preceding pattern that is causing the problem and to display it in an Eye Line diagram. As ***Figure 5*** shows, the histogram can be used to 'slice' the waveform to reveal subtle details and offer an insight into the waveform behavior, helping the designer to focus on sources of error.

Low-jitter clock distribution and high speed data pathways are at the heart of today's wireless infrastructure, consumer electronics, broadband and other applications. PicoScope sampling scopes are ideal for critical analysis and verification of high performance waveforms, giving the designer confidence to sign off a design before moving it into production. PicoScope 9300 Series scopes are physically small, to preserve SI close to the device under test and low cost.

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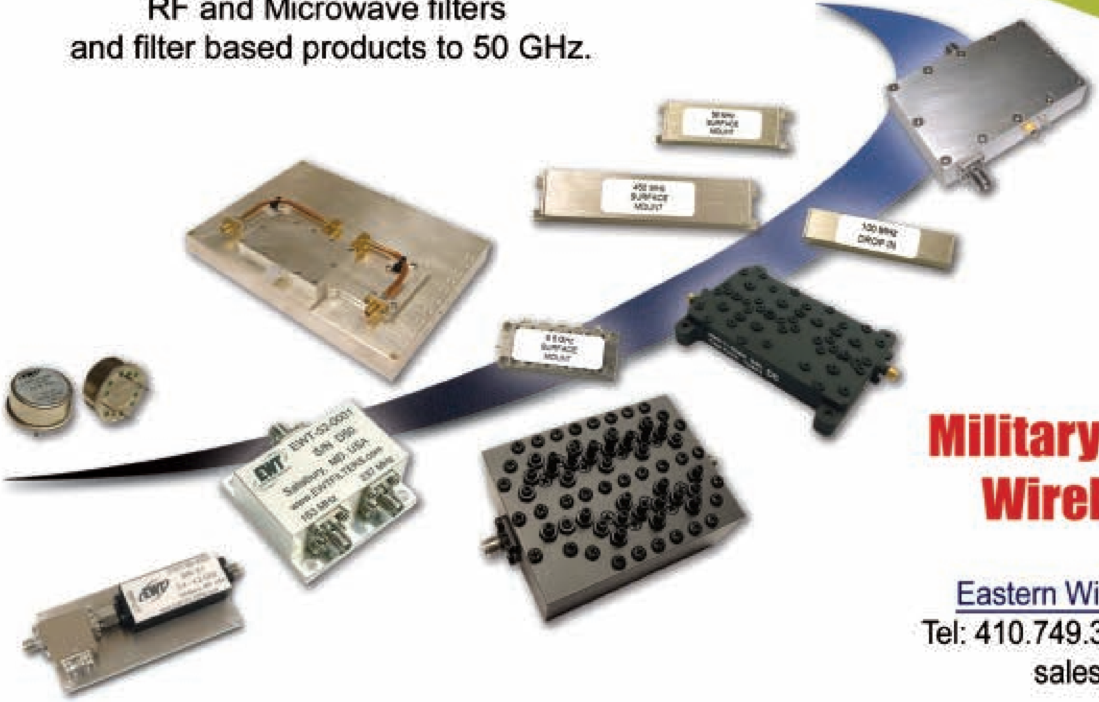
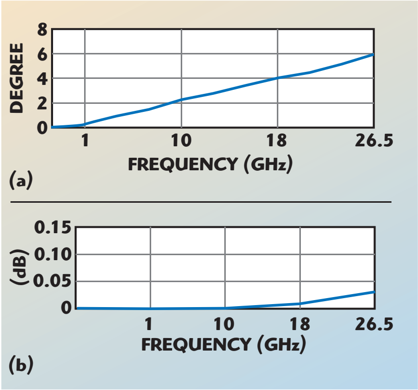


Optimized Cable Assemblies Per Application Requirements

Cable assemblies are some of the most widely used components in military and commercial electronic systems. They are used as connections between components within racks, subsystems, antenna feeds and various test platforms, among many others. Although a cable assembly looks like a very simple component, consisting of just coaxial cable and connectors, in many situations it can be the critical factor determining system performance, life and cost. Developing the most suitable and effective cable assembly for a particular application with a reasonable cost is a real challenge for every system or subsystem designer. Good communication between customer and vendor is necessary for the proper choice of cable, connector and assembly technique.

The designer/customer must first be able to transfer the requirement and specification for a cable assembly to the vendor/manufacturer of a cable assembly. Cable and connector selection are the next steps, possibly with assistance from the manufacturer, to ensure that all requirements are met within cost and delivery constraints. In some situations, existing cable and connectors are not suitable, and custom design may be necessary to meet the specifications. Assembly techniques must also be examined as they may dictate the use of alternative cable or connectors, due to manufacturing problems of availability, time, cost or quality. Finally, testing must be done at all stages to ensure that the assemblies meet electrical, environmental and reliability requirements. Test data will indicate whether the assembly procedures and techniques will produce a final product meeting all specifications and application requirements.



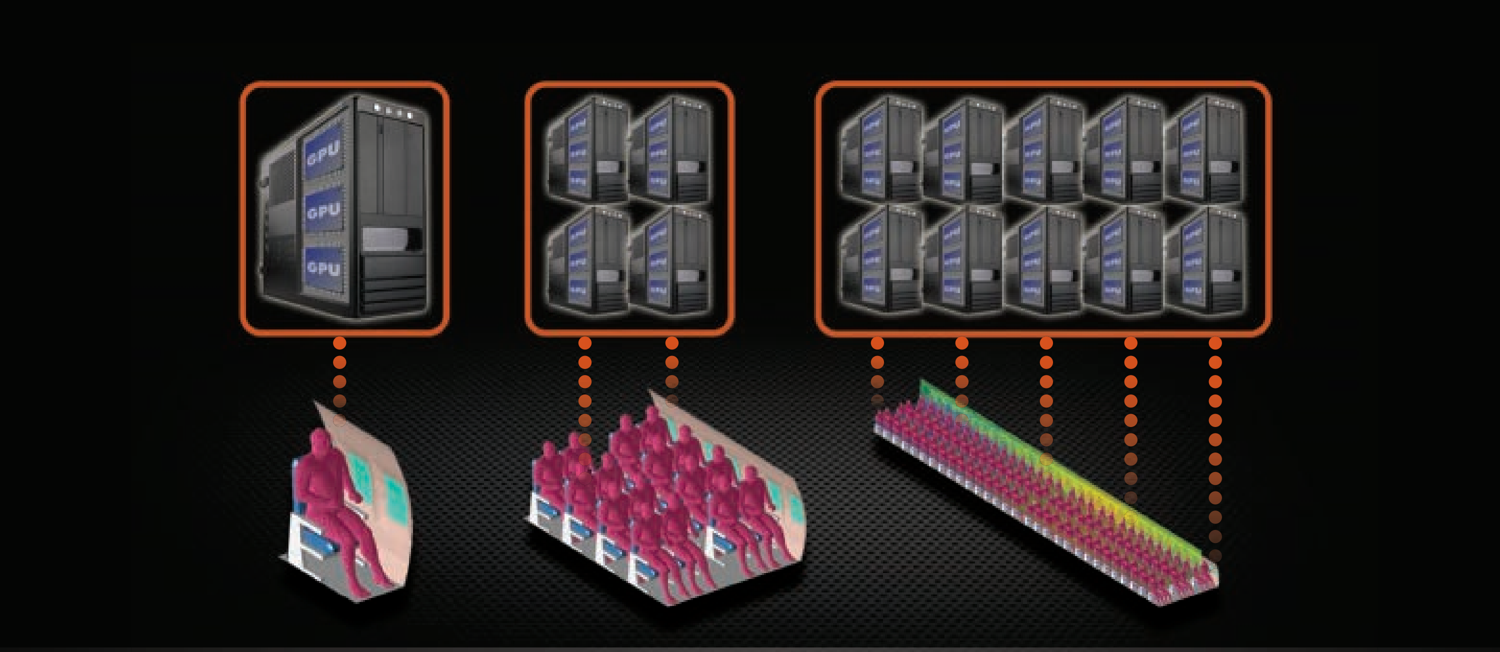
▲ *Fig. 1 Phase stability (a) and amplitude stability (b) vs. flexure.*

TEST CABLES

MIcable worked with one customer to develop a new DC to 26.5 GHz test cable assembly that uses a custom designed cable with 0.195" outer diameter, soft and flexible PVC jacket, solid PTFE dielectric and improved braid layer design. The strong and rugged connectors, special strain release design and improved assembly technique were used in the new cable assembly. This process of cable assembly design and manufacturing produced a new and successful assembly.

Figure 1 shows the 36" long cable has phase stability less than 4° and 6° with the cable wrapped 360° around a 1.95" radius mandrel at 18 and 26.5 GHz, respectively, with amplitude stability of 0.03 dB max. ***Table 1*** and ***Figure 2*** show that even after up to 20,000 bending cycles, the VSWR, insertion loss and phase/amplitude stability exhibits almost no change. ***Table 2*** shows good electrical performance with the same tests after 25 temperature cycles from -55° to +85°C. Customers have been pleased with this DC to 26.5 GHz test cable assembly after they evaluate and compare it to others.

MICABLE INC.
Fuzhou, Fujian, China



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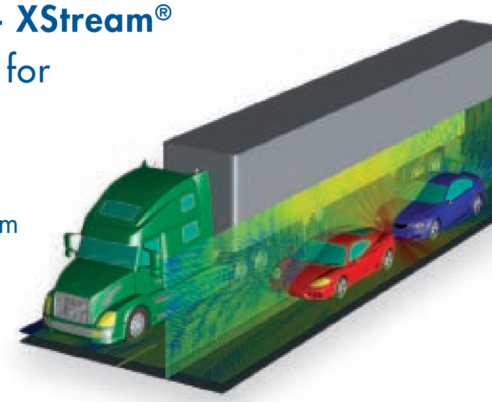

Vehicle-to-vehicle communication at 3.7 billion cells, 22 minutes to complete

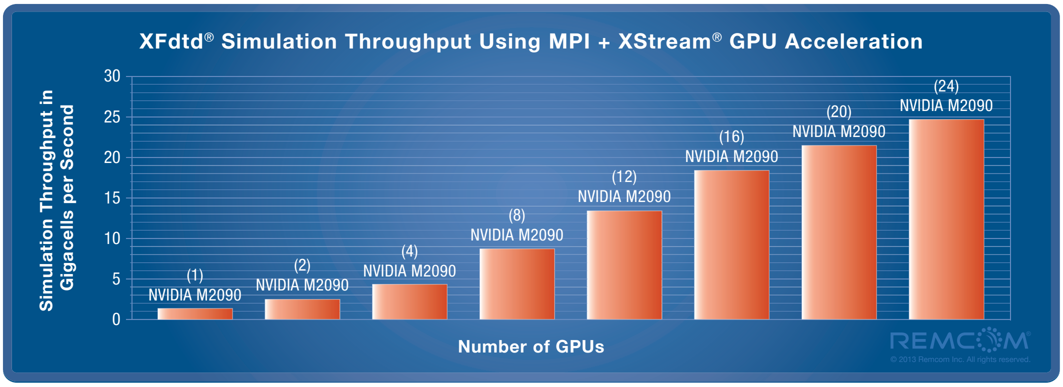

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TABLE I

Data for C04I-01-01-1M cable assembly during bending up to 24,000 times.

# of Bending Times	S_{11}/S_{22}	S_{12}/S_{21}	Insertion Loss Change*	Phase Change*
0	18.56/19.13	2.63/2.65	0.04	4.63°
1500	18.38/19.97	2.61/2.61	0.03	4.89°
3000	18.43/18.57	2.58/2.63	0.03	4.45°
4500	17.92/18.78	2.58/2.63	0.03	4.51°
6000	19.13/17.85	2.64/2.68	0.04	4.77°
7500	18.91/17.66	2.67/2.69	0.04	4.58°
9000	17.72/19.12	2.61/2.63	0.03	4.64°
10500	18.83/17.74	2.69/2.69	0.05	4.95°
12000	18.83/17.67	2.68/2.67	0.04	4.44°
13500	19.00/17.20	2.64/2.66	0.05	4.85°
15000	19.21/17.24	2.69/2.69	0.03	4.72°
16500	19.18/17.66	2.61/2.62	0.04	4.77°
18000	18.93/17.71	2.70/2.68	0.05	4.46°
19500	19.20/17.57	2.67/2.75	0.05	4.81°
21000	19.21/17.49	2.75/2.71	0.04	4.50°
22500	19.22/17.57	2.73/2.75	0.03	4.39°
24000	18.93/17.67	2.67/2.73	0.05	4.75°

* The above data is from a 36” long assembly with the cable wrapped 360° around a 1.95” radius mandrel.

TABLE II

PERFORMANCE OF C04I-01-01-1M AFTER TEMPERATURE CYCLES:
-55° TO +85°C , FREQUENCY RANGE, DC TO 26 GHz

	No. 1 Cable Assembly		No. 2 Cable Assembly	
Number of Cycles	Insertion Loss (dB)	Return Loss (dB)	Insertion Loss (dB)	Return Loss (dB)
0	2.67	18.9	2.78	19.6
25	3.11	18.5	3.18	19.6

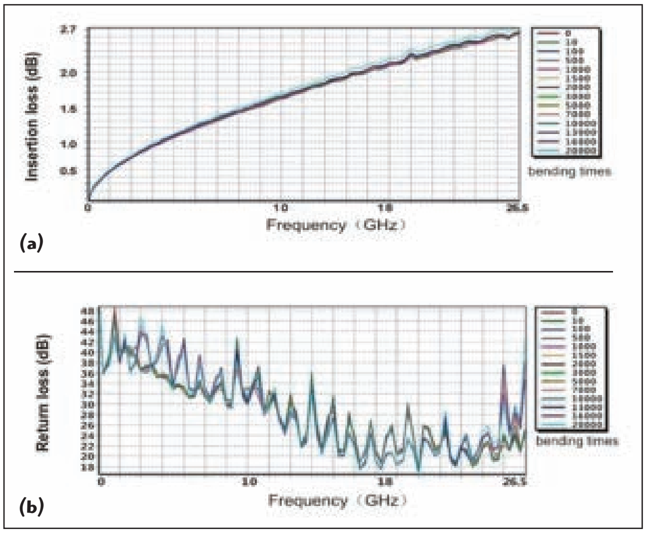


Fig. 2 Insertion loss change (a) and return loss change (b) over 20,000 flex cycles (C041 cable assembly, 1 m).

PHASED ARRAY CABLE

Phased array radar has become an important product around the world but has inherent problems for cable assembly manufacturers. Large numbers of assemblies are needed with close matching, making the specifications difficult to consistently manufacture. Airborne phased array system manufacturers state that their biggest problem is phase mismatching during rapid altitude change. Calibration will not correct the situation and cable assembly manufacturers have had many unsuccessful attempts to solve the problem. In addition, phase tracking over temperature is an equally important specification that the system engineers really should require. Many system engineers incorrectly emphasize the cable's phase stability over temperature instead of phase tracking. A tight phase tracking specification is the correct goal to achieve good phase matching over wide altitude and temperature variation. Making good phase tracking cable assemblies is a very big challenge, requiring strict consistency in materials and manufacturing techniques.

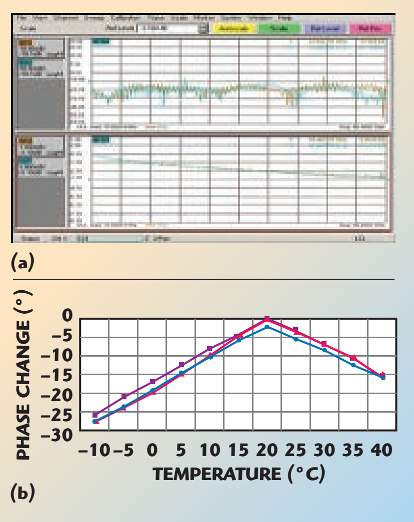


Fig. 3 B01-40-40-1M insertion loss (2.97 dB max) and VSWR (1.23:1) data from DC to 40 GHz (a) and phase tracking vs. temperature at 40 GHz (b).

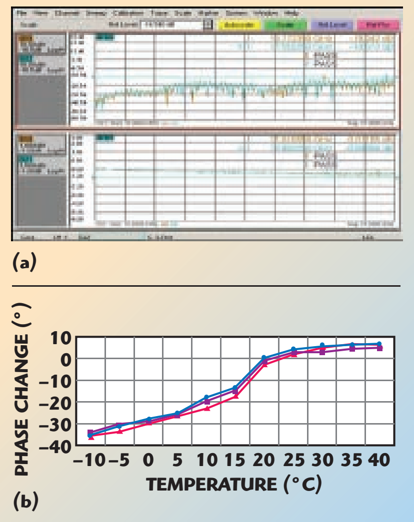
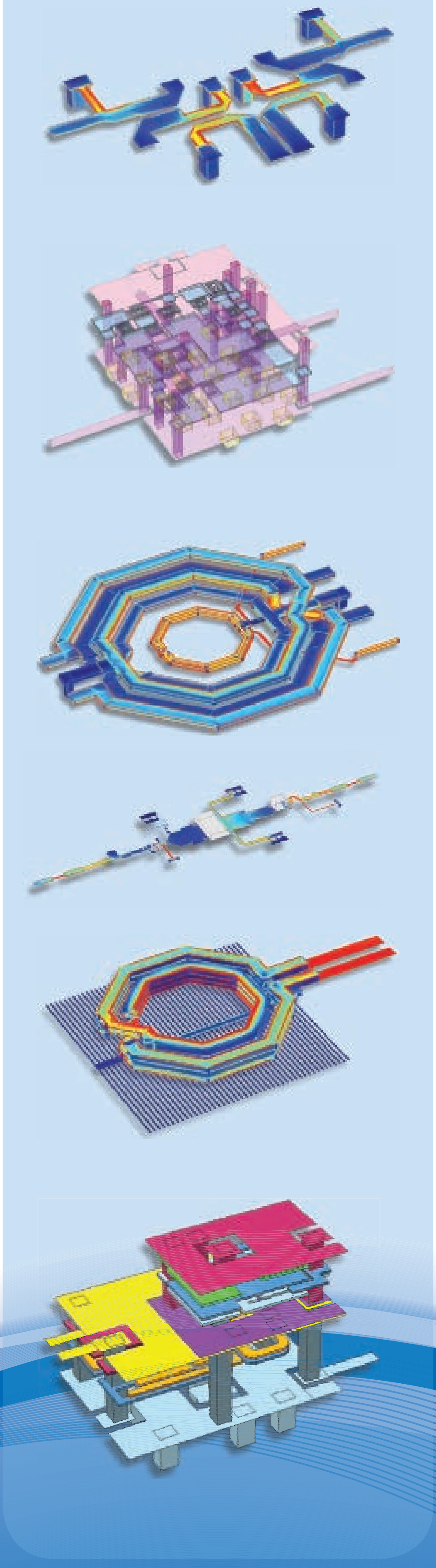


Fig. 4 A041-01-01-1M insertion loss (0.91 dB max) and VSWR (1.25:1) data from DC to 18 GHz (a) and phase tracking vs. temperature at 18 GHz (b).

MIcable has also designed cable assemblies for phased array radar application with a wide temperature range. MIcable has developed a set of comprehensive methods, including cable evaluation, connector design, manufacturing and assembling techniques, and inspection and testing procedures. The cable was chosen from a well known supplier, QPL approved, where previous experience had shown that they had high standards and good cooperation. Connectors were designed and tested in the company's facility and elsewhere for approval. To control quality and consistency, inspection after every process was emphasized and workers trained to



▲ *Fig. 5 Bent phase matching and tracking semi-rigid cable assemblies with phase match and phase tracking ≤1° at 2.3 GHz.*

IPC J-STD-001 and IPC/WHMA-A-620 standards. Rapid phase correcting techniques were developed; and computerized semi-rigid bending machines, fast and precise stripping equipment, and PNA vector network analyzers were utilized. Quality systems according to MIL-I-45208 and MIL-STD-2219 were used, along with ISO 9001 and China GJB-9001B-2009 standards.

Figures 3 and ***4*** show the test data for three phased array cable assemblies of each type. From the data, the temperature tracking performance of the cable assemblies was controlled within a very small range. The different cable assemblies have good consistency, proving the capability to offer good temperature tracking performance. As shown, B01-40-40-1M phase stability versus flexure is ±8° at 40 GHz, bend radius of 51 mm and phase stability versus temperature of 500 ppm from -40° to about +85°C. A041-01-01-1M phase stability versus flexure is ±5.4° at 18 GHz, bend radius of 76 mm and phase stability versus temperature of 250 ppm from +22° to about +100°C with power handling of 600 W at 10 GHz. From this performance, the company delivered 9 km of phased array flexible cable assemblies and a 1400 piece order for bent semi-rigid cable assemblies, with three bends, a minimum bending radius of 6 mm and matching and tracking within 1° over -40° to +70°C over all cable assemblies. The products were delivered within two weeks. The semi-rigid cable is shown in ***Figure 5***.

As the commercial and military markets come up with more strict challenges for higher performance and longer life for cable assemblies, a good combination of component design and assembly techniques are more important than ever before. The cable assembly designer/engineer must understand the customer's application and know how to transfer the application demand to the requirement of the cable assembly. The cable assembly manufacturer must then be able to source the proper components, assemble them with advanced techniques and equipment, and be alert for changes to meet the specifications and requirements of the project. Good communication between all parties is absolutely necessary – good teamwork is a must.

MIcable is a joint venture by US SSI Cable, a leading cable assembly company and Mitron, a leading distributor and agent for microwave products in China.

MIcable Inc.,
Fuzhou, Fujian, China,
sales@micable.cn,
www.micable.cn.

CETC 41

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AV3656A Vector Network Analyzer

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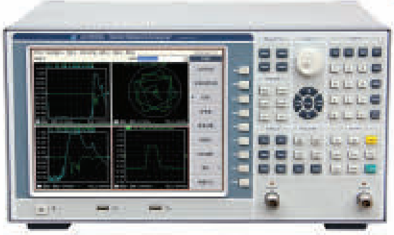
10.4 inch true color LED touch screen



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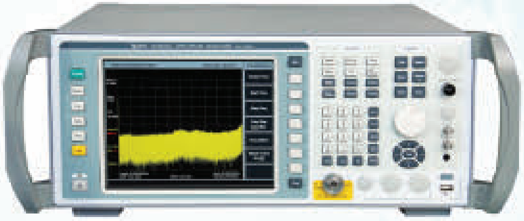
DANL: −152 dBm, typical
1 dB Compression Point: +3 dBm, typical
TOI: +16 dBm, typical
All digital IF design



Please visit www.ei41.com for more information

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WiGig Technology Antenna Evaluation

Wireless Gigabit applications that offer advanced high-speed data transmissions are gaining wide interest. The Wireless Gigabit Alliance (WiGig) is currently establishing specifications for the protocols needed to establish an industry uniform standard for data transmissions at rates of up to 7 Gigabits per second (Gbps). This rate is an order of magnitude faster than current communications standards.

The WiGig standard is based on the IEEE 802.11 protocol, and is backward compatible with previous generation capabilities. It can switch between any bands including the 2.4, 5, and the new broadband 60 GHz (7 GHz available bandwidth) spectrum. The switching is transparent and thus provides for seamless operation. The implementation will vary over a wide range of devices such as cell phones, laptop computers and other peripheral devices.

ORBIT/FR has developed a patent pending portable, low profile product (μ-Lab) that can be used to perform all the required testing on these wireless devices, ranging anywhere from a small on-chip antenna to a cell phone to a laptop computer. It comprises a small anechoic chamber measuring approximately 5 × 5 × 5 feet (152 × 152 × 152 cm). A rack area is underneath the chamber for the workstation computer and positioner controller. An adjacent rack is available for the VNA. The chamber and rack assembly below it will fit through standard double doors.

The chamber houses an azimuth positioner and elevation gantry arm, allowing spherical coverage of the AUT. The AUT is fixed and does not rotate. It is mounted on a column set on the center of the azimuth axis for connectorized antennas. For on-chip antennas, an offset mounted column is used to accommodate the micro-probe assembly. A manual or motorized polarization rotation capability for the near-field probe is supplied. The system can either support spherical near-field measurements using the appropriate near-field to far-field transformations, or directly measure the far-field characteristics for appropriate conditions.

Given the wide range of WiGig applications and devices, a cost-effective, small system such as μ-Lab is required to evaluate these devices rapidly with the ability to change out device types within an hour or two. The μ-Lab system meets these requirements for devices ranging from on-chip antennas to cell phones and small connectorized antennas to adaptive arrays. The antenna development will largely focus on the 60 GHz band, but will also encompass the 2.4 and 5 GHz bands as well. The baseline μ-Lab offering covers the 50 to 110 GHz bands (V- and W-Band), but the other bands can be added, if required. This system provides a unique capability for evaluating the new class of WiGig antennas. A sample of the data

MICROWAVE VISION GROUP,
ORBIT/FR INC.
Horsham, PA

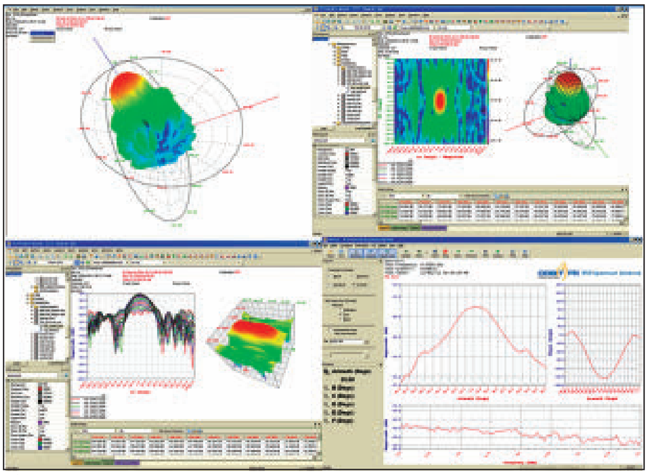

Fig. 1 *Sample μ-Lab data output.*

from the μ-Lab system is shown in ***Figure 1***, with 2-D and 3-D plotting and analysis capability.

A new millimeter wave test system for the collection of conventional far field and spherical near field EM data of chips and miniature antenna assemblies utilizing WiGig technology. The low profile μ-Lab can be used to perform all the required testing on these wireless devices, ranging anywhere from a small on-chip antenna to a cell phone to a laptop computer. While this system is targeted to support the test needs of the WiGig industry, the system also provides exceptional new capabilities that support antenna testing for existing and emerging technologies across the millimeter wave frequency range. ***Table 1*** shows a summary of the system measurement specifications.

TABLE I

SYSTEM MEASUREMENT SPECIFICATIONS

Parameter	*Specification*
Frequency Range	50-110 GHz (other bands available upon request)
Measurement Radius	15 inches (38.1 cm) nominal
Positioner Speeds	Up to 9 deg/sec typical
Typical Data Acquisition Speeds	10-120 minutes depending on the test scenario
Sidelobe Level Accuracy	±1 dB peak at -20 dB typical
Gain Accuracy	±-0.5 dB typical
System Dynamic Range	>60 dB, 50-110 GHz
System Dimensions	7'H × 5'W × 5'L (2.13 × 1.52 × 1.52 m) nominal
Maximum DUT Size	On center support column: as large as a standard laptop On offset column: 5 × 5 cm (chipset)

Microwave Vision Group,
ORBIT/FR Inc.,
Horsham, PA
(215) 674-5100,
www.orbitfr.com.

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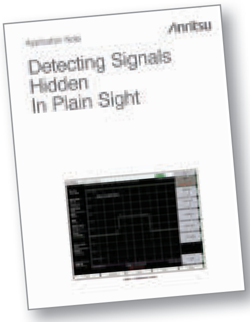

Application Note

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Anritsu

See us at EuMW Stand 107

37 to 40 GHz Power Amplifier with Power Detector

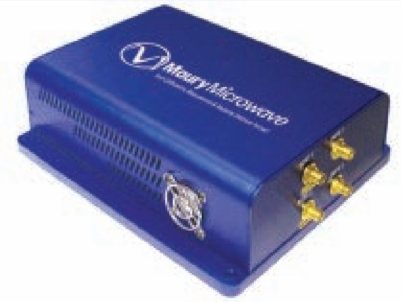
Hittite Microwave Corp. has developed a new power amplifier that is ideal for high linearity point-to-point and point-to-multipoint radios and VSAT and SATCOM applications. The HMC7229LS6 is a four-stage GaAs PHEMT MMIC power amplifier with an integrated temperature compensated on-chip power detector that operates between 37 and 40 GHz. Ideal for covering the 38 GHz licensed microwave radio band, the amplifier provides 24 dB of gain and +31.5 P1dBm of output power while drawing 1200 mA from a +6 V DC supply.

With an OIP3 of +40 dBm, the HMC7229LS6 is also ideal for linear applications such as high capacity point-to-point or multi-point radios or VSAT and SATCOM applications demanding +32 dBm of efficient saturated output power. The RF I/Os are internally matched and DC blocked for ease of integration into higher level assemblies. The HMC7229LS6 is housed in a ceramic 6 × 6 mm high frequency air cavity package that exhibits low thermal resistance and is compatible with surface mount manufacturing techniques.

The HMC7229LS6 complements Hittite's extensive line of power amplifiers that provide frequency coverage for all of the licensed microwave radio bands from 6 to 86 GHz. Samples are available from stock and can be ordered via the company's e-commerce site or via direct purchase order.

VENDORVIEW

Hittite Microwave Corp.,
Chelmsford, MA
sales@hittite.com
www.hittite.com.



Fast Solid-State Tuner

Maury Microwave's MACH2.7 solid state automated impedance tuner is the ideal solution for high speed VSWR testing. New calibration algorithms characterize the tuner at up to 250 frequencies in as little as 10 minutes, which means more time is spent measuring your device. Fast tuning delivers up to 1000 user-defined impedance states per second, between 1:1 and 15:1 VSWR, designed specifically for high speed pre-production and production testing.

Since the tuner is compact in size at 5.775" × 7.194" × 2.095" and weighs only 2.2 lbs, the MACH2.7 is small enough to integrate into most automated test setups. The MACH2.7 can be controlled via USB or Ethernet, using Maury's DLL or direct ASCII commands, and is easily implemented in any automated test software. Each unit comes with a MT1020F power supply, USB cable, Ethernet cable, Quick Start Guide, flash drive with Utility Software and operating manual (electronic).

Key features:

- High speed impedance tuning
- Fast wideband calibration
- High repeatability/high accuracy
- Small size/footprint
- Dual TCP/IP and USB serial interfaces for simple, fast and reliable control
- COM and DLL-Stle control library
- Ideal for ruggedness testing (VSWR testing)
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Maury Microwave,
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VIEW VIDEO

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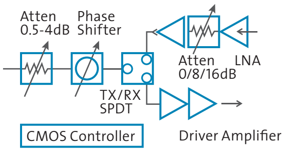
Core-Chip Functional Schematic



The surface-mount 7 x 7 mm plastic package is the industry's smallest and most cost-effective solution for space-constrained designs. The technology's versatility and flexibility make it ideal for weather, wildfire and related commercial radar applications.

Fully tested and ready to ship, the X-Band Core Chip is another industry first from MACOM's experienced engineering team.

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Tri- and Quad-Band Combiners for U.S./EU Markets

Pivotone has developed a new series of products: Tri- and quad-band combiners for multi-band, co-located sites. This series features a number of technical advantages: broadband, low insertion loss, high isolation, low PIM, DC and AISG Issue 2.0 which can pass through on any selected port. The compact structure makes them suitable for mounting on walls or poles in various situations. As well, they can either be packaged for indoor or outdoor applications.

The quad-band combiner for the European market includes bands of LTE 700, GSM 900, DCS and UMTS, while the bands for the North American market are: LTE 700, AMPS 850, PCS 1900 and AWS.

Pivotone uses self-developed wideband, filter design technology, proprietary multi-channel, common port integrated structural design and advanced manufacturing processes to produce a product that has good electrical performance and excellent reliability and stability. Pivotone can also customize multi-band combiners to suit individual customer requirements.

Pivotone,
Wuxi, Jiangsu, China,
www.pivotone.com,
sales@pivotone.com.

Dr. Guochun (GC) Liang,
President and CEO, Pivotone

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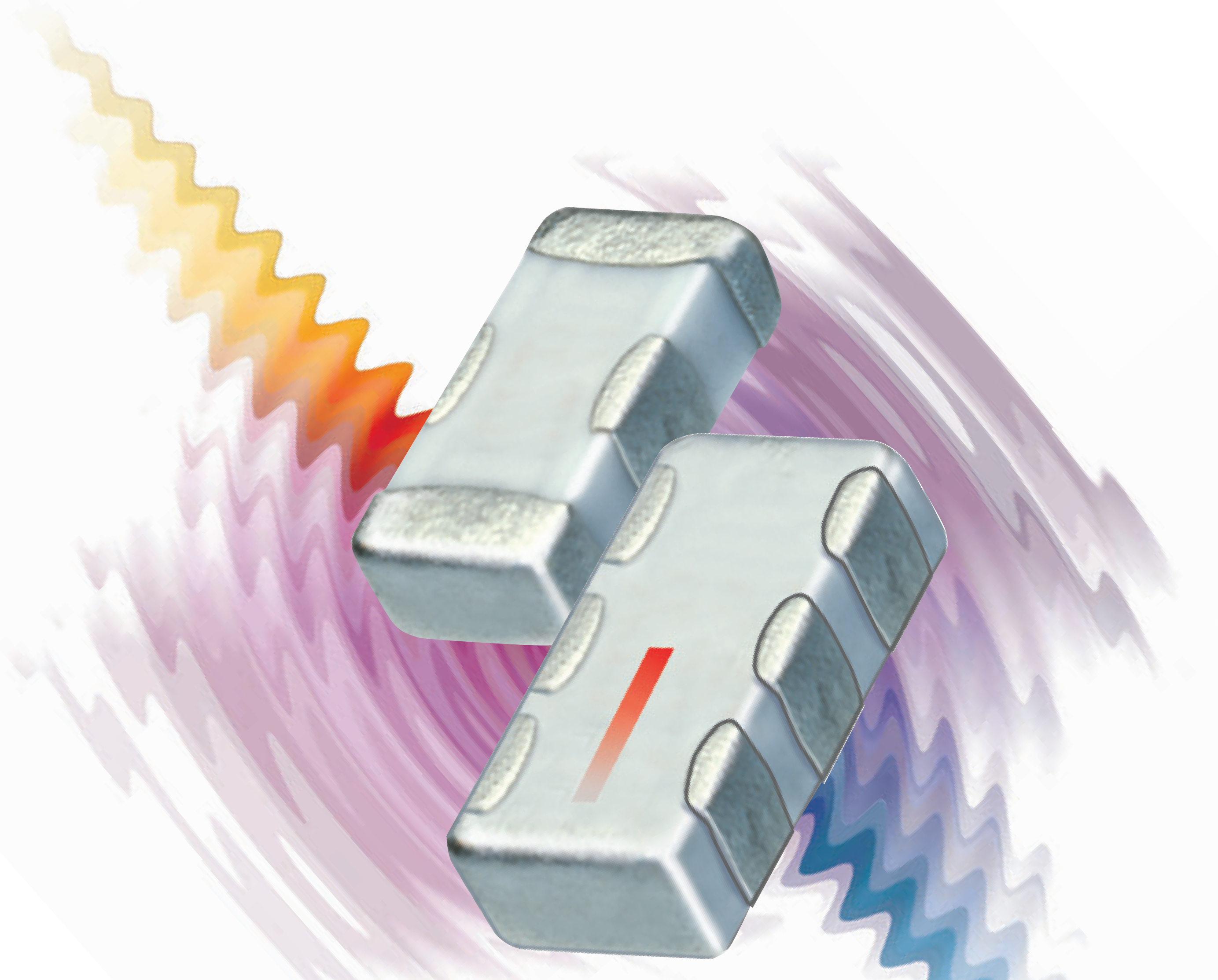

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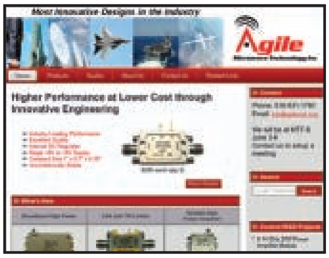
504 Rev C

Web Update

Mixer Line on Site



Agile Microwave Technology Inc. has added a new image reject mixer product line and new amplifier models to the company's website. It has added more than 25 new products with complete technical datasheets available by clicking on the part number.

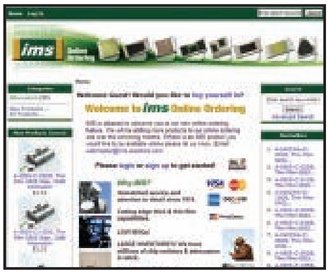
Agile Microwave Technology Inc.
www.agilemwt.com

New Website

Cuming Microwave announced that it has launched its new corporate website. This complex, 125-page site incorporates an online store along with a mobile responsive design to ensure cross-device compatibility for desktop computers, iPhones and tablets alike. It has been designed to create the most user-friendly experience possible with improved navigation, responsive design and valuable information for all visitors, including a wealth of technical data on all Cuming Microwave products, the latest news and employment opportunities.

Cuming Microwave Corp.
www.cumingmicrowave.com

Faster Online Ordering



International Manufacturing Services Inc. (IMS) has now made ordering its microelectronic components faster, simpler and easier with its new online ordering feature. Customers can currently order IMS' popular A Series thin film attenuators online, and shortly, all of IMS' line of high-quality products will be available through the website as well. IMS is a leading supplier of thick and thin film resistors, terminations, attenuators, planar dividers, planar filters and thermal management devices.

International Manufacturing Services
www.ims-resistors.com

Updated Site

VENDORVIEW

AR RF/Microwave Instrumentation made numerous changes to enhance both its corporate and RF/Microwave Instrumentation website by giving it a more modern look and feel, while offering easier navigation and more comprehensive information. The menu system and flash spotlights have been redesigned to work with various touch screen tablets and mobile devices and enhanced streamlining of code makes the site's menus much more search engine friendly and easier to read.

AR RF/Microwave Instrumentation
www.arworld.us

New Website

Dielectric Laboratories Inc. is pleased to announce the launch of its new website. The new website offers a modern look that will improve access to expanded technical content, capabilities and new products. You will find a show case of products from high Q multilayer and single layer capacitors, build to print thin film, cavity resonators, gain equalizers and RF and microwave filters.

Dielectric Laboratories Inc.
www.dilabs.com

Automatic Assembly Equipment

IKE Micro's new website includes hyperlinks to the company's cutting edge automatic assembly equipment and descriptions of all equipment capabilities for automated surface mount, die attach and wire bonding. The website also includes videos of various automatic assembly processes in action. IKE Micro offers build to print manufacturing, both turnkey and consignment, to the RF/microwave and microelectronics industries.

IKE Micro
www.ikemicro.com

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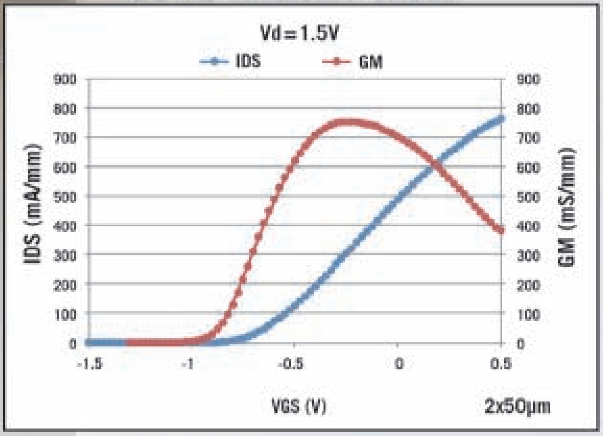
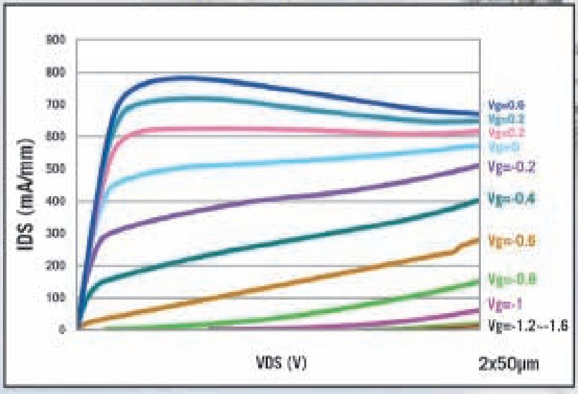
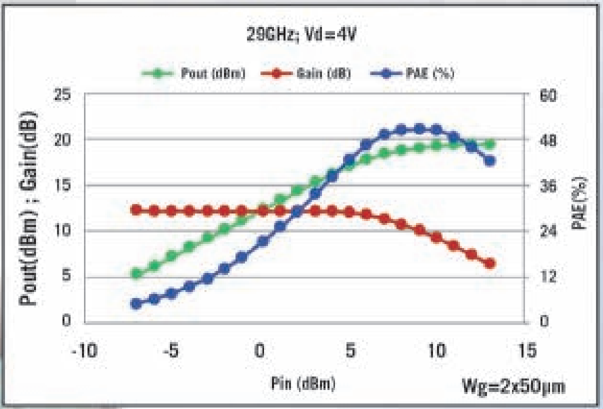
PP10 Transfer Curve



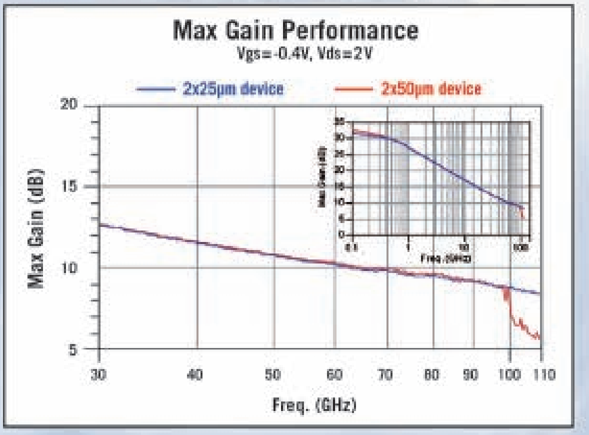
PP10 I-V Curves



PP10 Load Pull Data



PP10 Max Gain



WIN SEMICONDUCTORS CORP. Tel:+886-3-397-5999 Fax:+886-3-397-5069 http://www.winfoundry.com

See us at EuMW Stand 163

Web Update

PCB Stack Up Tool

IsoStack®, which allows PCB fabricators and OEMs to design stack-ups for printed circuit boards using Isola materials, is now available online. Designers will find an up-to-date database of globally available constructions and electrical data on leading high-speed digital Isola materials. This free tool features calculators for targeting desired impedance and is designed to reduce transition errors in the board design process. IsoStack can help design engineers share their requirements with Isola and relay information to fabricators efficiently.

Isola

www.isola-group.com

Transmission Line Components Site

Micro-Coax invites you to visit its new website to review its product offerings and take advantage of its quick-turn capability with deliveries in about one week. The company's complete line of quality transmission line components includes ARACON®, a brand metal clad fiber, lightweight EMI shielding material; UTiFLEX® Flexible Cable Assemblies, Ultralight UTiFLEX flexible cable assemblies; M-Flex® flexible microwave cable for signal transmission, Semi-Rigid Coaxial Cable, Semi-Rigid Cable Assemblies and Delay Lines; and UTiFORM®, an alternative to semi-rigid or flexible microwave cable.

Micro-Coax

www.micro-coax.com

VCO Builder

VENDORVIEW

RFMW Ltd. announces a web based tool that allows designers to create semi-custom voltage controlled oscillators (VCO) and phase locked loop (PLL) synthesizers. Designers can search a large database of existing products based on parametric requirements and jump directly to existing product information. Should the database not include an exact match, users can define their requirement for an RFMD factory review and feedback. Often, requirements are a simple derivative of existing products.

RFMW Ltd.

www.rfmw.com

Wireless Network Support

Kaelus, a Smiths Microwave business, designs and manufactures a wide range of innovative RF and microwave solutions for the wireless telecommunications sector. The Kaelus website offers information regarding site conditioning products, in-building DAS solutions and professional site service, PIM certification training and industry leading passive intermodulation (PIM) test equipment in English and Chinese as well as many other products and technical resources that support wireless network optimization.

Kaelus

www.kaelus.com

Brochure on Website

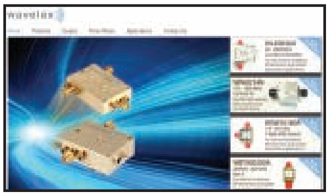
VENDORVIEW

The Narda Microwave-East website includes a downloadable copy of the new brochure describing its expanded waveguide product line. The line features 130 new models in the company's distinct categories: waveguide-to-coaxial adapters (right angle and end launch), gain horns and low and medium power terminations. Cross guide directional coupler models are available from stock and cover frequencies from 1.7 to 40 GHz.

Narda Microwave East

www.nardamicrowave.com/east

New Website



Richardson RFPD and Wavelex announced the launch of the Wavelex website. The new site offers the full portfolio of the company's RF, IF and microwave signal processing components for the RF and microwave industry, including amplifiers, attenuators, bias-Ts, couplers, DC blocks, SMA connectors and cables, splitters and combiners, switches, terminators and loads. Each product listing on the site includes key specifications and a link to the corresponding datasheet. Product category tables can be sorted by any of the key technical specifications.

Wavelex Inc.

www.wavelex.com

EuMW 2013 Exhibitor List

The following list is complete as of August 14, 2013. Exhibitors in red have an ad in this issue.

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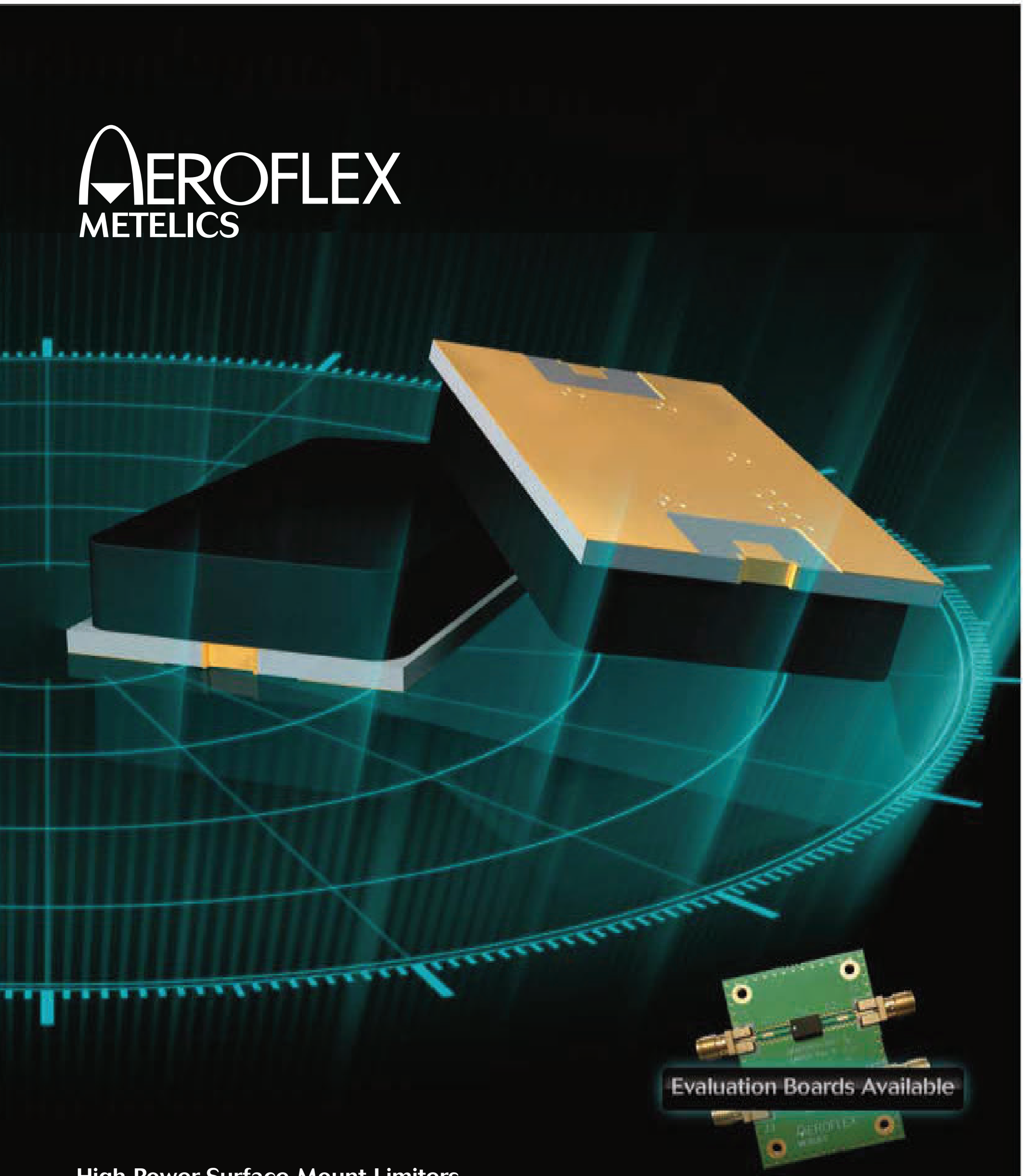
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An Introduction to Continuous Mode RF Power Amplifier Design
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Live webcast: 9/10/13, 11:00 AM ET

Filtering Solutions Improve Dynamic Range of IMD
Sponsored by: K&L Microwave
Live webcast: 9/12/13, 11:00 AM ET

INSIGHT – Analysis and Diagnostic Software for Antenna Measurement Post Processing
Sponsored by: MVG/Satimo
Live webcast: 9/18/13, 11:00 AM ET

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High Speed and High Power Connector Design
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Live webcast: 9/26/13, 11:00 AM ET

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- Mixers and Frequency Conversion

Technical Education Training Series

- RF PCB Design: Part 2
- Fundamental Tradeoffs for Space, Air and UAV SAR
- Maximize the Performance of Your RF Signal Analyzer
- LTE Performance Testing – Using a MIMO Over-the-Air Solution for Efficient Device Verification

CST Webinar Series

- CST STUDIO SUITE 2013 - MW&RF Simulation
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- Validating Performance of Satellite Navigation Systems and Receivers
- MIMO Over the Air (OTA) Handset Performance and Testing
- Your LTE Devices Need to Pass Conformance Tests – Now What?
- 8x8 MIMO and Carrier Aggregation Test Challenges for LTE

RF and Microwave Education Series

Presented by: Agilent Technologies
- Analyze Agile or Elusive Signals Using Real-Time Measurement and Triggering
- Signal Analyzer Fundamentals and New Applications

FieldFox Handheld Analyzers Series

Presented by: Agilent Technologies
- Correlating Microwave Measurements Between Handheld and Benchtop Analyzers

See us at EuMW Stand 278

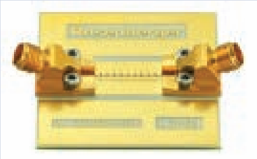
Microwave Journal
Frequency Matters.

EuMW Product Showcase Aisle 100

The following booth numbers are complete as of August 14, 2013.

Rosenberger Hochfrequenztechnik GmbH & Co. KG Booth 101A

PCB Connectors

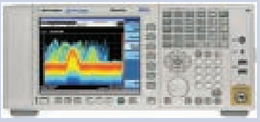


Rosenberger has developed multiple-use, solderless surface-mount PCB connectors for RF test and measurement applications, available in the RPC-2.92 (up to 40 GHz), RPC-1.85 (up to 70 GHz) and RPC-1.00 (up to 110 GHz) connector series and characterized by excellent RF properties. Pre-positioning of these connectors is determined by alignment pins, and even central positioning on the PCB is possible due to the 30° design. The mounting process is solderless and a wide range of board thicknesses can be utilized thanks to the clamping mechanism.

www.rosenberger.com

Agilent Technologies Booth 105

Signal Analyzer



The Agilent MXA signal analyzer now offers enhanced phase noise performance (standard) and options for 160 MHz analysis bandwidth and real-time spectrum analysis (RTSA). Phase noise is up to 10 dB better for close-in and pedestal regions, enabling precise characterization of oscillators and synthesizers. The analysis-bandwidth and real-time options address the challenges of measuring interference in next-generation wireless networks. Specifically, RTSA is a powerful tool for capturing and analyzing highly elusive signals. The options can be added as upgrades.

VENDORVIEW

www.agilent.com

Anritsu Booth 107

Vector Network Analyzer

The accuracy, precision, reliability and scalability of Anritsu's VectorStar vector network analyzer family lets you accurately measure over frequency ranges of 70 kHz to 20 GHz, 40 GHz, 50 GHz, 70 GHz, 110 GHz and a variety of bands to 750 GHz. Whether your application is signal integrity, on-wafer characterization, or design of active or passive components for radar or communications systems, VectorStar allows you to work with confidence on the cutting edge.

Spectrum Analyzer

Covering 9 kHz to 43 GHz with an optional full-band tracking generator, the MS2720T is the premiere handheld spectrum analyzer for civil and peacekeeping needs worldwide. It is excellent for 3G and 4G signal measurements and interference hunting. Delivering virtually desktop performance in a rugged, battery powered, handheld package it is the spectrum analyzer of choice for security and monitoring agencies. It is ideal for AM and FM broadcast measurements both for analog and HD radio proofing.

VENDORVIEW

www.anritsu.com

Teledyne Coax Switches Booth 101B

Switches

Teledyne Coax Switches has products for test and measurement, medical, industrial, defense (military) and space (HI-REL) applications. Teledyne products range from SPDT, transfer and multi-throw coaxial switches as high as SP10T. The switches are available to cover most of the RF spectrum from DC to 40 GHz and are available with SMA, mini-SMB, TNC, N or 7/16 connectors. In addition, Teledyne offers low passive intermodulation switches to achieve IP3 levels up to -165 dBc (select models) to switch microwave signals.

www.teledyne-europe.com

Teledyne Microwave Solutions Booth 101B

Ka-Band HPA

Teledyne Microwave Solutions introduced its 502 W peak Ka-Band HPA. It features high linear power, 502 W peak power and a robust design. It has the option of an integral L-Band BUC and is built around TMS's MEC-5530 traveling wave tube.

www.teledynemicrowave.com

Rohde & Schwarz Booth 106

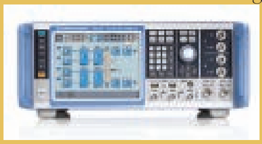
Realtime Signal Analysis

A new option for the R&S FSW high-end signal and spectrum analyzer supports realtime signal analysis for frequencies up to 50 GHz with an analysis bandwidth of 160 MHz. This makes it possible to detect even short and sporadic events as well as interfering signals to the exact level and without gaps. It is the ideal measuring instrument for the development, verification and production of components and equipment used in radar applications, satellite, military and civil communications systems.

Vector Network Analyzers

Rohde & Schwarz presents two new midrange vector network analyzers: the R&S ZNB20 for frequency ranges from 100 kHz to 20 GHz and the R&S ZNB40 from 10 MHz to 40 GHz. These powerful analyzers are equipped with two test ports and offer outstanding measurement characteristics on a similar level as high-end instruments. A dynamic range of up to 135 dB makes them perfect for tasks such as performing measurements on high-blocking DUTs like filters. They feature compact hardware and advanced 16:9 format touchscreen.

Signal Generator



The R&S SMW200A high-end vector signal generator combines a baseband generator, RF generator and MIMO fading simulator in a single instrument. The device covers the frequency range from 100 kHz to 3 GHz or 6 GHz and features an I/Q modulation bandwidth of 160 MHz with internal baseband. Exceptional modulation and RF characteristics make it ideal for developing high-end components, modules and complete products for wideband communications systems such as LTE-Advanced and WLAN IEEE 802.11ac.

VENDORVIEW

www.rohde-schwarz.com

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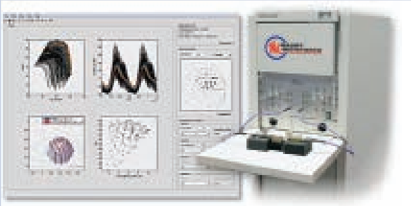
EuMW Product Showcase Aisles 100-200

Maury Microwave Booth 113A

Measurement and Modeling Solutions



Maury Microwave will be demonstrating state-of-the-art measurement and modeling solutions including: a patent-pending noise parameter system, a pulsed IV/S-Parameter and compact modeling system, a hybrid-active harmonic loadpull solution based on the PNA-X, and a patented mixed-signal active loadpull system capable of up to 1000 impedance/power measurements per minute and 120 MHz of instantaneous impedance control. Maury's component division will showcase its new Stability line of amplitude- and phase-stable cable assemblies as well as calibration kits, metrology and instrument-grade adapters and test essentials.

www.maurymw.com

HUBER+SUHNER AG Booth 116A

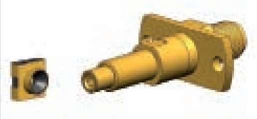
Connector Series

HUBER+SUHNER expands the QMA connector series with an ultra-compact solution for RF outdoor connections (miniBTS, outdoor WiFi, etc.). XQMA (QMA eXtreme) is the advanced version of the waterproof QMA, combining the quick lock mechanism and waterproof properties for harsh environmental conditions. The RF signal path and the coupling mechanism are both completely waterproof (IP68), thus protecting the connector against corrosion in a salty atmosphere and against freezing in case of high humidity and low temperature.

www.hubersuhner.com

INGUN Prüfmittelbau GmbH Booth 116A

Test Equipment

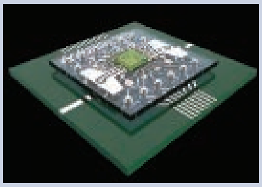


INGUN develops, manufactures and sells test probes and test fixtures and is regarded as one of the top addresses for test equipment in the electronic production industry. A new development by INGUN with a flange and advanced spring-loaded outer plunger is available for contacting switch connectors on routine tests. The inner conductor remains within the outer plunger during the complete testing phase and is therefore protected against side loading. Movements of the connection and the wire during work stroke are also avoided.

www.ingun.com

AWR Corp. Booth 126

Software Enhancements



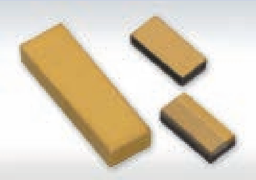
Stop by booth 126 to preview AWR V11. In addition to MMIC specific features and enhancements in AWR's flagship Microwave Office® software, its Analyst™ 3D FEM EM software will showcase a new user-defined, user-configurable Pcell interface. Visual System Simulator™ (VSS) software and AXIEM® 3D planar EM software will also be on display, as well as joint design and test solutions with parent company National Instruments.

VENDORVIEW

www.awrcorp.com

RFMW Ltd. Booth 156

Diamond Heat Spreaders



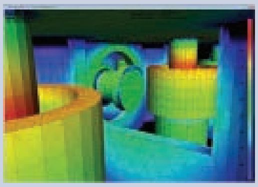
RFMW announces sales support for EMC Technology CVD Diamond Heat Spreaders. Designed to meet demanding requirements for higher power and longer life spans in semiconductor devices, CVD Diamond heat spreaders keep junction temperatures low and stable. EMC heat spreaders are available with a standard thermal conductivity of up to 1,400 W/mK, Ti/PtAu finishes and the option of custom designs optimized to meet specific application requirements. Common applications include GaN/GaAs Actives, Laser diodes and high brightness LEDs.

VENDORVIEW

www.rfmw.com

Mician GmbH Booth 164

Simulation Tool

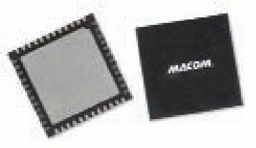


Mician µWave Wizard™ combines different solvers for increased simulation efficiency, overcoming limitations and shortcomings of single solvers. The modal port concept of µWave Wizard facilitates dissecting complex structures into more fundamental substructures. The program assigns each sub-structure to the most suited of the built-in solvers (MM, 2D-FEM or 3D-FEM), allowing it to operate within its comfort zone with little need for user interference. Results from individual solvers are afterwards cascaded multimodal to generate S-parameters of the composite structure for analysis and optimization.

www.mician.com

MACOM Booth 169

GaN Modules



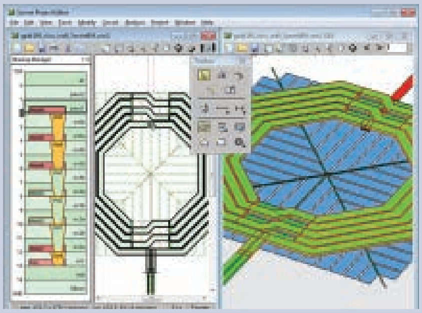
MACOM will announce three innovative offerings at EuMW 2013. Extending its leadership in GaN, MACOM will be introducing industry leading GaN modules that provide size, weight and power advantages. Building on decades of history in the radar market, MACOM will announce an industry-first X-Band Core Chip – a versatile and integrated solution for weather and commercial radar applications. Also on showcase will be MACOM's E-Band, high power amplifiers that cover the entire 71 to 86 GHz frequency band.

VENDORVIEW

www.macomtech.com

Sonnet Software Booth 198

Electromagnetic Analysis Software



Sonnet Software provides high-frequency electromagnetic analysis software. Sonnet's electromagnetic (EM) simulation software extracts models for planar circuits and antennas, including spiral inductors, filters, microstrip, stripline, co-planar waveguide and both PCB and integrated circuits incorporating large numbers layers of stratified dielectric material. Sonnet EM simulation operates completely from within the Cadence Virtuoso, AWR Microwave Office, and Agilent ADS environments. Sonnet will premiere Sonnet Suites Release 14, featuring technology layers for design flow integration, faster simulations, EDA framework interface enhancements and more.

www.sonnetsoftware.com

W. L. Gore & Associates Booth 208

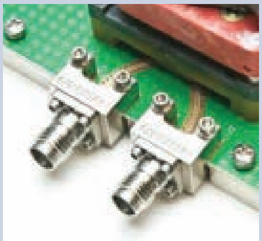
Microwave/RF Assemblies

Gore® Microwave/RF assemblies ensure precise, repeatable measurements for the life of your test equipment. The long-lasting, reliable performance of these durable assemblies delivers low loss, reduces total cost of test and improves system reliability. With excellent phase and amplitude stability with flexure, wide operating temperature range and crush and torque resistance, Gore assemblies decrease to-

tal operating costs by reducing cable replacement, retesting and recalibration.
www.gore.com

Southwest Microwave Booth 213

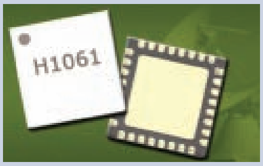
Test Equipment



Southwest Microwave is the leader in high-performance microwave products for microwave and millimeter-wave applications. In addition to standard testing, Southwest Microwave offers special HI-REL testing to meet critical SCD and DPA requirements. Stringent controls assure that all parameters are met. Test department equipment includes multiple VNA/PNA to 67 GHz plus offsite capability to 110 GHz.
www.southwestmicrowave.com

Hittite Microwave Corp. Booth 216

Track-and-Hold Amplifier

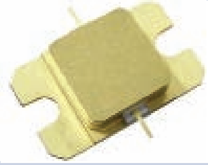


The HMC1061LC5 is a SiGe monolithic, fully differential, dual rank, track-and-hold (T/H) that provides unprecedented bandwidth and dynamic-range performance to wideband sampled signal systems. The T/H offers precision signal sampling over 18 GHz bandwidth, with 9- to 10-bit linearity from DC to beyond 5 GHz input frequency, 1.5 mV noise, and < 70 fs random aperture jitter. The device can be clocked to 4 GS/s with minimal dynamic range loss.

VENDORVIEW
www.hittite.com

Sumitomo Booth 220

SATCOM GaN Products



Sumitomo Electric introduces new devices to its line of high power GaN products for Ku-Band SATCOM applications. The Ku-Band products are available in 25 or 50 W GaN IMFETs. These devices operate in frequencies from 13.75 to 14.5 GHz and are optimized for high output power, gain and PAE in a 50 Ω system. The devices are available now.
www.sei-device.com

Phase Matrix Booth 263

Synthesizer

Phase Matrix's new Quicksyn® Lite synthesizer performs with wide coverage (0.65 to 10 GHz), fine resolution (0.001 Hz resolution), fast frequency switching (100 µs), and exhibits instrument-grade spectral purity. This new synthesizer includes SPI and USB control interfaces, and like all QuickSyn synthesizers, this new model is immediately deployable by connecting it to a PC and power source. Stop by the Semic RF booth (#263) to learn more about the QuickSyn Lite.
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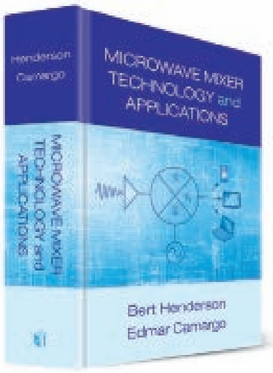

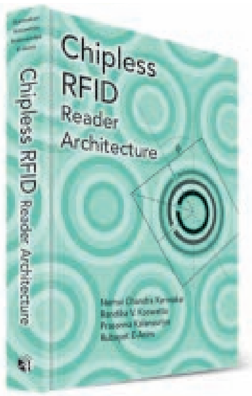

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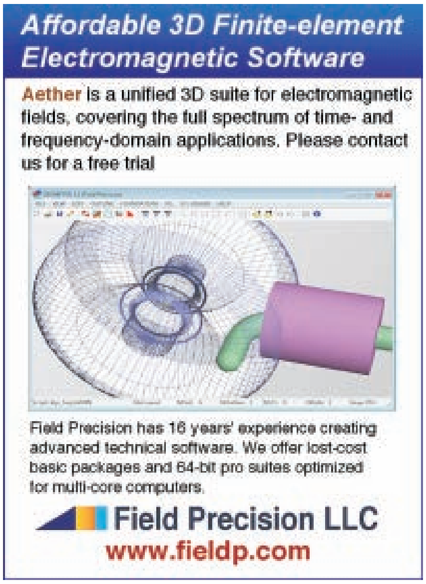

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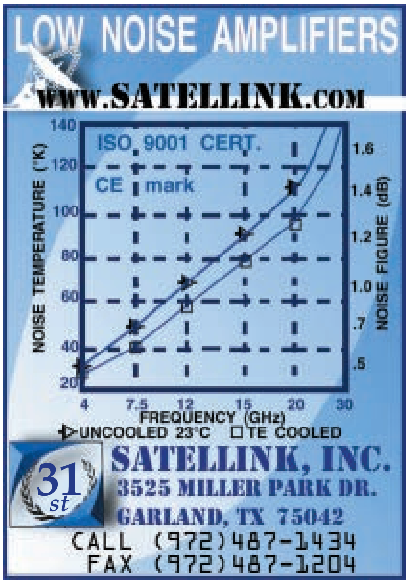

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PAPER SUBMISSION: Authors are invited to submit technical papers describing original work on radio-frequency, microwave, millimeter-wave, and terahertz (THz) theory and techniques. The deadline for submission is 9 December 2013. Paper submissions should be three pages in length (PDF format), and should not exceed one megabyte in file size. Hardcopy and email submissions will not be accepted. Please refer to the IMS2014 website (www.ims2014.mtt.org) for detailed instructions concerning paper submission. Authors must adhere to the format provided in the conference paper template available on the symposium's website. It is the authors' responsibility to obtain all required company and government clearances prior to submission. Please don't wait until the last day to start using the paper submission process. Those unfamiliar with the process may encounter paper formatting or clearance issues that may take time to resolve.

A double blind review process will be used. Papers will be evaluated on the basis of originality, content, clarity, and relevance to the symposium. For accepted papers, the electronic submission of a final manuscript along with a copyright assignment to the IEEE will be required no later than 3 March 2014. Symposium proceedings will be recorded on electronic media and archived in IEEE-Xplore. Authors of accepted papers should consider submitting an extended version of their symposium paper for possible publication in the IEEE Transactions on Microwave Theory and Techniques.

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IMS2014 enthusiastically invites submission of papers that report state-of-the-art progress in technical areas that are outside the scope of those specifically listed in this Call for Papers, or that may be new to the symposium, but are of interest to our attendees.

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Eligible students are encouraged to submit papers for the student paper competition. The papers will be evaluated using the same standards as all contributed papers. In addition, eligible students or student teams are invited to consider taking part in student design competitions during the IMS2014, which are organized and sponsored by various Technical Committees (TC) of the MTT-S Technical Coordination Committee (TCC). Please visit the IMS2014 website for full details.

MICROAPPS:

The Microwave Application Seminars serve as a forum for exhibitors at the IMS to present the technology behind their commercial products and their special capabilities. The presentations are open to all conference and exhibit attendees.

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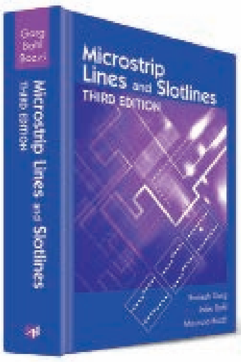

Microstrip Lines and Slotlines, Third Edition

Ramesh Garg, Inder Bahl and Maurizio Bozzi

Since the second edition of this book was published in 1996, planar transmission line technology has progressed considerably due to developments in ultrawideband (UWB) communications, imaging and RFID applications. In addition, the demands for compactness of wireless electronic devices while meeting improved performance requirements necessitates increased use of computer-aided design, simulation and analysis by microwave engineers. This book has been expanded and updated from the previous edition to help engineers successfully meet these challenges. Two new chapters were added – one on substrate integrated waveguide and the other on defected ground structures. The other chapters have been revised to include recent developments in those areas.

The book includes the development of governing equations, basis functions, Green's function and typical results. Special attention is given to the use of simulation software in the design of complex devices and understanding the connection between data collected from simulation software and the actual design process.

The book is primarily intended for microwave design engineers and R&D specialists who need to employ planar transmission lines in designing distributed circuits and antenna systems for a wide range of wireless applications. Advanced undergraduate and graduate students in electronics and telecommunication engineering will also welcome this addition to their library for reference. *Microstrip Lines and Slotlines* is a comprehensive text and written by experts in the field so it is recommended for those involved in this area.

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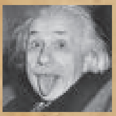
Mr. Smith's Deutschland Trivia

This common autobahn road sign means:

a. Rest area ahead
b. Caution
c. Exit
d. Passing allowed
e. No speed limit

Who was the German physicist who proved the existence of electromagnetic waves?



a. Hans Geiger
b. Heinrich Hertz
c. Albert Einstein
d. Hermann von Helmholtz
e. James Clerk Maxwell

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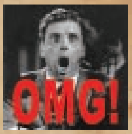
Who was the German monarch from the Second Reich?

a. Otto von Bismarck
b. Wenceslaus
c. Maximilian I
d. Wilhelm II

Which phrase would not be appropriate to say at dinner?

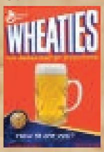


a. Mahlzeit
b. Guten Appetit
c. Ins Gras beißen
d. Prost

Which is not a German Federal State?

a. Saxony
b. North Rhine-Westphalia
c. Voldemort
d. Baden-Wüerttemberg

What is not part of a Bavarian breakfast?



a. Pretzel
b. Weisswurst
c. Scrambled eggs
d. Beer

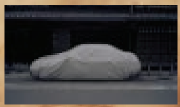
What is often associated with Oktoberfest?

a. Einen kater haben
b. Riesnbrezn
c. Wiesn Hendl
d. Hoiwe
e. all of the above

Name the German composer who only wrote one opera, Fidelio.

a. Mozart
b. Beethoven
c. Handel
d. Wagner
e. Strauss

What is "the people's car?"



a. Audi
b. BMW
c. Volkswagen
d. Mercedes Benz
e. Opel

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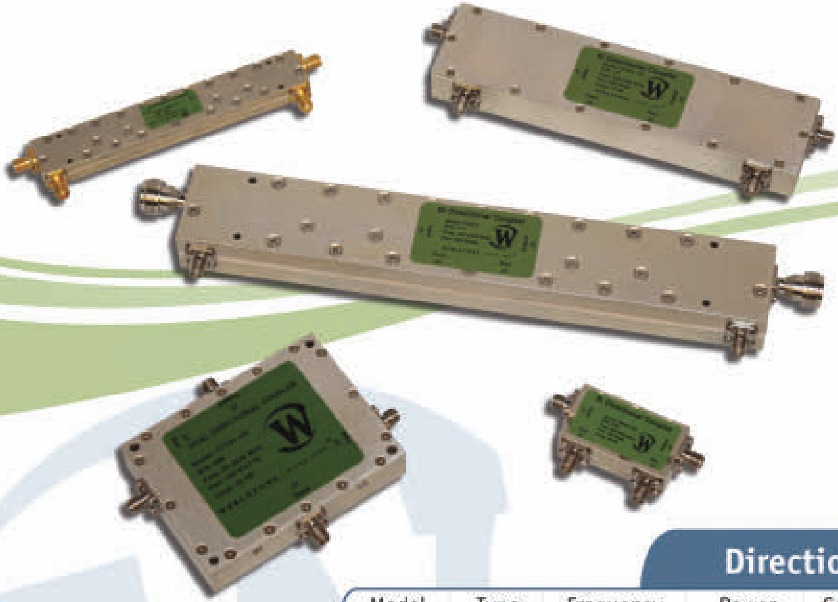

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C8188	Uni	30-3000	20	20	2.4	1.35:1	6 x 1.5 x 1.1
C3910	Dual	80-1000	200	40	0.2	1.20:1	3 x 3 x 1.09
C8373	Bi	100-2500	200	20	0.8	1.25:1	9.58 x 1.48 x 0.88
C7711	Dual	100-3000	100	40	0.35	1.25:1	3 x 2.2 x 0.7
C7058	Bi	200-2000	200	10	0.3	1.25:1	6.4 x 1.6 x 0.72
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