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December 2007

Microwave Journal

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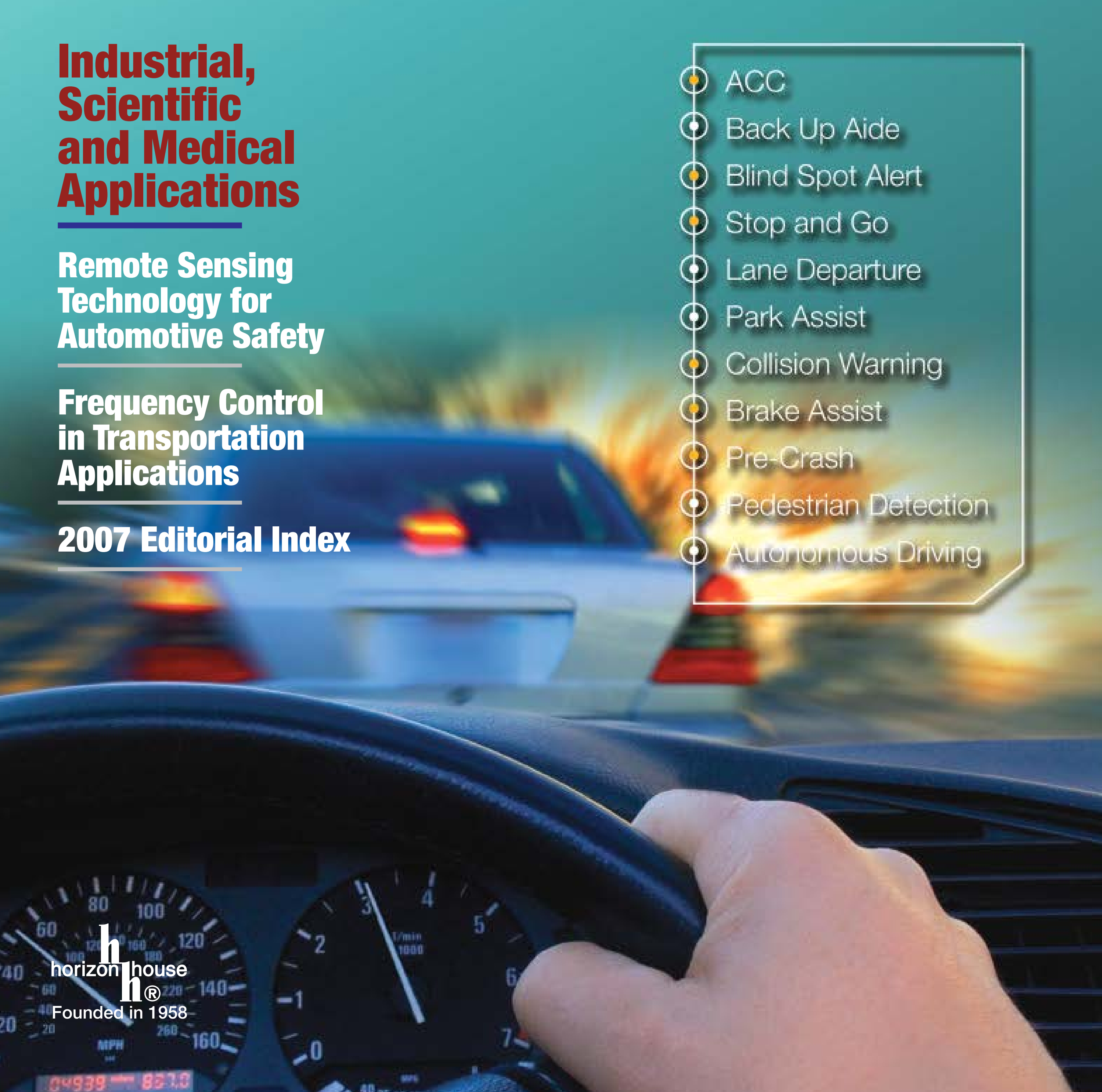
Industrial, Scientific and Medical Applications

Remote Sensing Technology for Automotive Safety

Frequency Control in Transportation Applications

2007 Editorial Index



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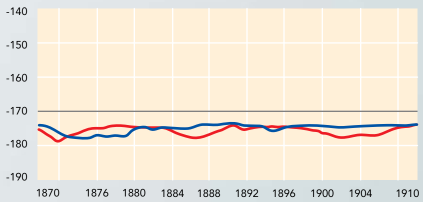

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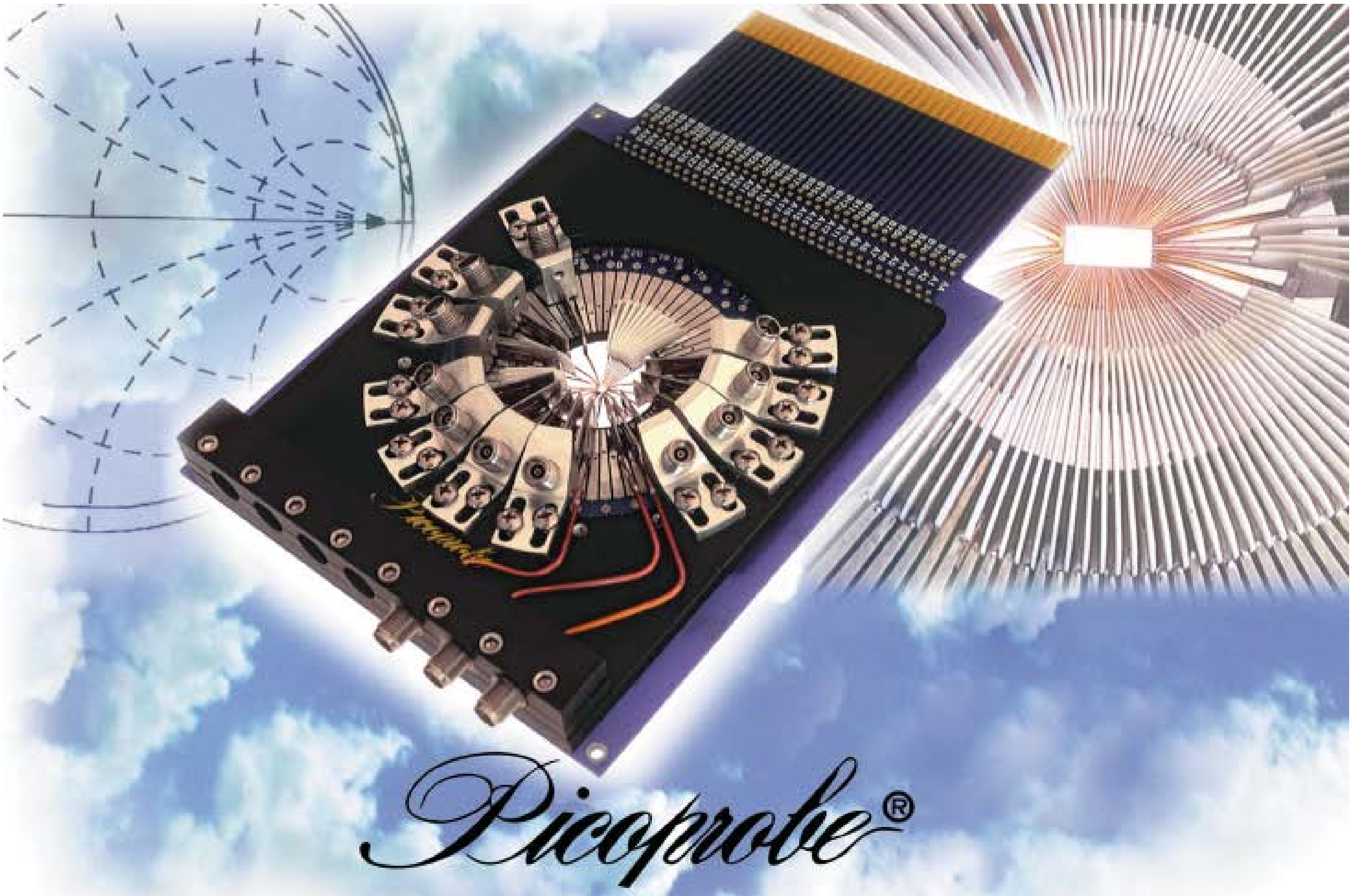

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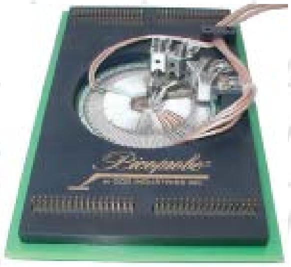

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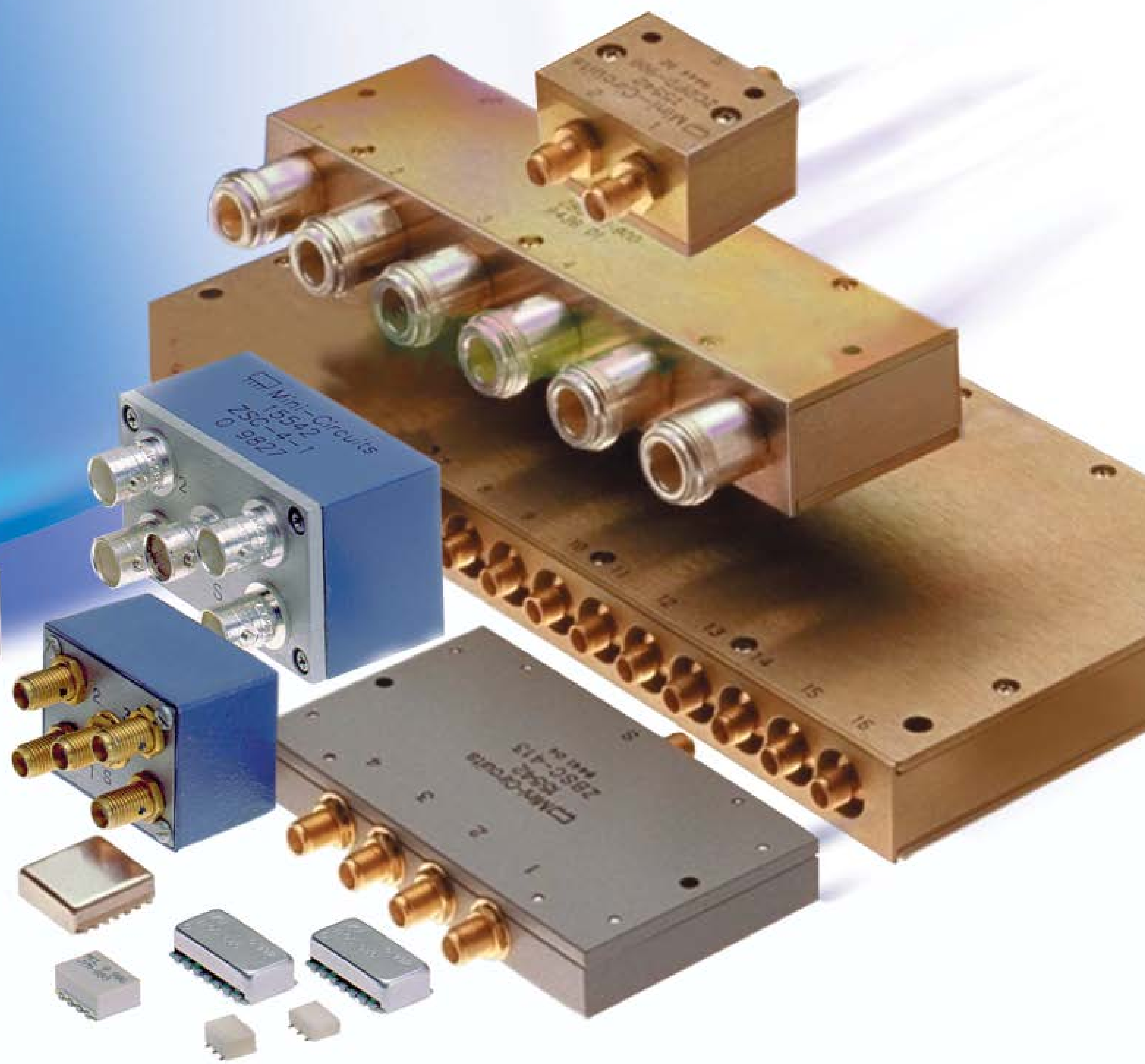
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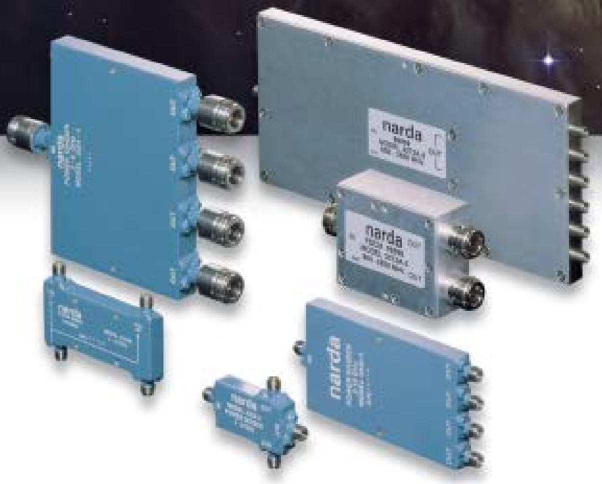

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FEATURES

NOTE FROM THE EDITOR

COVER FEATURE

TECHNICAL FEATURES

50 Years of Publishing Excellence

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Tune-up your skills. Join the growing number of engineers who participate in this monthly series on RF/microwave theory and practical applications.

Electrically Small Antennas

This month's Webinar presents basic antenna property definitions such as impedance, bandwidth and quality factor for general wireless, cellular and RF/microwave systems.

Presented by **Besser Associates** and *Microwave Journal*

Live webcast: 12/18/2007, 11:00 AM (EST)

Executive Interview

In this month's executive interview, *Microwave Journal* talks with Chuck Fox, Vice President, Sales and Marketing, **Jazz Semiconductor**, about how its .18 μm CMOS process and Analog-Intensive Mixed-Signal (AIMS) initiative are poised to deliver a complete silicon-based radio.

Resources

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Need to hire RF/microwave engineers? Looking for a new job? Check out the recent technical job postings and job-seeker tips in the career corner of the *Microwave Journal* resource page at www.mwjournal.com/Resources/. *Microwave Journal* partners with ElectroMagnetic-Careers.com to help engineers and companies connect. Search for jobs, post your résumé or find a recruiter specializing in the placement of RF/microwave engineers.

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"Acceleware Gains Speed for FDTD Solvers Used in Biomedical Simulations"
Heather Bota, Acceleware Corp.

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Walter R. Frei, COMSOL Inc.

"RF CMOS Assumes Wireless Data ICs Center Stage"
Dror Regev, Tower Semiconductor

"Total Radiated Power (TRP) Implications for a GSM Power Amplifier"
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Expert Advice

featuring Ask Harlan

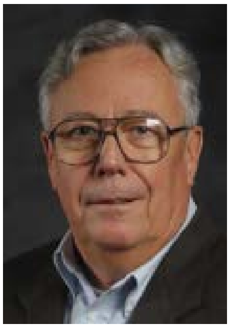
This month, industry expert Harlan Howe retires from the global microwave industry after 50+ years of service, bidding his readers farewell (see this month's letter from the editor). Harlan wraps up this popular feature by wrestling with his final question as a *Microwave Journal* editor. Next month our expert advice turns the table, so to speak. Stay tuned.

This Month's Question:

Gordon King from Unilock asks–

"Where can I locate information regarding how to design and build a microwave moisture meter?"

"Say Goodnight, Gracie"



HARLAN HOWE, JR., *Microwave Journal* Editor

This is the end of the "Ask Harlan" program since I will be retiring at the end of the year. I have answered over 2000 questions since we started the web feature several years ago. It's been a lot of fun for me and I hope it has been helpful and entertaining to our readers and the people who have sent in the questions.

I have enjoyed a 50-year career in the microwave community, including the past 17 years as Publisher/Editor of *Microwave Journal* and co-manager of the IEEE MTT-S IMS Exhibition. I have been fortunate to meet many new friends, colleagues and customers through the years, in industry, academia and IEEE/MTT-S. It's been a great run, but the time has come to step back and smell the roses.

Over the years, I have had the pleasure of working for some very enlightened bosses in the industry, including Dana Atchley, Ken Carr and Mark Rosenzweig. I am also grateful to the management at Horizon House for the support and flexibility that the company has afforded me during my employment. I was able to pass on the Publisher's position to Carl Sheffres six years ago when I cut back my schedule and he has done a great job of growing the magazine, particularly the electronic publishing services. David Vye, who joined us earlier this year as Technical Editor and Business Development Manager, is taking over as Editor. He has already introduced some new and exciting ideas and I'm sure there are more to come.

"Ask Harlan" will continue under a new title with a group of experts to answer your questions. More information on the new format will be announced in the January issue.

I am looking forward to this new phase in life. While I have a number of outside interests, I do expect to remain active in IEEE and MTT-S and hope to see many of you at future meetings and symposia. ■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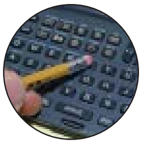

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http://pasymposium.ucsd.edu

IEEE Radio and Wireless Symposium (incorporating WAMICON)
January 22–24, 2008 • Orlando, FL
www.radiowireless.org

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National Association of Tower Erectors (NATE 2008)
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www.ctiawireless.com

WCA 2008
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www.wcai.com

JUNE

IEEE Radio Frequency Integrated Circuits Symposium (RFIC 2008)
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IEEE MTT-S International Microwave Symposium and Exhibition (IMS 2008)
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www.ims2008.org

AUGUST

IEEE EMC Symposium
August 18–22, 2008 • Detroit, MI
www.emc2008.org

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WiMAX World Americas
September 30–October 2, 2008 • Chicago, IL
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OCTOBER

European Microwave Week
October 27–31, 2008
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■ **Topics:** This course covers a broad range of topics from measurement techniques to PWB and chip package design and troubleshooting issues. The course describes in depth how to measure signal and noise in high speed digital and analog circuits. These measurements are then used to characterize high speed effects in electronic circuits including design verification and troubleshooting. Sources of measurement error are discussed. The measurement techniques are related to design issues to improve signal integrity, equipment EMC performance and improve the overall reliability of electronic systems.
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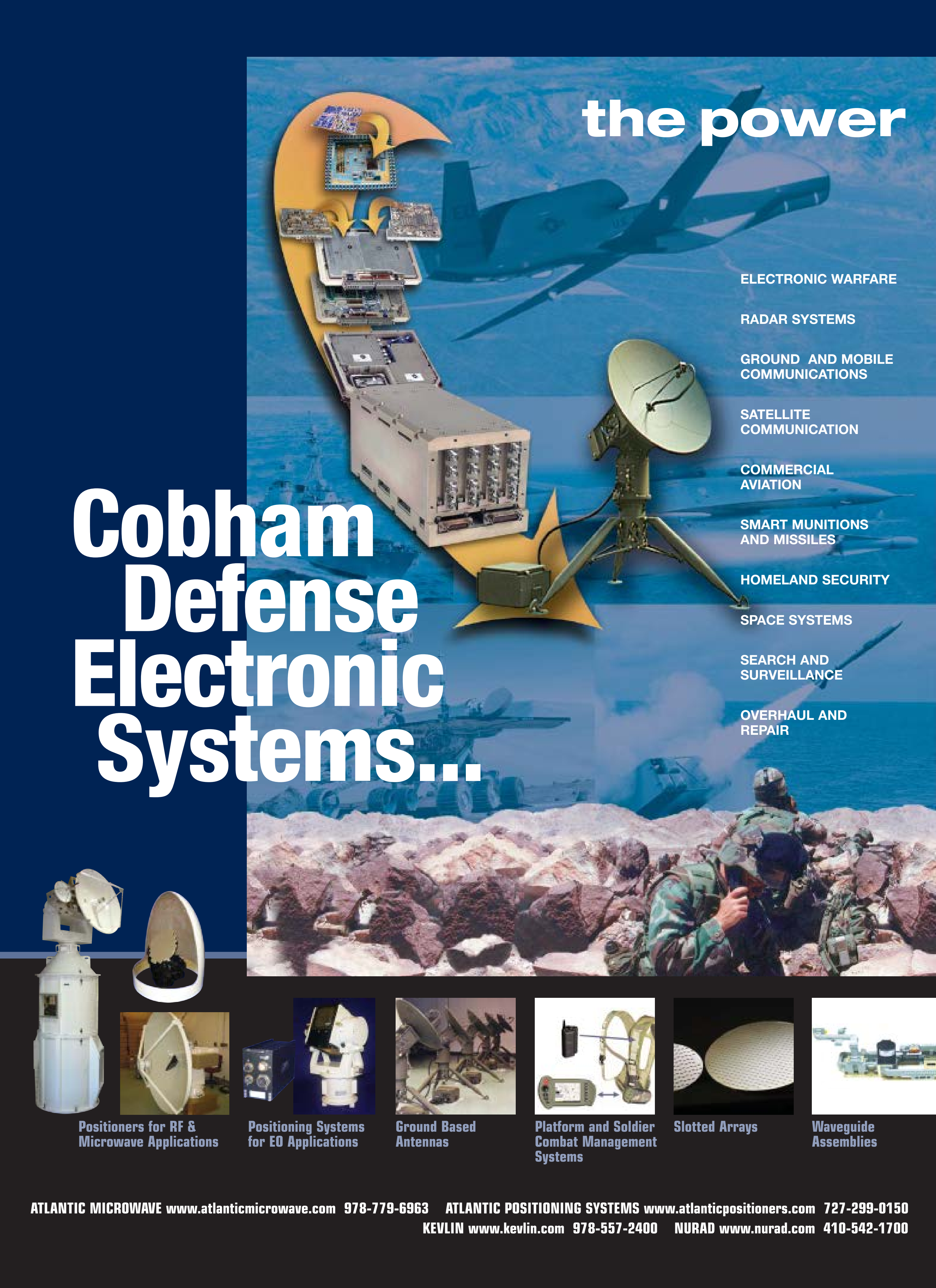

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REMOTE SENSING TECHNOLOGY FOR AUTOMOTIVE SAFETY

The emergence of sensor networks (acoustic, radar, lidar and video) on passenger automotive vehicles is indicative of the increasing complexity and sophistication of the electronic functionality of the world around us, as we apply technology to make our lives more convenient. In the same way that the simple cellular phone has morphed into an all-encompassing entertainment and connectivity device—camera, video, MP3 player, Internet connection and, on occasion, a device to speak to somebody with—the average motor vehicle is increasingly becoming a platform for electronic systems that seeks to make our journeys as comfortable (multimedia entertainment), hassle-free (GPS navigation, tire-pressure monitors, rain/light sensors, etc.) and now as safe as possible.

By way of example, radars exist today on vehicles in production. But why do we need such technology? The arguments are simple. Over the last 10 to 15 years, despite the wide deployment of airbag technology, advanced mechanical designs (crumple zones), new materials, etc., the death rate due to car crashes has remained stubbornly flat. To put it into perspective: In 2001, on US roads, a fatality occurred every 12 minutes. The EU has a similarly tragic statistic. How does a "remote sensing" technology like radar change the equation? Most previous technological solutions addressed survivability. Solutions like radar are a paradigm shift, as they attempt to address collision avoidance… the best way to survive an accident is not to have one in the first place.

A sensor such as M/A-COM's SRS (Short Range Sensor) is an example of a system based on mmWave technology, and is one of a family of technological solutions at play to address the next level in vehicle safety applications. This article will review the trends of technology implementation for microwave sensors (and others) in vehicles and highlight the directions that the industry is heading in. We will spotlight the direction of the vision of the OEMs for the vehicle of the future and how that is flowing down to the sensor and

ALAN JENKINS
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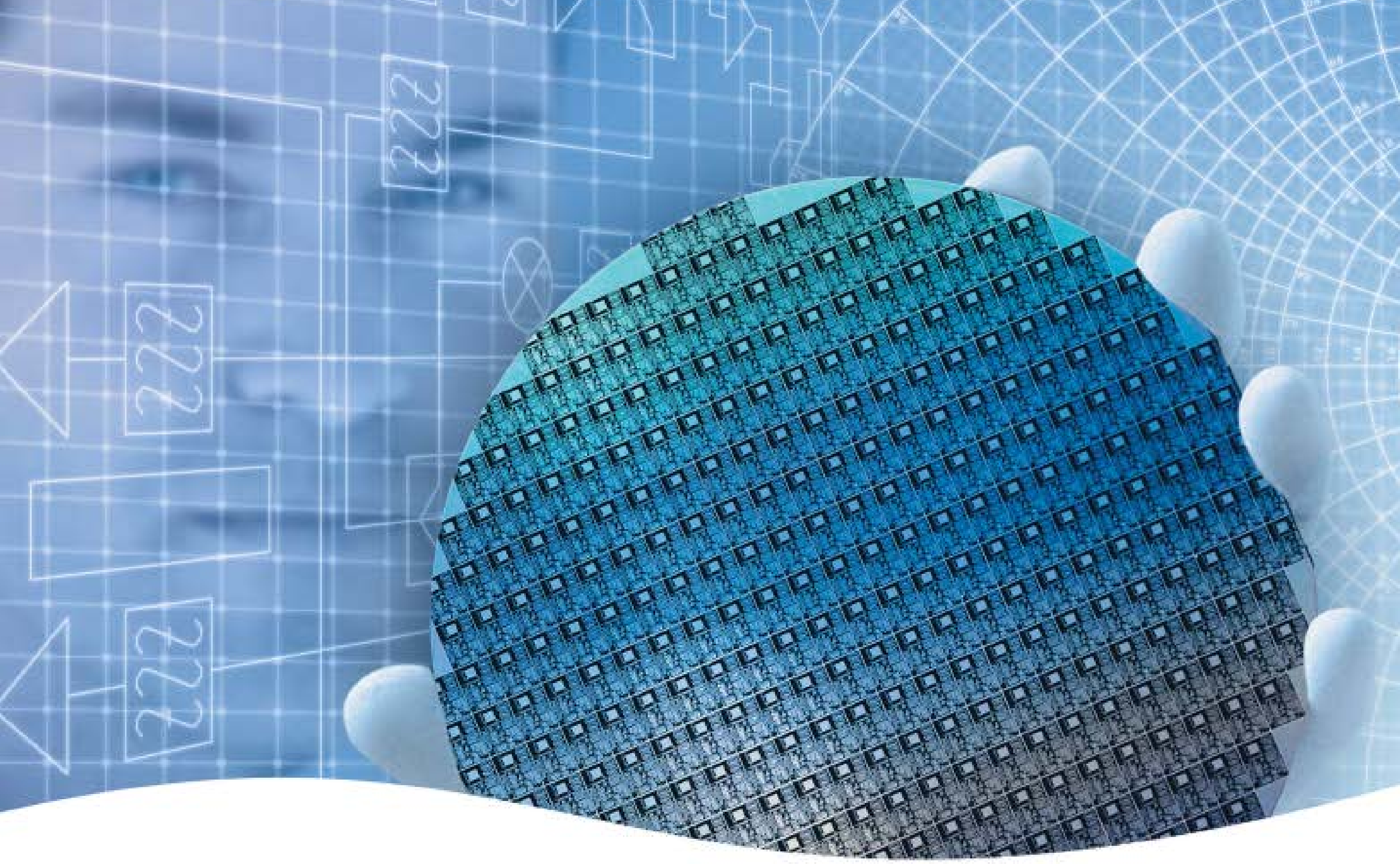
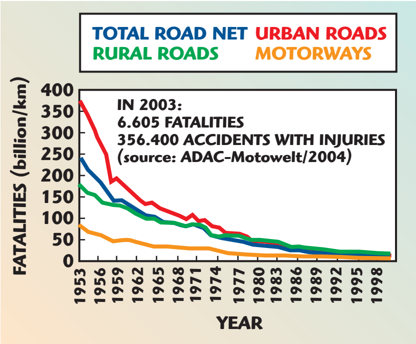
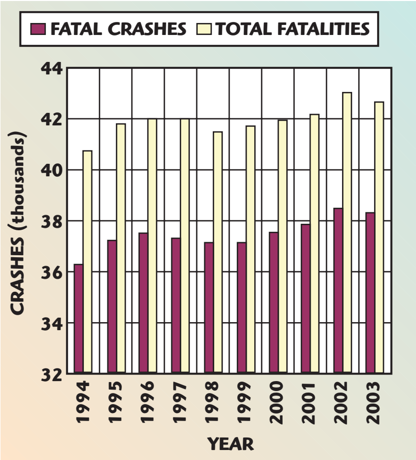


component manufacturers, within the boundary conditions imposed by spectral regulations. It will also discuss how understanding the intended application requirements of the sensor is the most efficient way for deriving lower-level specifications that can be used for technology definition and product development.

However, the challenge remains to deploy such complex systems in lower priced and affordable vehicles, across international boundaries. Attention to the harmonization of international regulatory requirements has an impact on volumes and thus price. Price drives the types of vehicle that such technology will be deployed on and ultimately the number of people that are able to benefit from increased levels of safety.



▲ *Fig. 1 Fatalities on German roads as a function of miles driven.*



▲ *Fig. 2 Deaths on US roads due to vehicle accidents.*

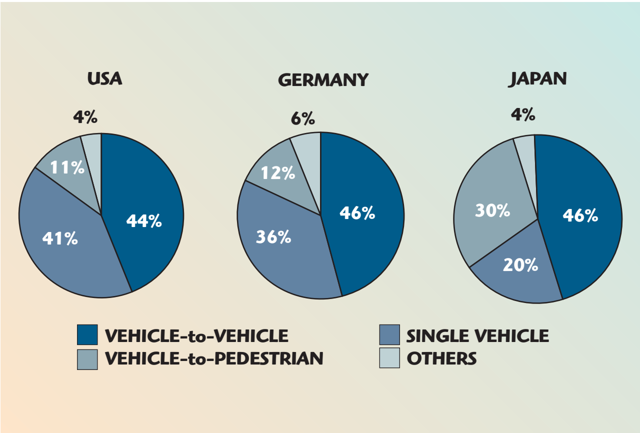
THE HUMAN COST OF THE AUTOMOBILE

In developed countries the car is a fact of life. It is practically essential to most people's way of life. In the developing economies of China, India and the Far East, it is fast becoming the same ubiquitous aide to everyday life. With the prospect of the introduction by Tata of the $3000 car in India, it has every indication of only becoming more so. Society has a love/hate relationship with the automobile. On the one hand, we have the incredible freedom that affordable personal transportation brings and, on the other, we have a technology that brings along with it a number of societal and environmental impacts. Exhaust emissions by internal combustion engines and their impacts are well documented and frequently discussed. However, the human cost of the widespread use of the car is less well known. Most people have probably seen a car accident and some probably know people who have been involved with one. This prevalence is a result of the huge number of vehicles on the roads today, coupled with the ever-increasing distances people are traveling. In the US, motor vehicle accidents are the leading cause of death for people between the ages of 1 to 34 years old (National Vital Statistics report, September 2002).

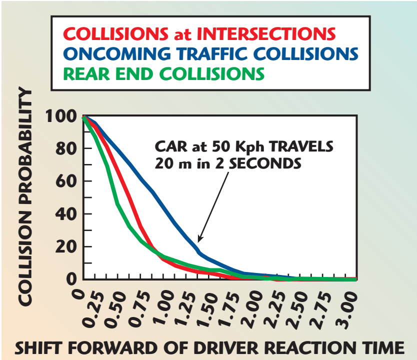
The statistics are humbling. In 2003, in the US alone, there were over 42,000 deaths due to car accidents (US DoT). As shown in ***Figure 1***, in the same year, Germany suffered the loss of 6605 of its citizens to car accidents (ADAC-Moterwelt 1/2004). To put this in perspective, in the US, there were more people killed by cars than by breast cancer (40,954 deaths due to breast cancer in 2003 according to the US Department of Health CDC).

While the absolute numbers involved in road deaths are staggering, the more sinister statistics are in the trend data. Despite the wide deployment of airbag technology, advanced mechanical designs (crumple zones), new materials, automatic braking system (ABS) and advanced stability controls to name but a few, the death rate due to car cashes has remained stubbornly flat (see ***Figure 2***). What lies at the root cause of this statistic is the simple fact that most previous technological solutions addressed survivability. Advanced sensor technology, with mmWave radar playing a central role, is quietly causing a paradigm shift in the equation as these new technologies address collision avoidance. It can be summed up simply: The best way to survive a crash is to not have one in the first place. And a route to avoidance is awareness, whether it be at the driver level, the vehicle level or the interaction of the two.

Of course, awareness is only part of the solution, but if we look at ***Figure 3***, it is evident that a significant proportion of all fatalities result from a collision between two or more vehicles. Thus, a clear role exists for remote sensing technologies that are able to increase the awareness of the driver-vehicle system. At one level, it is to forewarn the driver and, at the other extreme, the vehicle itself taking control over the situation. This is further supported by noting the curve in ***Figure 4***. It tells us that if we are able to give the driver an extra two seconds of reaction time, the probability of a collision reduces significantly. The role of remote sensing technologies is clear.



▲ *Fig. 3 Car-related fatalities by category.*



▲ *Fig. 4 How awareness affects the probability of collision.*

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The graph of car-related fatalities by categories also highlights some of the clear geographic differences. The US and Germany both have a modest (11 and 12 percent, respectively) fatality rate due to vehicle-to-pedestrian accidents. Japan is notably different, with this percentage being much higher at 30 percent. Road conditions, driving styles and environmental conditions all contribute. Again, the need for remote sensing is clear, but the application and vehicle response is different. For example, there are experimental systems that sense an impact and raise the bonnet of a car at the time of impact. This reduces fatalities due to cranial impacts on the engine block. Making such technology cost effective is the key to large-scale deployment and adoption as standard equipment on vehicles. Remote sensing can play a major role here also, as having more time for the vehicle to react to a situation (more awareness) lessens the speed requirements on actuators. Thus, hydraulic or electrical actuation can be used instead of pyrotechnics that are costly and "once only and back to the shop" type solutions.

ECONOMIC REGION INITIATIVES ON ROAD SAFETY

The EU, US and Japan are not blind to the trends. Over the last few years, all have instigated regional and national programs at various levels to attempt to address the issues. The EU has a long running eSafety initiative. eSafety is a joint initiative of the European Commission, industry and other stakeholders, and aims to accelerate the development, deployment and use of intelligent integrated safety systems that use information and communication technologies in intelligent solutions in order to increase road safety and reduce the number of accidents on Europe's roads.

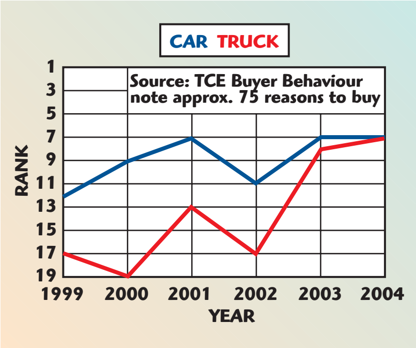
In the US, the Integrated Vehicle-Based Safety System (IVBSS) program recently awarded a $25 M contract to the University of Michigan Transportation Research Institute (UMTRI). Partnering with UMTRI are Visteon, Eaton, Cognex, Honda R&D Americas, Battelle and the Michigan Department of Transportation. The consortium will develop and test a new, integrated crash warning system in a fleet of 16 passenger cars and 10 heavy-duty trucks. UMTRI will serve as the primary contractor, coordinating the work of the partnership and conducting the field experiments.

OEM APPLICATIONS TODAY

Options or Standard Equipment?

Car manufacturers are often faced with a dichotomy. Safe cars sell and people expect the cars they drive to be safe. On the other hand, it is often the case that consumers, when faced with an options list, will pick more from the category of "driver comfort" rather than something that adds to the safety of the vehicle. Let us illustrate this point by proposing a hypothetical choice between two options which could be similarly priced when you are at the car dealership and we will let the reader play the mind game:

Option 1: A technology that prefills your brake cylinders before an impact, to shave 300 ms off your ef-

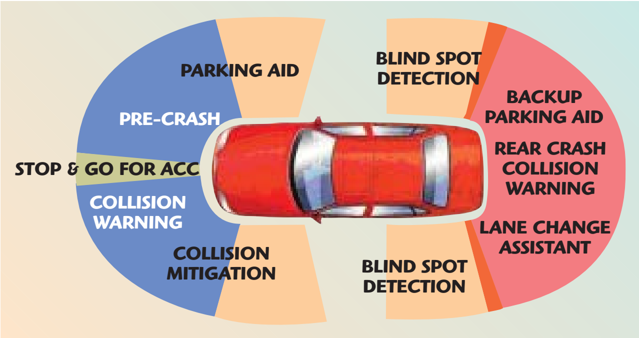


▲ *Fig. 5 Reasons for purchase: Features that protect in an accident (TCE Buyer Behaviour).*

fective reaction time (thus statistically increasing your survival rate in an accident by 15 percent).

Option 2: The drop-down flat screen DVD player for the kids in the back seat.

Where would you put your $500? While some people may argue that option 2 can also add to road safety (by keeping the children quiet in the back?), the point here is that when new technology is first introduced into the automotive world it is often in the form of options on the higher end vehicles. First, this allows the OEMs to recover some of their investment and also to test the waters in terms of customer acceptance of some of these new solutions. However, as shown in ***Figure 5***, if we look at the TCE buyer behavior survey, of the 75 reasons to purchase an option, features that protect in an accident are increasing in rank but are still only at 7, not in the top slot.



▲ *Fig. 6 With a suite of short-range sensors, a significant number of applications can be addressed with the same hardware.*

To address this issue, most car manufacturers are introducing remote sensing technology into cars on the back of Driver Assistance/Comfort type functions and most (if not all) have plans to migrate the functions towards active safety over time. Forces that increase volumes, such as harmonization of regulations, help to push costs down. This in turn makes it more feasible to offer such technology as standard equipment (or indeed compulsory) so that the consumer does not have to choose between a comfort feature or one that enhances safety. Functions like seat belts, ABS and airbags all went this route, as are ESP-like functions at the moment.

Some Example OEM Applications

By way of example, in the US, the most prevalent driver assistance application on the market is park assist. Many vehicles today have park assist applications: Cadillacs, Buicks, Lincolns, Chryslers and others. Most of these park assist systems utilize ultrasonic technology; however, many have added vision systems to enhance the driver's awareness in parking scenarios. This year, the Cadillac STS, DTS and the Buick Lucerne have begun to offer Side Blind Zone Alert as well. This is a system that will warn the driver of the presence of a vehicle in its side blind spot. Both park assist and blind spot detection can be characterized by short-range sensing and are promoted as driver assistance more than safety enhancing applications.

Perhaps more pertinent to this audience is the gradual adoption of mmWave radar technology as one of the leading contenders for the remote sensing technology in vehicles. While radar has been around for a while on luxury cars for ACC (Adaptive Cruise Control) applications, Mercedes was the first to introduce, in production series, a more comprehensive driver assistance system (Brake Assist Plus or BAS Plus) in 2005 and a year later in 2006 with the PRE-SAFE Brake in the S-class and CL-coupé models. In this particular deployment, the technology is based on both a long-range sensor and a suite of short-range radar sensors (at 77 GHz for long range and UWB at 24 GHz for short range in the front,

side and rear). The safety aspect of the system will attempt to alert a driver when the possibility of a collision exists and, if the driver does not react, will progressively apply braking to attempt to prevent the crash. Toyota has also launched a similar system on its Lexus platform. The system combines information gathered from a front-mounted millimeter-wave radar, as used in Lexus's established PCS system, and a twin-lens infrared stereo camera located on the top edge of the windscreen. Both of these deployments seek to address a range of applications, both in the driver assistance and the driver comfort application segments, and both attempt to facilitate this range of applications with the same set of sensor hardware (for example, the Mercedes system will also act as a back up aide, stop-and-go low speed ACC, etc.). This is an important strategy as it allows the cost for the more safety-oriented application to be offset by the driver comfort option (which as we may have illustrated, the customer may be more likely to pay for directly). With a suite of short-range sensors (30 m UWB radar type technology, for example) a significant number of new applications can be addressed with the same hardware. However, this puts more demanding specifications on the mmWave system design and components (see ***Figure 6***). ***Figure 7*** shows the diverse applications, what they do and how ready they are.

APPLICATION	DESCRIPTION	C/A/S
ADAPTIVE CRUISE CONTROL	ACC. Maintains fixed time delay to vehicle in front. Only activated at highway speeds	C
BACK UP AIDE	Provides indication of objects being too close to rear of car while maneuvering during parking	C
BLIND SPOT ALERT	Indicates object is in vehicle's blind spot when driver initiates a lane maneuver	A
STOP AND GO	Similar to ACC but functions down to zero velocity. Application enables driver to maintain comfortable distance to vehicle in front during stop and go traffic jam type scenarios and urban driving	A/C
LANE DEPARTURE	Alerts driver when the application thinks the vehicle is straying from the current traffic lane	A
PARK ASSIST	Push the button and the car parks itself	A
COLLISION WARNING	Alerts the driver when the probability of impact is high (e.g. a stopped vehicle in front)	S/A
BRAKE ASSIST	Progressively applies braking in the event that the driver fails to react to a bad scenario	S/A
PRE-CRASH	Predicative application. Recognizes imminent collision and prepares vehicle for impact. This can include pre-tension of safety belts, pushing head rests forward, pre-arming airbags, altering vehicle suspension dynamics to lessen impact	S
PEDESTRIAN DETECTION	Detects imminent collision with a pedestrian and prepares the vehicle so as to mitigate the impact to the pedestrian	S
AUTONOMOUS DRIVING	The DARPA Urban Challenge!	C/A/S

WIDELY DEPLOYED
RECENTLY DEPLOYED or IMMINENT
DEVELOPMENT STAGE ONLY

C: COMFORT
A: ASSISTANT
S: SAFETY

Fig. 7 Applications, what they do and how ready they are.

	SHORT-RANGE RADAR (24 GHz UWB)	LONG-RANGE RADAR (77 GHz)	LIDAR	ULTRASONIC	VIDEO
RANGE MEASUREMENT <2 m	++	-	0	++	-
RANGE MEASUREMENT 2 to 30 m	++	++	++	-	-
RANGE MEASUREMENT 30 to 100 m	-	++	+	- -	-
ANGLE MEASUREMENT <10 DEGREES	+	+	++	-	++
ANGLE MEASUREMENT >30 DEGREES	0	-	++	0	++
ANGULAR RESOLUTION	0	0	++	-	++
DIRECT VELOCITY MEASUREMENT	++	++	- -	0	- -
OPERATION in RAIN	++	+	-	0	0
OPERATION in FOG or SNOW	++	++	-	+	-
BLOCKAGE (DIRT on SENSOR)	++	++	0	+	- -
OPERATION at NIGHT	++	++	++	++	- -

++ IDEALLY SUITED
+ GOOD PERFORMANCE
0 POSSIBLE, MODEST PERFORMANCE
- FEASIBLE, ONLY WITH LARGE EFFORT
- - IMPOSSIBLE

Fig. 8 The different sensor technologies.

TECHNOLOGY NOW

Remote sensing solutions currently available cover a wide range of technologies. It is probably fair to say that no one single technology is ideally suited to address all the applications and problems that need to be solved for a comprehensive safety system to work well over all conditions. ***Figure 8*** is an attempt to depict the trade space among the competing technological solutions. It is clear from the table that most of the factors that are important to safety applications can be addressed relatively well by the use of some kind of radar. It is also true that the fusion of radar with an optical technique (such as video cameras) has the potential to produce overall a very effective solution. Shown in ***Figures 9*** to ***13*** are examples of different types of remote sensors currently available on vehicles. Figures 9 and 13 show 77 GHz long-range radars originally deployed for ACC applications, Figure 10 is a video camera-based system, Figure 11 is a Lidar (or laser-based) system and Figure 12 is a 24 GHz UWB short-range sensor.

RADAR NOW?

The historical barriers that slowed the widespread deployment of radar sensor networks were threefold: Technological (mainly affordability); Applications (and the link to specifications); and Regulatory. Let us first consider the technological challenge of affordability. Although the cost structure of the microwave industry has changed enormously due to the charge led by the development of RF wireless devices, this has been largely below 10 GHz. Finding the appropriate balance between where regulations are most flexible, where the physical and electrical size of sensors gives the most information of the vehicles' environment and where the cost of the available

technology is compatible with consumer expectations, is a trade-off without a simple or ideal answer. The second problem has been the ability to adequately and accurately define the application and thus determine a well-defined set of specifications for the underlying components and systems. Unlike the development of telecommunications equipment, where the hardware and software engineers can expect well-defined air interface documents, component specifications and interface protocols, the definition of radar sensor operational requirements has been partly an empirical problem due to the subjective nature of some of the requirements. Also, the interpretation of the same application (a parking aide, for example) may vary across geographical and cultural boundaries, as driving habits and road conditions differ considerably. Often a major route to finding what details matter from a

▲ *Fig. 9 Long-range 77 GHz radar (courtesy of Denso Corp. Japan).*

▲ *Fig. 10 Camera-based sensor (courtesy of Denso Corp. Japan).*

▲ *Fig. 11 Laser-based sensor or lidar (courtesy of Denso Corp. Japan).*

▲ *Fig. 12 M/A-COM UWB 24 GHz radar sensor (courtesy of Tyco Electronics).*

▲ *Fig. 13 Another example of a 77 GHz long-range radar (courtesy of Tyco Electronics and Continental Product).*

sensor network down to circuit level implementation has been to install it on a vehicle and collect data. However, the discussion is irrelevant without a regulatory framework to work in (such as frequency allocations and rules). It is thus worth a short sojourn through this somewhat tangled path.

THE REGULATORY FRAMEWORK

The Regulatory hurdle is a largely electro-political challenge of working with several global institutions to seek approval for consistent and harmonious spectrum allocations that support sensor development without interfering with other users. The themes at play here are frequency and power; the goal should be harmonization for a low cost solution that enables worldwide deployment to benefit the largest number of people.

At this time, there are three fundamental frequency bands at play in the various markets around the world. ***Figure 14*** attempts to summarize these. Two are classified as ultra-wideband (UWB) and one as a long-range radar (LRR) band. Historically, there has been a worldwide frequency allocation at 77 GHz for ACC applications (Autonomous Cruise Control, known as LRR) for some time. While the bandwidth allocated is adequate for the intended application (1 GHz of spectral occupancy), more advanced applications require higher resolution, which translates into wider spectral occupancy. More advanced safety applications require a greater degree of precision and certainty about the targets they see. This leads to higher requirements for resolution. Thus, two parallel frequency allocations for UWB for automotive applications have emerged.

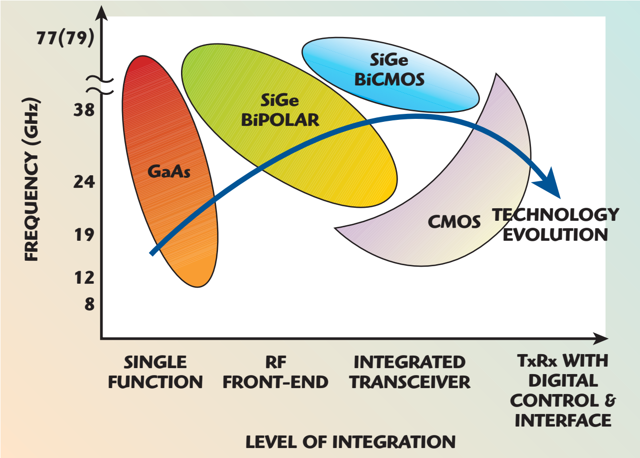
MARKET / FREQUENCY	EUROPE	NORTH AMERICA	JAPAN
UWB SRR 24 GHz/26 GHz	FREELY AVAILABLE SUNSET DATE IN 2013	FREELY AVAILABLE	PENDING
LRR (77 GHz ACC)	FREELY AVAILABLE	FREELY AVAILABLE	FREELY AVAILABLE
UWB SRR 79 GHz	FREELY AVAILABLE (REVIEW IN 2009)	PENDING	PENDING

▲ *Fig. 14 Current status of worldwide frequency allocation for mm-Wave radar for automotive applications.*

The first of these is centered in the 79 GHz band with an allocated bandwidth of 4 GHz. As can be seen, this has been allocated in Europe, but is still pending in the two other major geo-political automotive markets. Currently there are no products in production for vehicles in this frequency band. However, significant research efforts exist to address both the semiconductor technologies and cost reduction strategies at these very high frequencies and also to examine the difficult deployment issues surrounding use of 79 GHz (for example, interactions and losses in a bumper fascia, etc.). An example would be the Kokon project, a comprehensive German government sponsored collaborative effort (see www.kokon-project.com).

The other UWB frequency allocation is based around 24 GHz (here we include the possible shift in EU regulations to cover a 26 GHz center frequency). This band has an allocated bandwidth of around 7 GHz in the US. While products are currently on the market on vehicles today (in both the EU and US), which meet the cost performance objectives of the applications required of them, there is still uncertainty about the regulatory environment in Europe and Japan. The 24 GHz band is shared with fixed services (point-to-point back haul) and also earth exploration satellite services and radio astronomy and the EU has currently mandated a "sunset date" on UWB at 24 GHz in 2013 (no more production after this date). This comes up for review in 2009, with a possible shift to 26 GHz being mooted. The regulation by the FCC is simpler (22 to 29 GHz) and the band is licensed for the foreseeable future. There are currently technical studies in progress in Japan on co-existence issues in the approximately 22 to 30 GHz band, with an initial outcome expected early 2008.

Suffice to say that worldwide, the regulatory framework is somewhat



▲ *Fig. 15 Frequency, technology and level of integration; a complex trade space for auto radars.*

RANK	2000	2003	2006	2009	2013
1	US	US	US	US	US
2	JAPAN	JAPAN	JAPAN	JAPAN	CHINA
3	GERMANY	GERMANY	CHINA	CHINA	JAPAN
4	FRANCE	FRANCE	GERMANY	GERMANY	GERMANY
5	KOREA	CHINA	KOREA	KOREA	INDIA
6	SPAIN	KOREA	FRANCE	FRANCE	KOREA
7	CANADA	SPAIN	SPAIN	INDIA	FRANCE
8	MEXICO	CANADA	CANADA	CANADA	BRASIL
9	UK	UK	BRASIL	BRASIL	CANADA
10	ITALY	BRASIL	MEXICO	SPAIN	SPAIN
11	BRASIL	MEXICO	UK	MEXICO	MEXICO
12	CHINA	ITALY	INDIA	RUSSIA	RUSSIA
13	BELGIUM	RUSSIA	RUSSIA	UK	THAILAND
14	RUSSIA	INDIA	ITALY	THAILAND	UK
15	INDIA	BELGIUM	THAILAND	ITALY	IRAN

▲ *Fig. 16 Top 15 ranking of countries by production volume of cars (the last two columns are projections).*

fragmented and in flux, neither of which is helpful for deploying radar-based safety systems in the international marketplace within which the automotive OEM's function nor does it help the worldwide adoption of technology that has the potential to save lives. However, harmonization efforts are at work (refer to www.sara-group.org) that hope to create more cohesion across the different geographic and political market places. There is considerable debate over this issue worldwide. While 24 GHz solutions have the advantage of being able to offer lower cost solutions now (due to lower IC technology cost, availability of plastic package technology at 24 GHz, lower cost volume test solutions, etc.), they do trade some advantages that 79 GHz solutions offer, such as smaller size and the impact that the sensors may have on the vehicle styling.

THE FUTURE

What will drive the future direction of active safety systems and in particular the role that mmWave radar technology will play? Semiconductor technology, as an enabler, has the potential to reduce costs by higher levels of integration thus facilitating the deployment on affordable cars. Advanced applications, made possible by remote sensing, will enable car OEMs to offer a wider range of products and applications. Finally, higher volumes from new and emerging markets have the potential to drive the economies of scale necessary to put active safety systems within reach of everyone.

Semiconductor Technology Trends

One of the great debates regarding the development of sensor technology for future microwave and millimeter-wave sensors has been that of selecting the optimum semiconductor technology. ***Figure 15*** illustrates some of the varying technology solutions that have been proposed as a function of operating frequency and level of integration. Traditionally, the choice has been restricted to GaAs or III-V semiconductors, which are superior in terms of their low noise, power and linearity capabilities. In order to minimize their area (cost), they have been largely restricted to single function circuits. Depending upon the specific radar architecture, these functions have been distributed across a frequency plan between 12 to 76 GHz, with several up- and down-conversion stages included to

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perform the frequency conversion. However, the rapid growth and relative maturity of high-speed SiGe processes has meant that for relatively short-range and low-power applications (such as automotive radar), there has been a move to substitute more highly integrated transceiver ICs in place of the single-function and more expensive GaAs-based circuits. There is still the trade-off between selecting the optimum process for a given application versus the level of integration to be addressed however, and as the frequency increases, the relative level of integration in the SiGe bipolar circuits tends to reduce. One of the ways that this can be addressed is by moving to a SiGe BiCMOS process, where the high performance front-end circuits (Tx amplifier, Rx LNA) are realized using the bipolar process, but more flexibility and control is introduced by the availability of small-feature CMOS. Lastly, the rapidly decreasing technology size of CMOS has led to many proposals and development programs for an all RF-CMOS-based front-end, with much higher integration.

As always, this becomes a question of a complex trade-off between technology and economics. The available market size for automotive sensors is still (at least) an order of magnitude smaller than that of the wireless industry, and so the economics of using the latest and greatest 65 nm (or smaller) technology node in CMOS may be less clear than utilizing a previous generation CMOS or SiGe BiCMOS process. In addition, many of the publications for all-CMOS solutions have not discussed the all-pervasive automotive requirements on reliability, operating life and temperature. Promising operation and results may not easily translate to extended operation at highly elevated junction temperatures. The end result may be a technology evolution arc that becomes a function of regulations (operating frequency) and the emergent volume of the market with time.

Emerging Markets

For many years, the US, Japan and Europe have lead the pack in terms of the volume of cars manufactured. Saturation has occurred in most of these traditional markets, with year-on-year volume growth being very modest. Increasing individual economic wealth and a large population are two key factors which drive numbers in markets such as China and India. This can be clearly seen from the trend analysis shown in ***Figure 16***.

These markets are quite different, however. The emphasis is on the small

▲ *Fig. 17 Exploded view of a 24 GHz UWB automotive sensor currently available in the US and EU. The unit is approximately the size of a deck of cards.*

to micro-sized vehicle with very small engine sizes at very low cost. Almost, one would say, the rebirth of the original term "Volkswagen." For radar and remote sensing technologies to be able to play a role here, the cost requirements and thus the scope for design innovation are significant. The most recent 2007 all inclusive safety package option on a high-end car will probably cost more than an entire vehicle in one of these emerging markets.

It is worth considering at this point another dynamic, which is different in the automotive world when compared to the conventional consumer market environment. The timescales involved are radically different. A typical product life cycle in consumer electronics is 12 months to maybe two years. In the automotive world, it takes that long just to have a piece of hardware qualified to go on a car. Patience and deep pockets are the name of the game for companies participating in this competitive marketplace. Worldwide production today is over 60 million cars a year, with a trajectory upwards. Thus, if mmWave and radar designers are able to design products that hit the cost/performance points required, there is a very real market out there with very real growth prospects (see ***Figure 17***).

CONCLUSION

The deployment of mmWave-based radar technology for remote-sensing applications in cars is real and taking place in the market today. Parts of this complex story are still in flux: the shifting regulatory landscape and the continuing march of semiconductor technology to name two. It is clear, however, that the human benefits, the opportunity and the market are here now.

Radar system engineers and mmWave designers have a rare opportunity to participate in the widespread deployment of technology that will impact life saving applications. The intelligent choice of semiconductor processes will leverage economies of scale. More design innovation will improve the cost/performance ratio of systems and harmonization of worldwide regulation will drive cost through volume. Perhaps, some time in the future, such developments will allow regulatory bodies to consider such technology as compulsory (remember, safety belts once used to be optional equipment). With remote sensing as an enabler, OEMs are likely to develop more advanced applications that will contribute to a feature-rich driving environment that is safer for all. ■

ACKNOWLEDGMENTS

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NetFires Delivers First Future Combat System Equipment

NetFires LLC, a joint venture between Raytheon Co. Missile Systems business and Lockheed Martin Missile and Fire Control, delivered the first two Non-Line-of-Sight-Launch System Container Launch Units to Army Evaluation Task Force soldiers in Fort Bliss, TX.

The NLOS-LS CLU is the first Future Combat System (FCS) equipment to be delivered, taking FCS closer to providing the warfighter a much-needed precision weapon system capable of engaging both moving and stationary targets. "Putting real hardware on schedule and in the hands of soldiers is what we are all about," said Col. Doug Dever, the Army's Non-Line-of-Sight-Launch System project manager. "This is the first FCS Spin Out 1 system to be delivered. It is a credit to the dedication and outstanding cooperation of the LLC, US Army and US Navy teams." During the next year, the FCS Army Evaluation Task Force will evaluate operational concepts, conduct testing and training, and provide continuous feedback on NLOS-LS equipment at Fort Bliss, allowing the Army to evaluate technologies and develop tactics, techniques and procedures. "I am excited to see new, innovative equipment in the hands of our soldiers that will provide the brigade combat team commander with an organic capability to precisely engage moving targets," said Col. Gary Kinne, Army Training and Doctrine Command capabilities manager for rockets and missiles. Steve Bramlet, the Army's NLOS-LS CLU product manager, said, "NLOS-LS is envisioned to provide the soldier precision—one shot, one kill. Having NLOS-LS on the ground, on time and interoperable with the current force, as well as ready to progress with the Future Combat System, says it all."

Northrop Grumman's C-MANPADS System Achieves 12,000 Operating Hours

Northrop Grumman announced that its Guardian™ Counter-Man Portable Air Defense System (C-MANPADS) currently installed on nine wide-body aircraft flying commercial revenue service has achieved 12,000 on-aircraft operational hours.

"The program and system are a continuing success," said Robert Del Boca, sector vice president and general manager of Northrop Grumman's Defensive Systems Division. "The accumulation of operating hours in the intended environment is providing significant data regarding the veracity of the design. We will continue the flight test program for the next four months and anticipate ongoing positive achievements."

Northrop Grumman began Phase III of the US Department of Homeland Security's (DHS) C-MANPADS program in August 2006. The program is scheduled to conclude in March 2008 with a final report to DHS. The Northrop Grumman-led industry team has completed all program production and hardware delivery requirements and is currently fully engaged in daily flight test operations across the nation. As of October 12, the Guardian system has accumulated more than 2500 revenue service flights, logging more than 12,000 hours of on-aircraft time. The Guardian system is a defensive aid utilizing proven military technology to defend against the threat that anti-aircraft, shoulder-fired missiles poses to commercial aviation. Once launched, the missile is detected by the guardian system, which then directs a non-visible, eye-safe laser to the seeker of the incoming missile, disrupting its guidance signals and protecting the aircraft.

To date, Northrop Grumman has completed an extensive flight test program in commercial test operational environments that included the use of a ground-based electronic missile surrogate to simulate the launch of a shoulder-fired missile toward aircraft during takeoff and landing. The tests were performed on an MD-11, an MD-10 and a B-747 aircraft. In each test, the Guardian system functioned as designed, automatically detecting the simulated launch and mock missile.

The company's Guardian system makes use of multiband laser and other technologies from the company's military directional infrared countermeasure system, the only such protection system currently in production for the US military and several allied nations. Northrop Grumman's Guardian system was developed as part of the Department of Homeland Security's initiative aimed at protecting commercial aircraft from attack by ground-based, shoulder-fired missiles. The DHS program is focused on demonstrating the viability, economics and effectiveness of adapting existing military technology to protect commercial aircraft, both passengers and cargo, from this terrorist threat.

Lockheed Martin's Guided MLRS Rockets Successful in Anti-jamming Tests

Lockheed Martin successfully conducted two Guided Multiple Launch Rocket System (GMLRS) Unitary Rocket Phase II Product Qualification tests at White Sands Missile Range, NM. These "GPS2 jamming" tests demonstrated both GMLRS rocket performance while in a GPS jamming environment at long range, as well as the functionality of the warhead using the Point Detonating fuze within the jamming environment. All test objectives were achieved.

"Throughout the process to achieve these milestones, the highest levels in the Department of the Army, the Office of the Secretary of Defense and the Joint Staff have recognized the outstanding success of the GMLRS program," said Lt. Col. Mark Pincoski, US

Army product manager, Precision Guided Missiles and Rockets. "I wish to express my gratitude to the entire GMLRS team, without whose hard work and expertise, these milestones may have never been achieved. The efforts of the team are particularly significant due to the urgent need for the GMLRS Unitary Rocket in combating our nation's foes and the tremendous success it has demonstrated in combat." The two missions were fired from the HIMARS launcher using one rocket per mission after the launch pod container was conditioned to the "hot" temperature extreme. The first rocket employed the GMLRS "vertical trajectory shaping" software that allows the rocket to impact the target vertically, while the second incorporated the "nominal trajectory shaping" software, which allows for the standard ballistic trajectory flight pattern. Both rockets flew their expected trajectories and functioned as designed in the target area.

"The GMLRS Unitary rocket continues to demonstrate incredible capabilities which our warfighters need," said Al Duchesne, director of Missile and Rocket Programs at Lockheed Martin Missiles and Fire Control. "These tests validated a very tough requirement. This means that GMLRS Unitary can be effectively and productively employed every time—when low collateral damage is a concern and in close proximity to friendly troops—given its surgical precision." The tests further qualified the effects of the unitary warhead on the target following detonation and continued to demonstrate that the Follow-On configuration hardware and software design complies with the program objectives and requirements. "This mission specifically demonstrated rocket performance and provided system performance data in a GPS jamming environment," Pincoski concluded.

Raytheon Wins $36.1 M US Air Force Paveway Contract

With the award of $36.1 M, Raytheon Co. has won the majority share of US Air Force competitive contracts for Paveway™ II laser guided bomb components for fiscal year 2007. This is the third consecutive Air Force majority share award for Raytheon, setting a benchmark for affordability and performance in the precision-guided weapons market. The $36.1 M contract calls for Raytheon to provide the Air Force with laser guided bomb computer controlled and air foil groups that transform conventional bombs into precision-guided munitions. The Air Force awarded Raytheon's Paveway II program the majority of the funding available for the fiscal year 2006 and 2007 laser guided bomb production awards, including the maximum computer control group award allowed under the competitive contract. Raytheon was also awarded the majority share of the Air Force competitive foreign military sales contracts for Paveway II in June 2007. ■

EADS DS and Astrium Win Satellite Intelligence Contract

The French armaments directorate (DGA) has awarded EADS Defence & Security and Astrium a contract worth €28 M for the design, development, installation and operational maintenance of the Portail Hôte d'Accès au Renseignement de l'Observation Spatiale (PHAROS) system. From 2009, PHAROS (an access portal for satellite intelligence) will enable the forces based in mainland France or deployed in theatres of operation abroad to have common access to the images acquired by the HELIOS (France), COSMO-SkyMed (Italy) and SAR-Lupe (Germany) military satellites and by Pléiades, the future French dual satellite system.

The technical solution proposed by the industrial group and accepted by the DGA is based on a services-oriented architecture and involves the use of innovative technologies deriving from both the civil sphere (virtualisation, image compression) and the military sphere (digitisation). The project will be implemented jointly by teams specializing in Intelligence Systems within EADS Defence and Communications Systems, the prime contractor, and Astrium Satellites Ground Systems, the joint leading contractor, who will also rely on the expertise of three subcontractors: Cap Gemini, Pixelion and GAEL Consultant.

Norwegian Chip Company Formed

New Norwegian chip company, Energy Micro AS, has been created by former key executives of Chipcon. The new company's stated aim is to create the industry's most energy friendly microcontrollers based on modern and powerful microprocessor architectures. The company has already received financial support from Innovation Norway and will seek to establish further financial support through other Norwegian Institutions. The founders and early employees will invest a total of $1.5 M in start-up capital.

Geir Førre, president and CEO of Energy Micro, was previously co-founder and CEO of Chipcon, a successful semiconductor company focusing on low power RF products. Chipcon was acquired by Texas Instruments for $200 M in January 2006. Øyvind Janbu, CTO of Energy Micro, was one of the early employees at Chipcon and held several key technical positions within the company. The company aims to be fully operational on 1 January 2008.

Førre said, "We aim to fund the company development ourselves during the first two years of operations. Thereafter we will invite external investors to participate in Energy Micro. All new employees will also be offered stocks in the company, at a level that really matters. Our 10-year goal is to establish over a 1 percent market share in a market that today is worth more than $15 B and growing more than five percent per year."

STMicroelectronics and ACS Support VII Initiative

STMicroelectronics and Automotive Communications Systems (ACS) are to jointly develop communications integrated circuits for Vehicle and Infrastructure Integration (VII). The VII initiative is investigating the potential safety benefits of car-to-car and car-to-roadside high-speed communications. Contributors include the US Federal Government, state governments, the world's leading car companies, suppliers, consultants and others. This programme is part of a plan to significantly improve roadway safety and utilization, lower travel times and provide unprecedented access to information for the driving public.

As a long time leader in automotive electronics and semiconductor manufacturing, STMicroelectronics brings to the relationship significant technology and product expertise in the automotive semiconductor arena as well as communications and location expertise. ACS brings a patent pending architecture for resolving some of the major challenges facing the VII initiative such as channel access, reliability of communications, and precision vehicle location at a much lower cost than current solutions.

QinetiQ is a Good LISTENER

QinetiQ, as part of the KAIROS Consortium, which L-3 Communications leads and also includes LogicaCMG, has been awarded a share in a £1 M, 10-month UK MoD contract for the Assessment Phase of Project LISTENER, for risk reduction and solution definition. The Project integrates sensor products in order to provide actionable intelligence against selected targets and to achieve interoperability between UK Intelligence, Surveillance, Target Acquisition and Reconnaissance (ISTAR), and US and Coalition systems and networks, and aims to dramatically improve target location accuracy, timeliness and combat identification for the war fighter. Main Gate approval is expected in 2009 for follow-on demonstration and manufacturing through 2015.

L-3 will be prime contractor, providing programme management, airborne platform integration, and systems engineering for requirements development and test and evaluation. QinetiQ is leading in the areas of land and sea platform integration, human factors, training and operational analysis, and is involved in architecture and technology development. LogicaCMG will look at integrated logistics support, security and communications, and L-3 has committed to perform at least 60 percent of the LISTENER effort in the UK.

"Project LISTENER is blazing the trail for UK network-enabled capability," said Bob Drewes, president of L-3's Integrated Systems Group. "It takes advantage of our success in fielding the Network Centric Collaborative Targeting capability, modified for the UK collection, processing, dissemination and security context."

ITU Banks on AfDB to Support African Interconnection

The International Telecommunication Union (ITU) and the African Development Bank (AfDB) have agreed to collaborate on interconnecting all African capitals and major cities with ICT broadband infrastructure and strengthen connectivity to the rest of the world by 2012. As part of this collaboration, both organisations will actively mobilize partners and financing to close ICT broadband infrastructure gaps between major centres in Africa.

AfDB hosts the Secretariat of the African Infrastructure Consortium, which brings together major donors and financial institutions active in the region. This group plays a crucial role in the financing of projects, as well as in ensuring a coherent approach among those involved. To support the implementation of ICT infrastructure projects funded by the AfDB or other interested financing partners, the ITU will serve as an executing agency and provide telecommunications expertise and technical assistance, where the need arises. It will also mobilize its base of more than 650 Sector Members, including many leading ICT industry players.

The ITU and AfDB will jointly undertake feasibility studies and develop project proposals in consultation with Member States and other stakeholders in the region. With the aim of rationalizing available funds and building on efforts in other sectors, the two organisations will also work together to promote wider integration of ICT with other major infrastructure investments. This would include laying broadband fibre alongside transport and energy projects, as well as encouraging innovative infrastructure sharing approaches among telecommunication/ICT operators.

Commenting on the challenge ahead, the president of the AfDB, Donald Kaberuka, said, "In recent years, private investment in ICT infrastructure, especially in mobile phone networks, has had an enormous impact in many parts of Africa, but major gaps remain. The development banks and other financing partners have a responsibility to step in where these gaps are holding back development in the region." ■

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Male to Male					
CBL-1.5FT-SMSM+	SMA	1.5	0.7	27	68.95
CBL-2FT-SMSM+	SMA	2	1.1	27	69.95
CBL-3FT-SMSM+	SMA	3	1.5	27	72.95
CBL-4FT-SMSM+	SMA	4	1.6	27	75.95
CBL-6FT-SMSM+	SMA	6	3.0	27	79.95
CBL-10FT-SMSM+	SMA	10	4.8	27	87.95
CBL-12FT-SMSM+	SMA	12	5.9	27	91.95
CBL-15FT-SMSM+	SMA	15	7.3	27	100.95
CBL-2FT-SMNM+	SMA to N-Type	2	1.1	27	99.95
CBL-3FT-SMNM+	SMA to N-Type	3	1.5	27	104.95
CBL-4FT-SMNM+	SMA to N-Type	4	1.6	27	112.95
CBL-6FT-SMNM+	SMA to N-Type	6	3.0	27	114.95
CBL-15FT-SMNM+	SMA to N-Type	15	7.3	27	156.95
CBL-2FT-NMNM+	N-Type	2	1.1	27	102.95
CBL-3FT-NMNM+	N-Type	3	1.5	27	105.95
CBL-6FT-NMNM+	N-Type	6	3.0	27	112.95
CBL-15FT-NMNM+	N-Type	15	7.3	27	164.95
CBL-20FT-NMNM+	N-Type	20	9.4	27	178.95
CBL-25FT-NMNM+	N-Type	25	11.7	27	199.95
Female to Male					
CBL-3FT-SFSM+	SMA-F to SMA-M	3	1.5	27	93.95
CBL-2FT-SFNM+	SMA-F to N-M	2	1.1	27	119.95
CBL-3FT-SFNM+	SMA-F to N-M	3	1.5	27	124.95
CBL-6FT-SFNM+	SMA-F to N-M	6	3.0	27	146.95

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RF/IF MICROWAVE COMPONENTS

403 Rev I

New Competition Heats Up the Market for RF Power Amplifier Vendors

Chinese vendors, led by Huawei Technologies and ZTE, have become more active in the RF power amplifier market with significant effect on the device market. "This is both an opportunity and a threat," says ABI research director Lance Wilson. "The Chinese position in the RF power amplifier and device market is not insignificant. Growing Chinese participation is an addition to the markets, but at the same time represents competition for incumbent vendors."

Much of the Chinese output is directed at the domestic market, where it will reduce earlier demand for equipment sourced from elsewhere. The start of TD-SCDMA network deployment in China will also contribute to overall market size.

A recent ABI Research report on this market points to two significant factors that have changed the market landscape in recent months: the entry of Chinese vendors and the growing use of high efficiency amplifier designs. Moreover, updated ABI Research forecasts for the global RF power amplifier market indicate that while the total available market for these essential cellular base station equipment components is shrinking, the decline is not as severe as had been feared.

"The RF power amplifier market for this segment is still showing a downward trend," explains Wilson, "but the good news is that the descent is not as precipitous as originally thought. Though basic GSM is slowly declining, EDGE has satisfied the data needs of many users to a greater extent than anticipated. Many operators are becoming more wary of big 3-G related spending. The result is that such GSM-based systems have enjoyed a longer life cycle, which in turn stretches out the growth period of 3-G. This has a direct impact on what happens in the power amplifier and devices market."

High efficiency RF amplifiers for wireless infrastructure are starting to enter the mainstream and will be seen in increasing quantities over the next five years. Greater amplifier efficiency means lower base station costs in initial price, lower power consumption and operating cost.

The recent ABI Research report, "RF Power Amplifiers: Equipment and RF Power Device Analysis for Cellular Mobile Wireless Infrastructure Markets," examines amplifier cost, size and efficiency, illuminates the relationship of power semiconductors to RF amplifiers and presents quantitative market forecasts through 2012 for both segments. It forms part of three ABI Research Services: RF Power Devices, Wireless Semiconductors and Wireless Infrastructure.

ABI Research is a market research firm focused on the impact of emerging technologies on global consumer business markets. Visit www.abiresearch.com for more information.

Ultra-wideband Devices Finally Hitting Store Shelves

According to In-Stat, after years of promises, Ultra-wideband (UWB) devices are finally here. Based on short range, high data rate radio technology, most early UWB-enabled devices deliver in the range of 40 to 100 Mbps, with future devices delivering much higher speeds.

The first UWB device to hit the market was a Toshiba R400S4834 notebook PC and docking station. The two devices connect wirelessly using a UWB chip solution provided by start-up WiQuest. Lenovo also launched UWB in its T61 notebook and Dell has recently launched UWB in its Inspiron line of notebooks. UWB backers hope that these PC design wins lead to a UWB ecosystem that encompasses not only PCs, but PC peripherals, consumer electronics (CE) and mobile devices.

While notebooks with embedded UWB are great, what about the millions of PCs already in homes and businesses across the world without UWB? These devices can jump on the UWB bandwagon through hub and dongle solutions. The UWB dongle connects to the PC's USB port and connects wirelessly to the UWB hub. The UWB hub, in turn, connects via USB cables to peripherals such as printers and multifunction devices, as well as CE devices, including digital still cameras and portable media players. Belkin, IOGear and D-Link hub and dongle solutions are currently available for prices as low as $150. Hub and dongle solutions represent an intermediate step between a world of USB cables and a world of embedded wireless connectivity in PCs and devices that connect to PCs.

UWB radio technology in turn can support a number of standards. UWB serves as the basis for the Certified Wireless USB and high data Bluetooth specifications. The certified Wireless USB standard has been approved and is the basis for the hub and dongle solutions hitting the market. The specification for high data rate Bluetooth, also referred to as Bluetooth 3.0, should be completed in 2008, with devices hitting the market by the second half of 2009. Other UWB standards and technologies include IP over UWB (also known variously as WiNet, WLP or WXP), and video over UWB.

The future of UWB devices is fairly bright. The next few years will be spent seeding the PC and PC peripheral marketplace with UWB enabled devices, with CE and mobile devices hitting the market in late 2009 and 2010. Overall, UWB-enabled devices should see abundant growth through 2011.

In-Stat is a provider of actionable research, market analysis and forecasts of advanced communications services, infrastructure, end-user devices and semiconductors. Visit www.instat.com for more information.

Commercial Market

GPS Chip Market Driven by Integration into Mobile Devices

Over the next few years, the GPS chipset market will be driven by integration into mobile devices, including personal navigation devices (PND), cellular headsets, mobile PCs and a variety of portable consumer electronics (CE) devices, reports In-Stat. The most promising portable CE categories include ultra mobile devices (UMD), handheld games, portable media players and digital cameras, the high-tech market research firm says. "Although there are external GPS receivers available for mobile PCs, PDAs, smartphones, digital cameras, handheld games and other portable CE devices, volumes for these applications have been limited," says Gemma Tedesco, In-Stat analyst. "Integration of GPS within these products will allow for more widespread use of GPS and will spur much greater GPS chipset shipment volumes."

Recent research by In-Stat found the following:

- Currently, the two largest mobile device market segments for GPS chips are cellular handsets and personal navigation devices.
- Sales of mobile devices with integrated GPS are expected to grow from 180 million units in 2007 to 720 million units in 2011.
- The cellular handset market, especially the WCDMA space, will be a major battleground for GPS chipset vendors.

The research, "GPS Chips in Mobile Devices," covers the worldwide market for GPS chipsets integrated into mobile devices. It provides worldwide forecasts for GPS chipset shipments, by device category, through 2011. It also includes analysis of market trends, featuring a look at device segments that hold promise for growth. Profiles of GPS IC vendors are provided, including Qualcomm, SiRF, Broadcom, TI, u-blox, NemeriX, eRide, CSR, CellGuide, GloNav, Infineon, SiGe Semiconductor, STMicroelectronics, SkyTraq and MediaTek. In addition to the report, Gemma and other In-Stat analysts provide consulting services on a variety of technical and market topics regarding the semiconductor and electronics industries. For more information, visit www.instat.com.

This research is part of In-Stat's Cellular and Wireless Broadband Technologies service, which analyzes worldwide semiconductor component trends within the cellular, Wi-Fi, WiMAX and other emerging wireless broadband technology markets. This service provides comprehensive coverage of cellular and wireless broadband IC component markets and trends within mobile devices, Customer Premises Equipment (CPE) and infrastructure. ■


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INDUSTRY NEWS

■ **Theodore "Ted" L. Kozul** died November 6th, in his home after a long illness. He was 80 years old. Ted was the founder and president of Baytron Co., one of the first companies to offer a full line of millimeter-wave components. His products looked like jewelry and were the standard for many years. Baytron was acquired by M/A-COM in the early '80s, but was later divested and the company was re-established as Aerowave Inc. Aerowave is still in business today under the leadership of Ted's son, Leon Kozul. Ted was a member of the IEEE and a veteran of WWII. He was an active participant at MTT-S exhibitions for many years and was well known and respected throughout the industry.

■ On October 12, 2007, the business known as **Sage Laboratories Inc.** was acquired by **TRU Holdings Inc.** Sage Laboratories designs and manufactures RF and microwave components and subsystems for technically demanding applications. Sage solutions are targeted to OEMs and prime contractors in the space, defense, homeland security, medical and commercial markets. TRU Holdings Inc.'s strategy is to build a diverse group of leading RF and microwave technology companies focused on the design, development and manufacture of innovative solutions across the space, defense and commercial markets.

■ WiMAX test leader **Aeroflex** and **Sequans Communications**, a developer of WiMAX semiconductor solutions, have entered into a test technology partnership. Under the terms of the partnership, the two companies will collaborate closely to further speed the ongoing development of their respective WiMAX solutions. Sequans will provide Aeroflex with early access to its new and upgraded WiMAX semiconductor solutions and reference designs. Aeroflex will use them for the ongoing verification of its WiMAX Protocol Conformance Tester (PCT) that is being developed under the auspices of the WiMAX Forum.

■ **Hittite Microwave Corp.** announced that it has entered into a strategic agreement with **Northrop Grumman** to license Northrop Grumman's Velocium line of Monolithic Microwave Integrated Circuit (MMIC) products and related intellectual property. Under the agreement, Northrop Grumman's Space Technology sector will license to Hittite a specified list of standard products and associated technology. Hittite will assume the related customer contracts and will become the worldwide supplier for the Velocium products.

■ **Acceleware® Corp.**, a developer of high performance computing (HPC) solutions, announced a partnership agreement through which **Agilent® Technologies** will resell the Acceleware acceleration products throughout its worldwide sales organization to Agilent Antenna Modeling Design System (AMDS™) customers. Agilent is the leading supplier of electronic design automation (EDA™) software for high frequency system, circuit and modeling applications. Acceleware develops the fastest electromagnetic solver technology available on the market. These combined technologies will produce immense benefits for AMDS customers by increasing speeds of simulation processing by more than 35 times, thus reducing the time required to run a typical simulation from 10 hours to under 20 minutes.

■ **Andrew Corp.** and **Nokia Siemens Networks** have agreed to revise their long-standing relationship in custom filter production. The agreement provides more design and manufacturing control to Nokia Siemens Networks, supported by Andrew's research and development expertise, as it readies to market its next generation radio frequency filter products. Under the agreement, Nokia Siemens Networks acquired the rights to all Andrew intellectual property related to Nokia Siemens Networks' filter products for wireless networks.

■ **Ideal Aerosmith Inc.** has entered into a cooperative effort with **Diamond-Roltran LLC** to demonstrate the use of Roll-Rings® in rate tables. Roll-Rings will allow Ideal Aerosmith's products to benefit from higher performance while experiencing lower life cycle costs.

■ **Mini-Circuits** received numerous industry awards in 2007 as well as in previous years. Most recently, **Huawei Technologies**, one of the world's most respected telecommunications companies, named Mini-Circuits "The Excellent Supplier." **Rockwell Collins** is also among the company's customers that have recognized Mini-Circuits during this past year. The avionics giant named Mini-Circuits a top supplier on three separate occasions this year and four times last year. In 2006, one of the awards received from Rockwell-Collins was the coveted "President's Award," the highest accolade that a supplier can receive.

■ **Auriga Measurement Systems LLC** announced the opening of its European-based sales office in The Netherlands. The office will support all European sales and service for the company. **Hi-Tech Electronics** in The Netherlands, Auriga's reseller for the Benelux territory, will work for Auriga as a dedicated sales management arm and technical support system for the rest of Europe. The European office is comprised of: Olaf Biezeman; Arnout Peters, sales director, Europe; Jim Creed, applications manager, Europe; and Bjorn Hendrikx, account manager, Europe. Contact information: ph: +[31] 346 550660 or e-mail: europeansales@auriga-ms.com.

■ **Skyworks Solutions Inc.**, an innovator of high performance analog and mixed signal semiconductors enabling mobile connectivity, announced that given heightened de-

mand for its products from tier-one handset OEMs and a diverse set of analog customers, it is expanding its manufacturing capacity. Skyworks has already commenced the conversion of its internal gallium arsenide heterojunction bipolar transistor (HBT) fabrication facility in Newbury Park, CA, from 4 to 6 inch wafers. The company is also complementing its internal manufacturing capabilities by expanding partnerships with several leading Taiwanese foundries.

■ **RF Micro Devices** (RFMD®) announced plans to expand its compound semiconductor manufacturing capacity to support growth expectations in the company's cellular and multi-market product groups. RFMD anticipates increased demand for its industry-leading compound semiconductor process technologies as a result of favorable market trends in the company's primary markets. In the cellular handset market, the increasing adoption of highly integrated, multi-chip transmit modules and the migration to 3G multimode devices are expected to drive increased demand for RFMD's GaAs PHEMT and RFMD's GaAs HBT (both AlGaAs HBT and InGaP HBT).

■ **Nextreme**, a manufacturer of micro-scale thermal and power management products for the electronics industry, is relocating and expanding its North American corporate headquarters and manufacturing facility within Research Triangle Park, NC. Increasing Nextreme's production capacity, the 14,000 square-foot, state-of-the-art facility includes semiconductor grade clean rooms and an advanced application laboratory to better serve customer needs as Nextreme enters product qualification, pilot production and ultimately volume production. Nextreme's new facility is located at 3908 Patriot Drive, Durham, NC 27703. Nextreme expects to complete the move by the end of December 2007.

■ **Ion Beam Milling Inc.** announced that it has further increased its dicing capacity with the purchase of a third Disco dicing system. Due to increasing customer orders the addition of the third Disco dicing system positions Ion Beam Milling to serve its current customers as well as prepare for future growth in the microelectronics, photonics and medical industries. Ion Beam Milling recently celebrated its 25th year in business.

■ **Keithley Instruments Inc.**, a leader in solutions for emerging measurement needs, announced that the American Association for Laboratory Accreditation (A2LA) has accredited Keithley's German service center to ISO/IEC 17025:2005, a metrology standard for test and measurement products. At the same time, the Metrology Services Department at Keithley's Cleveland, OH headquarters, which received A2LA ISO/IEC 17025:2005 accreditation a year ago, dramatically expanded its capabilities to add even more Keithley products to its list of accredited calibration offerings.

■ **Integrated Test Corp.**, a manufacturer of high performance ATE printed circuit boards and ATE test interface hardware, announced that its Dallas, TX facility has been certified to meet ISO 9001:2000 standards. WCS Quality Registrars LLC, the North American division of World Certifications Service Ltd., conducted the audit.

■ **Alereon Inc.**, an ultra-wideband (UWB) technology leader for WiMedia and Certified Wireless USB applications, has successfully completed the official WiMedia Alliance Registration Program for its AL5300/4100 and AL5300/5100 WiMedia chipsets, both members of the company's AL5000 family, which is based on the WiMedia common radio platform.

■ **Symmetricom Inc.**, a leader in precise time and frequency technologies that accelerate the deployment and enable the management of next generation networks, announced its XLi SAASM Time and Frequency Receiver with a new Ground-based GPS Receiver Application Module (GB-GRAM) SAASM receiver has been granted security approval by the Global Positioning Systems Wing (GPSW), meeting the latest security requirements of the Department of Defense (DoD). The GB-GRAM GPS Receiver is integrated into Symmetricom's XLi SAASM, an ultra precision time and frequency instrument.

■ **AR RF/Microwave Instrumentation** has announced that its family of advanced laser probes—models FL7030 (5 kHz to 30 MHz), FL7006 (0.1 MHz to 6 GHz) and FL7018 (3 MHz to 18 GHz)—will now be offered with a NIST traceable calibration with A2LA accreditation at no additional charge. The company previously sold its laser probes with a NIST traceable calibration only, with the option of having them calibrated with A2LA accreditation.

■ **Jacket Micro Devices Inc.**, a supplier of integrated RF modules for high performance wireless products, has received notification of issuance of a European patent for "liquid crystalline polymer (LCP) and multilayer polymer-based passive signal processing components for multiband applications." The patent covers fabrication of organic passive components, including bandpass filters, baluns, diplexers, multiplexers, couplers and combinations of these devices made using LCP and other multilayer polymer substrates.

■ Having previously recognized **State of the Art Inc.** (SOTA) with its 2006 Supplier Excellence Award, Honeywell FMT (Kansas City, MO) nominated SOTA to the Department of Energy for further recognition. It has now been announced that SOTA has been honored with the United States Department of Energy Small Business Manufacturing Firm of the Year award for fiscal 2006. Consideration for this award is based on the areas of quality performance, order administration, cost control, technical support, responsiveness and delivery performance along with other factors.

■ **TREK Inc.**, a designer and manufacturer of high performance electrostatic instrumentation and high voltage power amplifiers, recently received the 2007 EuroAsia IC Industry Award. TREK's Infinitron™ (an innovative electrostatic voltmeter) won in the category of "Yield Management – Best Process" during special award ceremonies held in San Francisco, CA.

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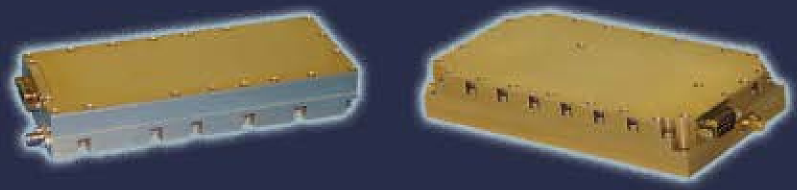

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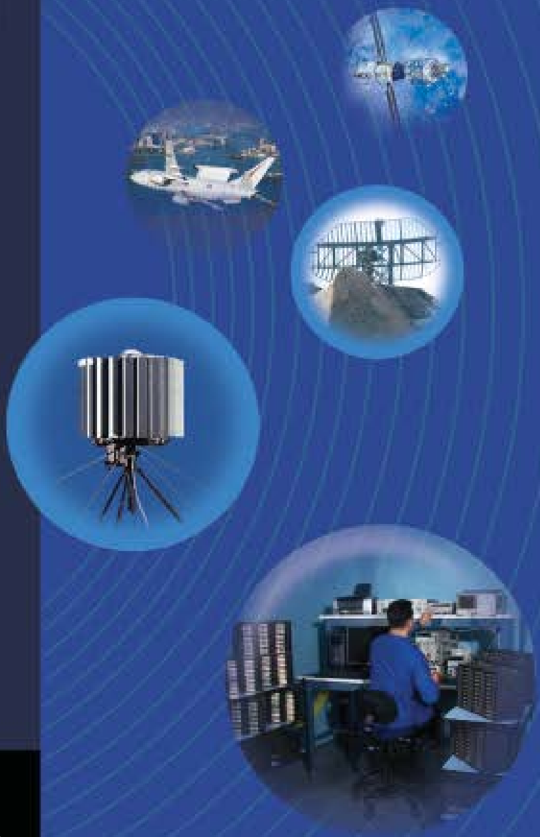
VHF/UHF Narrow Band	100+ Watts	60 - 80%*
L Band	100 - 200 Watts	50 - 67%*
S Band	50 - 100 Watts	50 - 65%*
Higher Frequencies C Band and X Band	20 - 50+ Watts	40 - 60%*

** Note: Bandwidth dependent.*



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CONTRACTS

■ **MI Technologies** announced it has received a $9.9 M contract from **Lockheed Martin** MS2's Radar Systems business to design and build a radar test and measurement system in support of the Medium Extended Air Defense System (MEADS). Under terms of the contract, MI Technologies will provide a large, spherical, near-field measurement system at Lockheed Martin's Liverpool, NY facility, which will be used to analyze and characterize a 16' × 16' (4.9 m × 4.9 m) ground-based phased-array antenna.

■ **Elcom Technologies Inc.** announced the receipt of a new contract in excess of $4 M from a major United States military contractor, for a high performance VME-based synthesized RF source and synthesized broadband downconverter. These integrated microwave subsystems are used in support of critical military ATE applications, where consistent quality, reliability and performance at a competitive price are key components for success. This recurring contract will require support through 2009.

■ **Microsemi Corp.**, a manufacturer of high performance analog/mixed signal integrated circuits and high reliability semiconductors, has announced that the Air Force Research Laboratory (AFRL) has awarded $1.6 M to allow Microsemi's Power Products Group (formerly Bend, Oregon-based Advanced Power Technology) to develop technology related to the use of silicon carbide RF power semiconductor components in military avionics applications.

■ **COM DEV International Ltd.**, a manufacturer of space hardware subsystems, announced that it has been selected as prime contractor in an open bid process to provide a communication payload test system for **Orbital Sciences Corp.** The system will perform automated RF testing on communication satellite payloads, a function that is critical to the success of every mission.

■ **KOR Electronics** announced that a specialized version of its Miniature Airborne three-bit DRFM system is deployed on the recently declared Initial Operational Capability (IOC) of the AN/ALQ-188(V)4 Electronic Attack Training Pod for the US Air Force F-15 jet fighter. The AN/ALQ-188(V)4 pod provides generic capability to simulate enemy threat electronic countermeasures (ECM) for aircrew training and weapons evaluation. KOR Electronics supplied model 1275 DRFM to prime contractor Northrop Grumman's Quick Reaction Capability (QRC) Team in support of this IOC effort.

FINANCIAL NEWS

■ **TriQuint Semiconductor** reports sales of $122.9 M for the third quarter ended September 30, 2007, compared to $103.3 M for the same period in 2006. Net income for the quarter was $1.9 M ($0.01/per diluted share), compared to a net income of $8.1 M ($0.06/per diluted share) for the third quarter of last year.


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■ **Tower Semiconductor Ltd.** reports sales of $57.1 M for the second quarter ended June 30, 2007, compared to $44.6 M for the same period in 2006. Net loss for the quarter was $34.4 M ($0.28/per share), compared to a net loss of $43.6 M ($0.55/per share) for the second quarter of last year.

■ **Ceragon Networks Ltd.** reports sales of $44.5 M for the third quarter ended September 30, 2007, compared to $30.5 M for the same period in 2006. Net income for the quarter was $4.1 M ($0.13/per diluted share), compared to a net income of $1.9 M ($0.07/per diluted share) for the third quarter of last year.

■ **RF Monolithics Inc.** reports sales of $14.8 M for the fourth quarter ended August 31, 2007, compared to $14.5 M for the same period in 2006. Net loss for the quarter was $1.3 M ($0.14/per diluted share), compared to a net income of $77,000 ($0.01/per diluted share) for the fourth quarter of last year.

■ **RF Industries Ltd.** reports sales of $4.3 M for the third quarter ended July 31, 2007, compared to $3.9 M for the same period in 2006. Net income for the quarter was $434,000 ($0.12/per diluted share), compared to $407,000 ($0.11/per diluted share) for the third quarter of last year.

NEW MARKET ENTRIES

■ **White Mountain Labs**, a leader in test and characterization of advanced technologies, now offers complete electrical characterization of semiconductor products through its Automated Test Equipment (ATE) division, ClearTest ATE Services. The new business offering, called CZ Express, is a standardized methodology, which analyzes a sample of customer devices over temperature, voltage and process variation, and then generates a comprehensive characterization report back to the customer. The report becomes a valuable tool for the customer product engineer, as it identifies possible sensitivities that could develop into yield issues when the device is released to volume production.

■ **New Era Electronics Ltd.** (NEE), a world leader in volume production of microwave printed circuit boards, together with **EastBridge Partners LLC**, a global business consultancy specializing in Asia business development, have established **NEE International LLC**, to act as the sales, marketing and technical service company for NEE outside of Asia. Located in Phoenix, AZ, NEE International is chartered with creating a microwave knowledgeable sales force and expanding sales, primarily in the US and Europe.

PERSONNEL

■ Park Electrochemical Corp. announced the appointment of **Matthew Farabaugh** as vice president and controller. Farabaugh was corporate controller of American Technical Ceramics, a publicly traded international company located in Huntington Station, NY, from 2004 to September 2007 and assistant controller from 2000 to 2004.

▲ *Joseph G. Streko II*

■ ET Industries, a pioneer in providing innovative wireless solutions and RF components, recently announced the appointment of **Joseph G. Streko II** as vice president and director of operations. Prior to joining ET Industries, Streko was the vice president of sales and marketing with Diamond Technology. Previously, Streko held the position of vice president of sales with Integrated Solutions. With nearly 20 years of experience in the telecommunications industry, Streko's responsibilities with ET Industries will include the company's overall strategy, operations and business growth.

■ Kaben Wireless Silicon Inc., a wireless semiconductor design company, announced the appointment of **James S. Wight** as chief scientist. In his new role, Wight will be responsible for spearheading Kaben's development activities in innovative RF technologies. He will also be instrumental in marketing projects aimed at enhancing the company's industry standing as the world's authority in frequency synthesis and advanced filtering which are at the core of most wireless integrated circuits. Wight is an RF industry veteran with over 30 years of experience in antennas, microwave circuits, and synchronizer circuits for wireless communications, radar and radio navigation.

▲ *Monnie Weems*

■ King Aerospace Commercial Corp. (KACC) announced that **Monnie Weems** has joined the company as avionics manager. Weems has two decades of corporate and military experience as an avionics manager, technician and installer. He has demonstrated expertise with installation, troubleshooting and modifying avionics and electrical systems on a wide range of corporate aircraft. Prior to joining King Aerospace, Weems worked for Tyler Jet, Gulfstream, Galaxy Aerospace, McKinney Aerospace, PHAZAR Aerocorp and MAV Aircraft Services.

REP APPOINTMENTS

■ **Richardson Electronics Ltd.** announced it has signed a global partnership agreement with **Valpey Fisher**, to distribute its entire product line of high performance crystal oscillators and timing modules. Valpey Fisher's products provide the essential timing signals needed in advanced applications including cellular base stations, broadband datacom infrastructure, avionics instrumentation, homeland security equipment and military defense systems.

■ **Digi-Key Corp.** and **Crystek Corp.** announced that the companies have entered into a global distribution agreement. Crystek products stocked by Digi-Key are featured in its print and online catalogs and are available for purchase directly from Digi-Key. This new distribution agreement will enable Digi-Key to fulfill both the prototype/design and production quantity needs of its diverse customer base.

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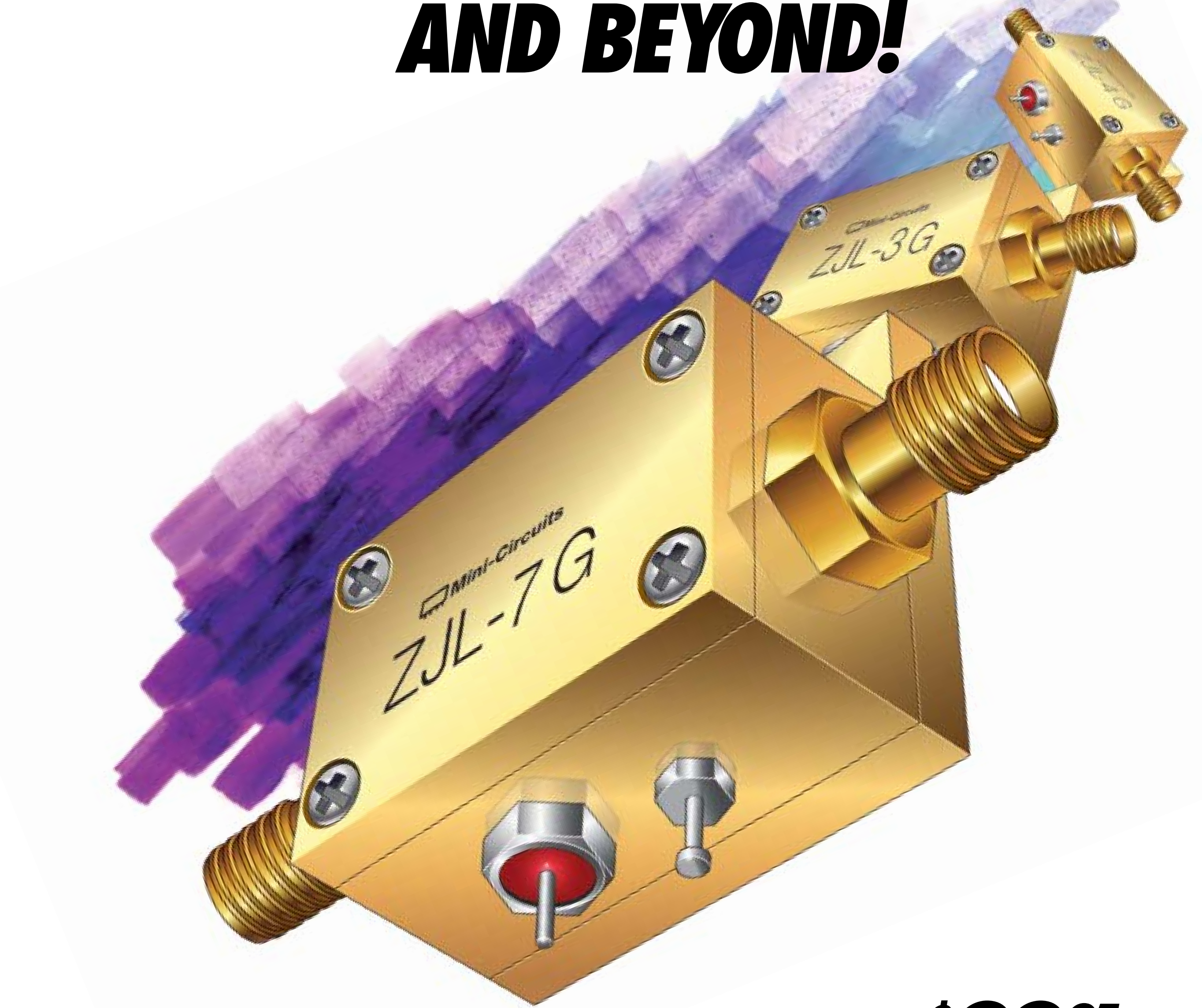

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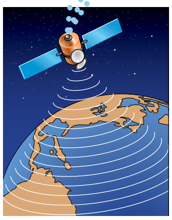

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SPECIFICATIONS

Model	Freq (MHz)	Gain (typ) Midband (dB)	Gain (typ) Flat (±dB)	Max. P_{out}1 (dBm)	Dynamic Range (Typ @2 GHz[2]) NF(dB)	Dynamic Range (Typ @2 GHz[2]) IP3(dBm)	I(mA)[3]	Price $ea. (1-9)
ZJL-5G	20-5000	9.0	±0.55	15.0	8.5	32.0	80	129.95
ZJL-7G	20-7000	10.0	±1.0	8.0	5.0	24.0	50	99.95
ZJL-4G	20-4000	12.4	±0.25	13.5	5.5	30.5	75	129.95
ZJL-6G	20-6000	13.0	±1.6	9.0	4.5	24.0	50	114.95
ZJL-4HG	20-4000	17.0	±1.5	15.0	4.5	30.5	75	129.95
ZJL-3G	20-3000	19.0	±2.2	8.0	3.8	22.0	45	114.95
ZKL-2R7	10-2700	24.0	±0.7	13.0	5.0	30.0	120	149.95
ZKL-2R5	10-2500	30.0	±1.5	15.0	5.0	31.0	120	149.95
ZKL-2	10-2000	33.5	±1.0	15.0	4.0	31.0	120	149.95
ZKL-1R5	10-1500	40.0	±1.2	15.0	3.0	31.0	115	149.95

NOTES:
1. Typical at 1 dB compression.
2. ZKL dynamic range specified at 1 GHz.
3. All units at 12V DC.

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RF/IF MICROWAVE COMPONENTS

232 Rev F

■ **LeCroy Corp.**, a provider of oscilloscopes, announced a new exclusive government services partnership agreement with **Technical Communities Inc.**, the premier one-stop service solution for technical organizations that sell to US government agencies, military organizations and prime federal contractors. Technical Communities is the owner and operator of GSAMart, TestMart, NAVICP-Mart and EurekaSpot. The agreement authorizes Technical Communities to present a catalog of LeCroy oscilloscopes ranging from 100 MHz to 100 GHz.

■ **Eastern Wireless TeleComm Inc.**, a custom designer and manufacturer of RF and microwave filters and filter-based products for military, commercial, wireless and space applications, announced the appointment of two new representatives for the company's products. **Brennan Associates** will be responsible for the company's products in the territories of Georgia, Alabama, Mississippi, Tennessee and Florida. **Val Jackson & Associates** will cover the territories of northern California, northern Nevada, Oregon and Washington.

■ **Diamond Antenna & Microwave Corp.**, a manufacturer of microwave rotary couplers, located at 59 Porter Road, Littleton, MA 01460, announced the appointment of **KJS Marketing Inc.** (www.kjsmarketing.com) to represent Diamond in Illinois, Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, South Dakota and Wisconsin.

■ **Crystek Corp.** has signed an agreement with **Allied Electronics**, a subsidiary of Electrocomponents plc, naming Allied as a distributor of Crystek's portfolio of frequency control technology. Allied will carry a broad range of products from Crystek, including quartz crystals, clock oscillators, TCXOs, OCXOs, VCXOs and VCOs.

■ **Coaxial Dynamics** has appointed **Y C International** as its representative in South Korea. Based in Seoul, the company's main objective is to continue its business as an importer and distributor of professional electronic equipment such as RF/microwave, wireless communication and broadcast engineering products. Contact information: Y C International, Samsun Building #610, 891-46 Daechi-Dong, Kangnam-Gu, Seoul, 135-810, Korea, Yungchul Kim, president, ph: +82 2 538 2707, fax: +82 2 538 2709, e-mail: ycintl@kornet.net or visit: www.ycinternational.co.kr/.

■ **Weinschel Associates**, a designer and manufacturer of high quality broadband RF and microwave products for commercial and military markets, announced the appointment of **Bradford RF Sales**. Bradford RF Sales will cover the New England territory, including Maine, New Hampshire, Vermont, Connecticut, Massachusetts and Rhode Island. Contact information: Mike Crittenden, 86 South Cross Road, Bradford, MA 01835 ph: (978) 521-1701, fax: (978) 521-7001 or e-mail: mike_bradfordrfsales@comcast.net.

STRATEGY FOR RFID VALIDATION AND VERIFICATION USING SOFTWARE-DEFINED INSTRUMENTATION

The global market for radio frequency identification (RFID) continues to expand as the technology repeatedly demonstrates real benefits across multiple application areas at lower cost. To take full advantage of this growing market, companies continue to investigate ways to differentiate themselves through time to market, better performance and research into new implementation methodologies. At the same time, ongoing research is leading to new target applications and standards. For example, the benefit of short-range wireless communication is driving the growth of near field communication (NFC), a technology based on short-range 13.56 MHz RFID, in applications such as tire pressure monitoring and contactless payment.

This pressure to quickly get to market with a differentiated product compounds the already difficult challenges of testing RFID devices. A flexible test strategy is needed to meet current and future test requirements in order to:

- Reuse test and development efforts for existing and developing standards
- Address evolving regional RF regulations
- Enable in-depth analysis leading to performance and interoperability benefits for product differentiation

Such a strategy can benefit greatly from software-defined instrumentation using techniques similar to another fast-growing RF field, software-defined radio. To illustrate these benefits, this article briefly covers the technology behind RFID, the basic testing requirements and a software-defined instrumentation strategy to meet these challenges.

RFID TECHNOLOGY

It is important to note that RFID covers a tremendous range of applications. Each target application has requirements for communication

SEAN THOMPSON
National Instruments
Austin, TX

range, managed asset lifetime, regional RF regulations and information to be tracked. This has led to multiple implementation strategies within RFID, containing a variety of RF and communication techniques. However, while there are many different implementations, the basic model remains consistent.

RF Interface

At the heart of RFID technology is the interface between the reader (or interrogator) and the tag (or transponder). ***Figure 1*** shows the basic components of the reader: a transceiver, antenna or coil, and the embedded signal processing that implements a particular standard and application. The tag is composed of an antenna, a silicon memory chip and the substrate on which both are mounted. In the case of active or semi-active tags, an onboard supply provides power. In passive tags, the RF signal sent from the reader supplies the power. The communication initiated from the reader is modulated on a CW signal that generates an AC voltage across the tag's antenna. This voltage is rectified to supply power, and the tag responds by alternating the loading of the antenna between absorptive and reflective to transmit data back to the reader. This process of backscattering results in small variations in the carrier's amplitude at about 60 to 70 dB down, which the reader must peak detect and decode according to the modulation and coding schemes defined by the standard. In many ways, implementations of passive tag systems represent the greater challenge for design and development. As a result, this article concentrates on passive design test.

RFID implementations are typically grouped into four frequency bands: low frequency (125 kHz), high frequency (13.56 MHz), ultra-high frequency (860 to 960 MHz) and microwave (2.45 GHz). The long wavelengths of low frequency (LF) and high frequency (HF) RFID standards necessitate the use of electromagnetic or inductive coupling between the reader and the tag. Read distances vary from a few centimeters to about 1 meter. By contrast, true RF links are used in ultra-high (UHF) and microwave standards, and distances in passive tag-based systems can reach 7 to 10 m. In general, higher carrier frequencies are attractive because of higher possible data rates and smaller tag sizes. However, not all applications have the same requirements, and advancements continue in all four categories. As a result, many companies must develop technology across multiple frequency bands. Many components, such as the software powering the embedded processing in the reader, can be used across different RF front ends.

Digital Communications: Modulation and Coding

Regardless of the frequency band, the manner in which data is passed over the RF link follows the fundamental functional blocks of any digital communications system.

Knowing this basic representation of these functional blocks within a receiver and transmitter (see ***Figure 2***)

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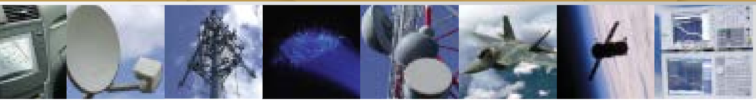

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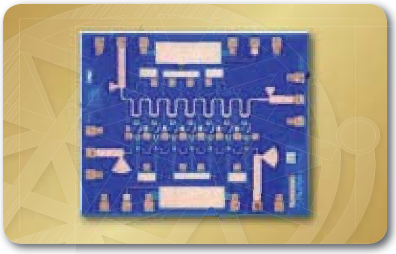

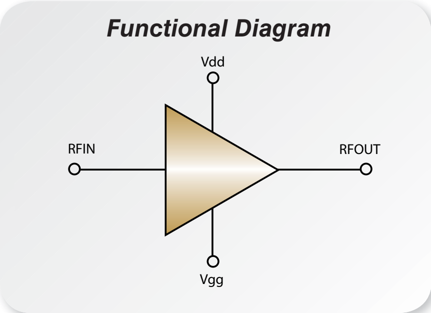

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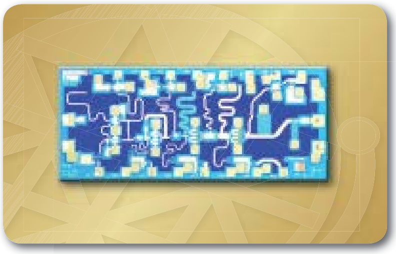
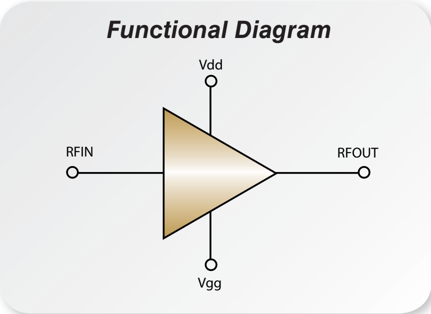
	Frequency (GHz)	Function	Gain (dB)	Group Delay Variation (ps)	Output P1dB (dBm)	Output Voltage Level (Vpk-pk)	VELOCIUM Part Number	HITTITE Part Number
NEW!	DC - 35	Wideband Optical Driver	15	±10	21	8	AUH249	**HMC-AUH249**
NEW!	DC - 45	Wideband Optical Driver	14	±10	16.5	8	AUH232	**HMC-AUH232**
NEW!	0.5 - 65	Wideband Optical Driver	10	-	-	2.5	AUH312	**HMC-AUH312**

HMC-AUH256 Microwave Driver Amplifier, 17.5 to 41 GHz





- Gain to 21 dB
- P1dB Output Power: +20 dBm
- Psat Output Power: +23 dBm
- Output IP3: +27 dBm

HITTITE - VELOCIUM WIDEBAND DRIVER AMPLIFIERS

	Frequency (GHz)	Function	Gain (dB)	P1dB (dBm)	Bias Supply	VELOCIUM Part Number	HITTITE Part Number
NEW!	17.5 - 41	Driver	21	20	+5V @ 295mA	AUH256	**HMC-AUH256**
NEW!	DC - 35	Wideband Driver	15	21	+5V @ 200mA	AUH249	**HMC-AUH249**
NEW!	DC - 45	Wideband Driver	14	16.5	+5V @ 180mA	AUH232	**HMC-AUH232**
NEW!	0.5 - 65	Wideband Driver	10	-	+8V @ 60mA	AUH312	**HMC-AUH312**

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is critical to understanding the benefits of a software-defined approach to test. For RFID, the emphasis is on two of the functional blocks: modulation and baseband signaling.

Modulation techniques for RFID communication are normally chosen for simplicity of design and, in the case of passive-tag systems, the use of the RF carrier as a power source. Common data modulation techniques used in RFID are amplitude-shift keying (ASK), frequency-shift keying (FSK) and phase-shift keying (PSK), although other schemes, such as phase jitter modulation (PJM), are being explored. In the UHF standard 18000-6 Type C, also known as EPC Class1/Gen2, the modulation schemes used for reader-to-tag (R->T) modulation are variations of ASK: double sideband ASK (DSB-ASK), single sideband ASK (SSB-ASK) and phase-reversal ASK (PR-ASK). SSB-ASK and PR-ASK are good examples of how specifications are evolving over time to improve performance. SSB-ASK eliminates one of the sidebands normally present in ASK modulation while maintaining the same information. This results in a reduced occupied bandwidth, which is especially important in regions such as Europe where a smaller spectrum is available in the UHF band. PR-ASK changes phase 180° on every symbol, creating a modulation depth of 100 percent as phase vectors of adjacent symbols cross and sum to zero. This provides for the lowest C/N requirement for error-free communication while minimizing the "off" time of the carrier, which maximizes carrier power for passive tags.

The second functional block of importance is baseband signaling. For RFID, pulse coding is used to convert between the bits representing the data on a tag and the baseband waveforms passed to the modulation block. Coding of a serial bit stream is used primarily to provide a more robust communication link resistant to noise and distortion. Coding schemes such as NRZ, FM and Miller differ in spectral characteristics, methods of error detection, synchronization and noise immunity while balancing simplicity of design and cost of implementation. One common coding scheme used in the uplink (T->R) is Manchester Coding (used in ISO 14443), where additional 1s and 0s are added to the bit stream to guarantee a level transition in the middle of each bit clock period. As a result, the bit stream is self-clocking and thus the complexity of synchronization is reduced within the tag. In a passive tag where power is at a premium, reduced complexity is obviously desirable.

RFID TEST

Testing RFID devices is a complex process with measurement requirements from a variety of sources. To begin, all electronic equipment manufacturers must meet regulatory requirements defined by local government bodies. Regulations limit transmitted signals in terms of power, bandwidth and frequency. Most regions also prohibit CW transmissions from devices unless used for a short period of time. Because passive tags use a CW signal from the reader for power as well as

communication, accurate timing measurements of independent transmissions become critical. In the case of passive tag-based RFID systems, there is only one true transmitter, the reader. Current regulatory laws do not have well-defined test procedures for passive tags. As a result, test strategies must adjust as different regions evolve their regulations.

Beyond regional regulatory testing, the primary source of test requirements is the RFID standard itself. Each standard contains a precise description of the physical layer of the communication link between tag and reader. RF parameters are often defined by detailed envelopes that illustrate power and timing requirements. ***Figure 3*** shows an example of the RF envelopes for reader-to-tag ASK and PR-ASK modulations defined in the standard for ISO 18000-6 Type C. Measurements must be made for modulation depth, envelope ripple, rise and fall times, and RF pulse width.

In addition, spectral masks define permissible RF emissions in frequency bands adjacent to the carrier under different conditions. ***Figure 4*** shows a spectral mask defined by the ISO 18000-6 Type C standard in an environment with multiple interrogators (readers). This mask is used when the number of interrogators is considerably less than the number of RFID channels available for communication. The standard has a different spectral mask defined for environments where the number of interrogators is large compared to the number of channels.

Finally, designers face the challenge of validating and improving RFID device performance under real-world conditions. Potential RFID device customers evaluate such characteristics as read-range, interoperability with devices from other manufacturers, and speed and robustness of communication in various environments. This results in several opportunities for product differentiation. Testing methodologies to improve performance are often self-imposed by the company developing the product and evolve as expertise with a particular technology improves. Often these are the requirements that drive the need for advanced data visualization in the frequency and time domains.

To meet these challenges, there are two main aspects to a successful validation and verification test strategy:

- Instrumentation that can capture all relevant information necessary for current and future measurements during a communications link between reader and tag
- A reconfigurable measurement layer that can evolve with new standards and test requirements

Instrumentation used for the testing of RFID devices must acquire all relevant information during a communication link. The full range of RFID measurements encompass frequency, power, phase and timing information. Spectral emissions tests and adjacent channel power measurements require that this information be acquired in a frequency band centered around the carrier. These are the key elements of a vector sig-

nal analyzer (VSA). The transient nature of RFID adds the requirement of a trigger mode that can start acquisition at the beginning of a pulsed communication link between reader and tag. This can be as simple as a trigger based on the power level contained in an IQ band in which RFID communication is taking place.

The basic setup of an RFID tag test system is illustrated in ***Figure 5***. To provide the actual communications link, a reference ("gold") reader or RFID simulator is used to initiate a session while the RF VSA is used to record and analyze the link. The VSA, which is set to trigger off the signal generated by the gold reader, captures the entire bandwidth of interest during the communication.

Acquired information can then be analyzed in both the frequency and time domains. Algorithms for RFID measurements, demodulation and decoding are often available as add-on processing packages for modern VSAs. In this case, the VSA provider has to implement the standards-based tests. For standards that are available in the public domain, the delay between advances in a developing standard and instrument capability can impact time to market. For proprietary RFID standards, a significant portion of the market, this is an even bigger problem. The lack of an open measurement layer can prevent measurement automation.

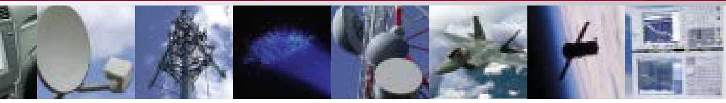
Fortunately, modern advances in instrumentation buses and multicore processors available in PCs enable an alternative test strategy. Instrumentation buses such as PXI and PXI Express have high data-transfer rates, making acquired data from an instrument available to a host processor at near real-time rates. This real-time acquisition, the processing power of multicore processors and the visualization techniques of modern programming environments create a powerful combination. With the ever-evolving nature of RF regulations and RFID standards, using an open-software platform to implement the data measurement and visualization offers many advantages over closed-box solutions with embedded software.

SOFTWARE-DEFINED TEST

Over the last few years, the software-defined radio initiative has gained momentum as a way to maximize efficiency and flexibility within wireless devices covering multiple standards. The same basic methodology of splitting an RF receiver into a generic RF front end and a series of modular software functional blocks can be equally beneficial to test instrumentation.

The architecture of a software-defined test system is a combination of the instrumentation defined previously with software libraries implementing the receiver functional blocks in a digital communications system. ***Figure 6*** illustrates how data from the VSA is made available to processing blocks that process the raw data into its data link elements in the digital communications chain. One of the key aspects of such an architecture is that the information required for RFID testing is broken out at each step of the process.

WIDEBAND LNAs



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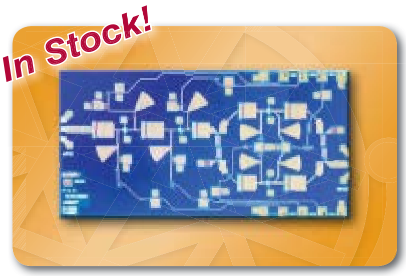
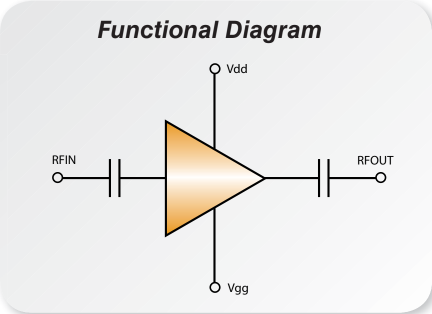


HMC-ALH459
71 - 86 GHz



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	Frequency (GHz)	Function	Gain (dB)	NF (dBm)	P1dB (dBm)	Bias Supply	VELOCIUM Part Number	HITTITE Part Number
NEW!	1 - 12	Low Noise	17	1.5	19	+5V @ 55mA	ALH444	**HMC-ALH444**
NEW!	2 - 22	Low Noise	16	1.7	14	+4V @ 45mA	ALH482	**HMC-ALH482**
NEW!	5 - 20	Low Noise	13	2.2	16	+5V @ 30mA	ALH435	**HMC-ALH435**
NEW!	14 - 27	Low Noise	18	2.5	14	+4V @ 90mA	ALH216	**HMC-ALH216**
NEW!	14 - 27	Low Noise	20	2	14	+4V @ 90mA	ALH476	**HMC-ALH476**
NEW!	18 - 40	Low Noise	10	3.9	12	+5V @ 45mA	ALH445	**HMC-ALH445**
NEW!	22 - 26.5	Low Noise	25	3	12	+2.5V @ 52mA	ALH311	**HMC-ALH311**
NEW!	24 - 32	Low Noise	21	2	7	+5V @ 68mA	ALH364	**HMC-ALH364**
NEW!	24 - 40	Low Noise	11.5	4	15	+4V @ 60mA	ALH140	**HMC-ALH140**
NEW!	24 - 40	Low Noise	12	3.5	13	+4V @ 45mA	ALH244	**HMC-ALH244**
NEW!	24 - 40	Low Noise	22	2	11	+5V @ 66mA	ALH369	**HMC-ALH369**
NEW!	27 - 33	Low Noise	20	3	12	+2.5V @ 52mA	ALH313	**HMC-ALH313**
NEW!	35 - 45	Low Noise	16	2	6	+4V @ 87mA	ALH376	**HMC-ALH376**
NEW!	37 - 42	Low Noise	22	3.5	12	+2.5V @ 52mA	ALH310	**HMC-ALH310**
NEW!	57 - 65	Low Noise	21	4	12	+2.5V @ 64mA	ALH382	**HMC-ALH382**
NEW!	71 - 86	Low Noise	14	4.5	7	+2.4V @ 30mA	ALH459	**HMC-ALH459**
NEW!	71 - 86	Low Noise	14	5	7	+2V @ 50mA	ALH509	**HMC-ALH509**
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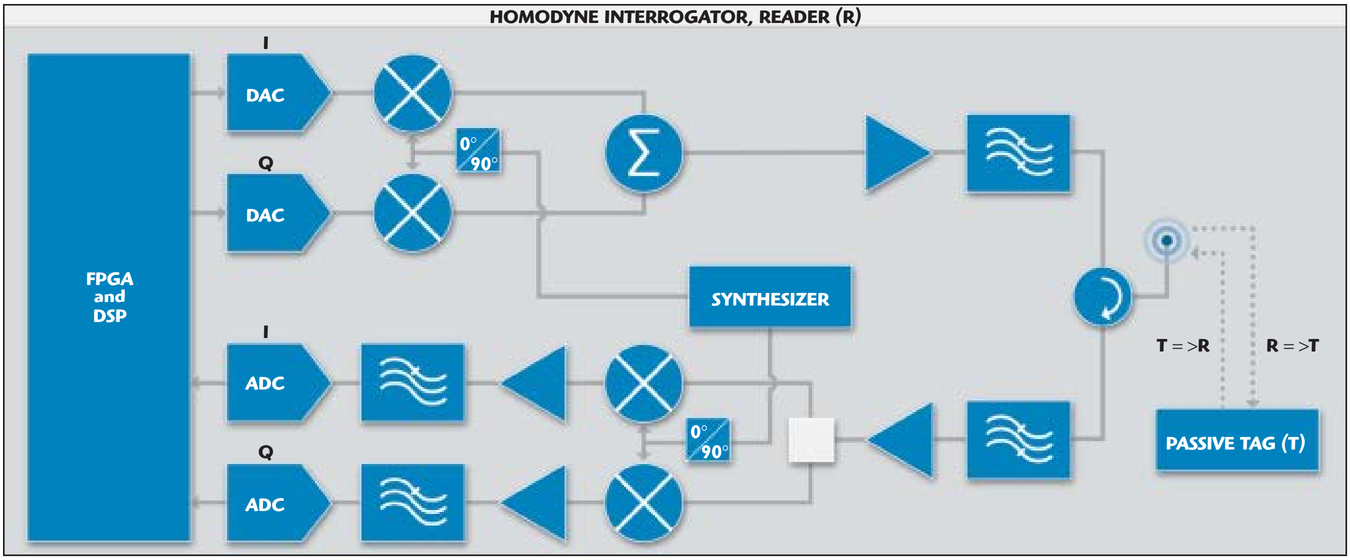


Fig. 1 Basic architecture of an RFID reader.

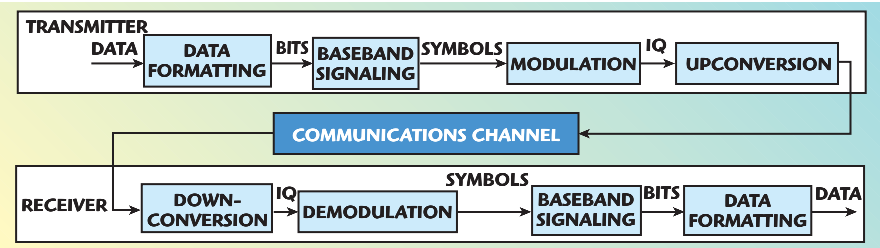


Fig. 2 Digital communication system.

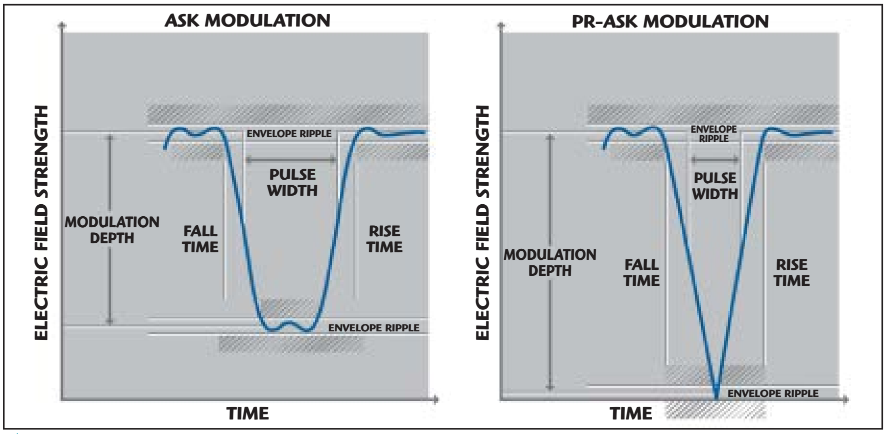


Fig. 3 Specified requirements for ASK modulation in ISO18000-6 Type C.

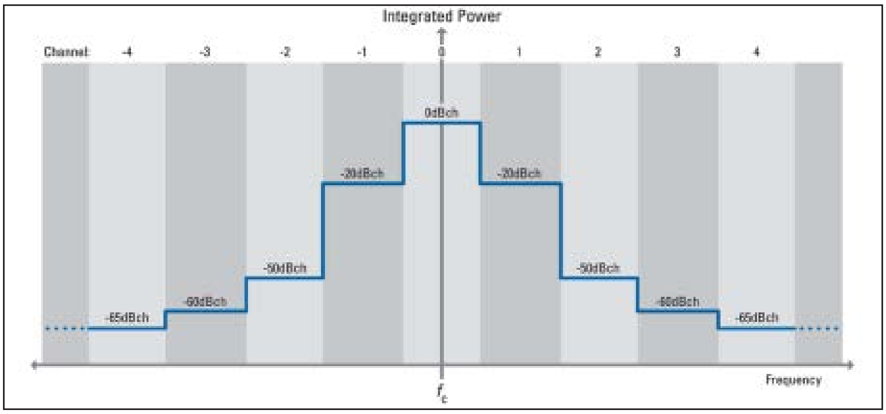


Fig. 4 Spectral mask defined for ISO18000-6 Type C transmission.

IQ DATA

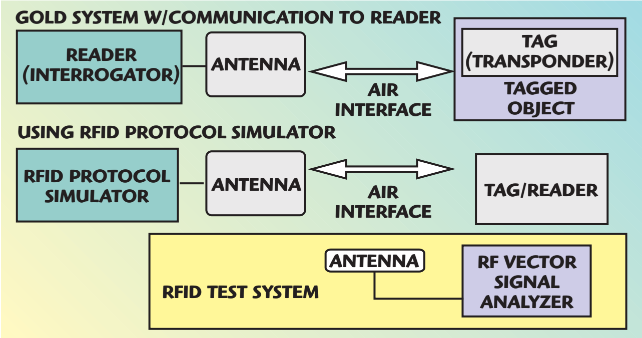
Spectral measurements dictated by government regulations and standards compliance mandate the measurements of power, frequency and bandwidth. With the VSA, this information is contained in the raw IQ data the instrument acquires. Once that data resides in the host computer, measurements such as carrier frequency, power in-band and spectral emissions can be as simple as calling measurement libraries and passing in the IQ data. For example, the integrated power in a given band simply involves first computing the discrete power spectral density P(*n*) of the IQ samples and then accumulating this over the bins of interest. For a T duration sampled signal, the integrated power over a band starting at f_{start} and ending at f_{stop} would be

$$P\left(f_{start}, f_{stop}\right) = 10 \log \sum_{n=f_{start}T}^{f_{stop}T} P(n) \quad (1)$$

The same IQ data can be used to make necessary measurements in the time domain. Carrier rise and fall times can be measured to make sure the tag receives enough energy to function while guaranteeing that the link terminates as quickly as possible to improve the transfer rate. Measurements of the implemented modulation scheme, such as those defined in Figure 3, are also straightforward. Modulation depth, fall time, pulse width and rise time can all be derived from the IQ data the VSA acquires.

SYMBOL INFORMATION

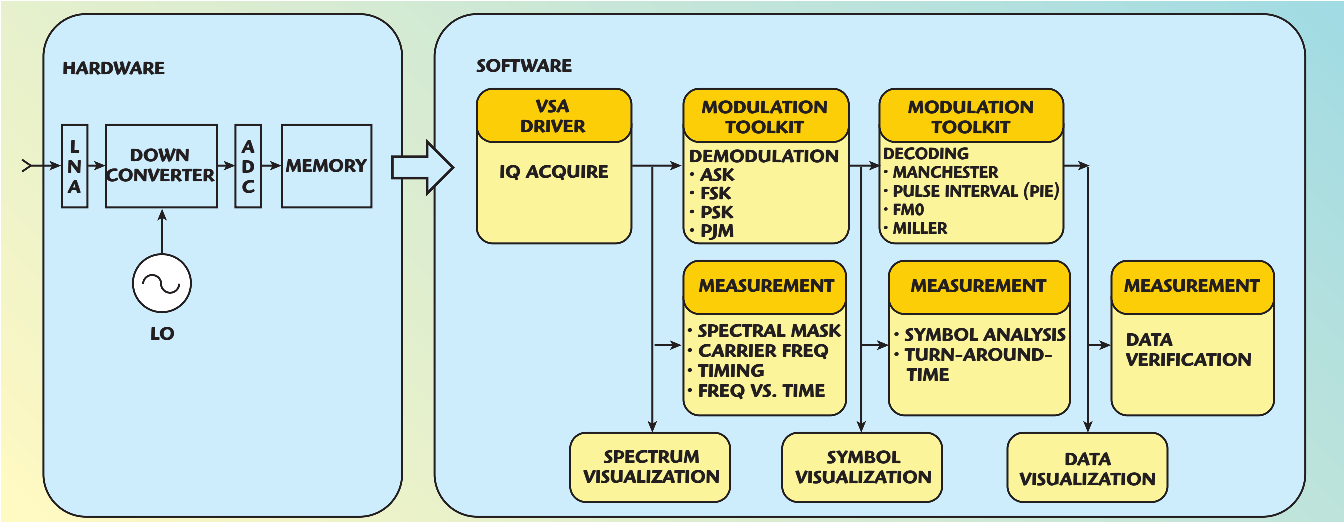
Past the demodulation block, symbol data is made available. ***Figure 7*** shows the symbol information for an ISO 18000-6 Type C RFID query transaction acquired by a VSA and passed through the demodulation block. Symbol rate measurements and in-depth analysis of the data encoding done by the tag or reader are possible with this information. By analyzing the symbol information as amplitude versus time, the period between one downlink transmission to the next can be easily calculated. The speed in which a tag can decode a query from a reader and respond under different conditions translates into better real-world performance. This is a critical part of performance optimization.



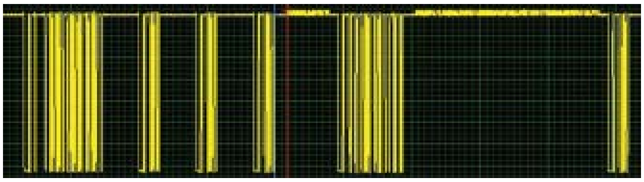
▲ *Fig. 5 Illustration of generic RFID test strategy.*

DATA BITS

Finally, the decoding block provides the actual data bits passed between the reader and the tag. Functional test of an RFID device can be performed by verifying that commands and responses are properly formatted and the data is correct. This can be used to test advanced functionality of RFID systems such as multiple read and write tags, encryption algorithms and intelligent tags that perform functions beyond simple inventory tracking. In each case, the measurements and visualization techniques are based on data as it moves from the VSA through the virtual receiver.



▲ *Fig. 6 Software-based RF test.*

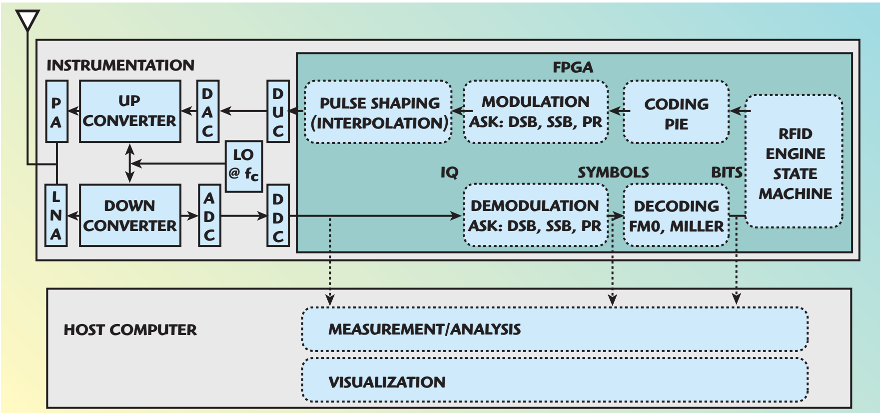


▲ *Fig. 7 Symbol information for an ISO18000-6 Type C RFID query transaction acquired by a VSA and passed through the demodulation block.*

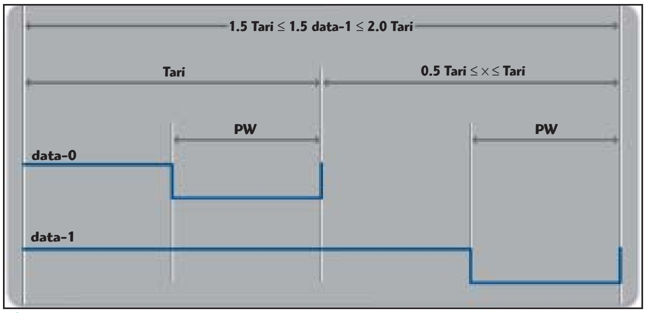
EXPANDING SOFTWARE-DEFINED TEST FOR RFID

One of the most exciting benefits of a software-defined test platform is the ability to include functionality not available in a traditional test system. By implementing transmitter functional blocks and adding the capability of a vector signal generator (VSG), the requirement for a "gold" reader/tag or a separate RFID simulator is negated. This enables a more controlled test environment with coordinated simulation and measurement.

For example, consider the case of combining a reader emulator and the instrumentation for testing an RFID tag into one cohesive system. The software that handles the modulation and coding for the transmitter communication chain is supplemented with software that initiates and manages the command transac-



▲ *Fig. 8 Software-defined test and simulator.*



▲ *Fig. 9 ISO18000-6 Type C preamble.*

tions (a reader's internal state machine). Additionally, the simulation handles the control of the CW carrier and internal timing parameters of the protocol. While the reader emulator executes a particular transaction, all data is made available to the same configurable measurement layer described in the previous section.

The architecture of the combined system depends on the timing requirements within the communications link between the reader and the tag. In RFID standards where a transaction does not require strict timing between command and response, the reader emulator can be implemented on a host computer connected to modular instrumentation (VSA+VSG). In this case, the test system is modeled as a stimulus-response test with the VSG providing the reader transmission and the VSA acquiring the response from the tag. However, some RFID standards require real-time processing during a transmission with timing on the order of microseconds. In this case, the instrumentation needs some sort of embedded signal processing engine. The National Instruments (NI) PCI-5640R IF Tranceiver is an example of an RF instrument with this functionality, containing an onboard field-programmable gate array (FPGA) that is programmable with the NI LabVIEW graphical programming language. ***Figure 8*** illustrates the architecture of a fully software-defined test system with built-in simulation capability.

Real-time device simulation adds a new dimension to device test and characterization. One of the best differentiators for RFID products is better performance under a wide range of real-world conditions. Bringing one side of the communications link into the test instrumentation allows the device to be characterized under all possible permutations of a standard, a critical step in developing this performance.

One of the best case studies for this test architecture is the characterization of an RFID tag for the ISO 18000-6 Type C standard. A quick study of the standard reveals a number of flexible data rates and link timing parameters implemented to operate under a variety of regional regulations and environmental conditions. Two possible characterization scenarios involve evaluating tag response while:

- **Varying data rates from R->T**

Data rates from R->T are defined by the minimum pulse duration used in the PIE channel coding. This value, the time interval for a data-zero, is

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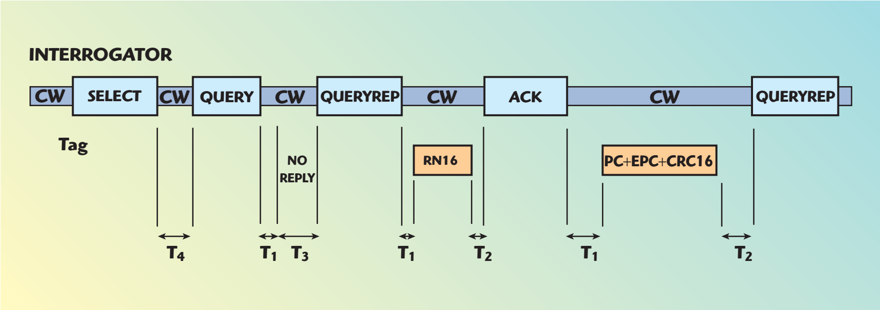


Fig. 10 Link timing parameters for ISO18000-6 Type C.

known as a Tari (type A reference) value. At the beginning of transmission, the reader transmits a preamble (see ***Figure 9***) or frame-sync that contains this timing reference. According to the standard, Tari values must be between 6.25 and 25 µs, inclusive. With the test system illustrated in Figure 8, it is now possible to adjust the Tari values within the reader emulator from just under 6.25 to more than 25 µs with a resolution of less than 0.05 µs to characterize the tag's response.

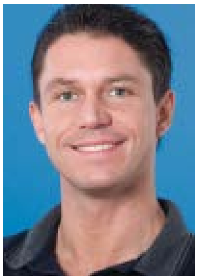
- **Varying turn-around time (TAT) values in link timing**

There are four link-timing parameters that specify TAT during a communication session between the reader and the tag. ***Figure 10*** illustrates these timing parameters in a possible inventory round initiated by the reader. Timing parameters controlled by the simulated reader (T_2, T_3, T_4) are swept through full range to get the best characterization of the tag.

In addition to the timing flexibility, parameters such as carrier frequency, output power, modulation depth and the RF envelope characteristics (defined in Figure 3) can all be swept through the range of values permitted by the standard while the tag response is characterized. An incredible amount of information is now available with regard to how the developed product will perform under all conditions.

CONCLUSION

RFID device testing is a challenging process that is made more difficult by ever evolving technology. Software-defined instrumentation allows for deeper test coverage, including all possible permutations in the implementation of standard, timing and modulation/coding schemes. ■



Sean Thompson *holds bachelor's and master's degrees in computer science from Rice University. He is the RF segment manager for National Instruments (NI). During his 16-year career at NI, he has served as business development manager for ATE, field sales engineer for telecom and military accounts, and manager of the VXI Applications Group.*

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AML28P3002-2W	2.0 – 8.0	30	±2.0	5.5	+33	2.0:1	2000
AML218P3203	2.0 – 18.0	32	±2.5	4	+25	2.0:1	450
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L0208-41	2 - 8	41	12	40	40	17
L0218-32	2 - 18	32	1.4	31	35	5
L0408-43	4 - 8	43	20	41.5	45	17
L0618-43	6 - 18	43	20	41.5	45	22
L0812-46	8 - 12	46	40	45	45	28
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L2240-28	22 - 40	28.5	0.7	27	30	3
L2630-39	26 - 30	39	8.0	38	40	15
L2632-37	26 - 32	37	5.0	36	38	10
L2640-31	26 - 40	31	1.2	30	30	5
L3040-33	30 - 40	33	2.0	32	33	9
L3337-36	33 - 37	36	4.0	35	40	12
L3640-36	36 - 40	36	4.0	35	40	10

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C090105-50	9 - 10.5	50	100	49	1	8.75
C140145-50	14 - 14.5	50.5	110	49.5	2	10.25
C1416-46	14 - 16	46	40	45	0.35	5.25
C1820-43	18 - 20	43	20	41.5	0.25	5.25
C2326-40	23 - 26	40	10	39	0.25	5.25
C2630-45	26 - 30	45	30	44	0.45	5.25
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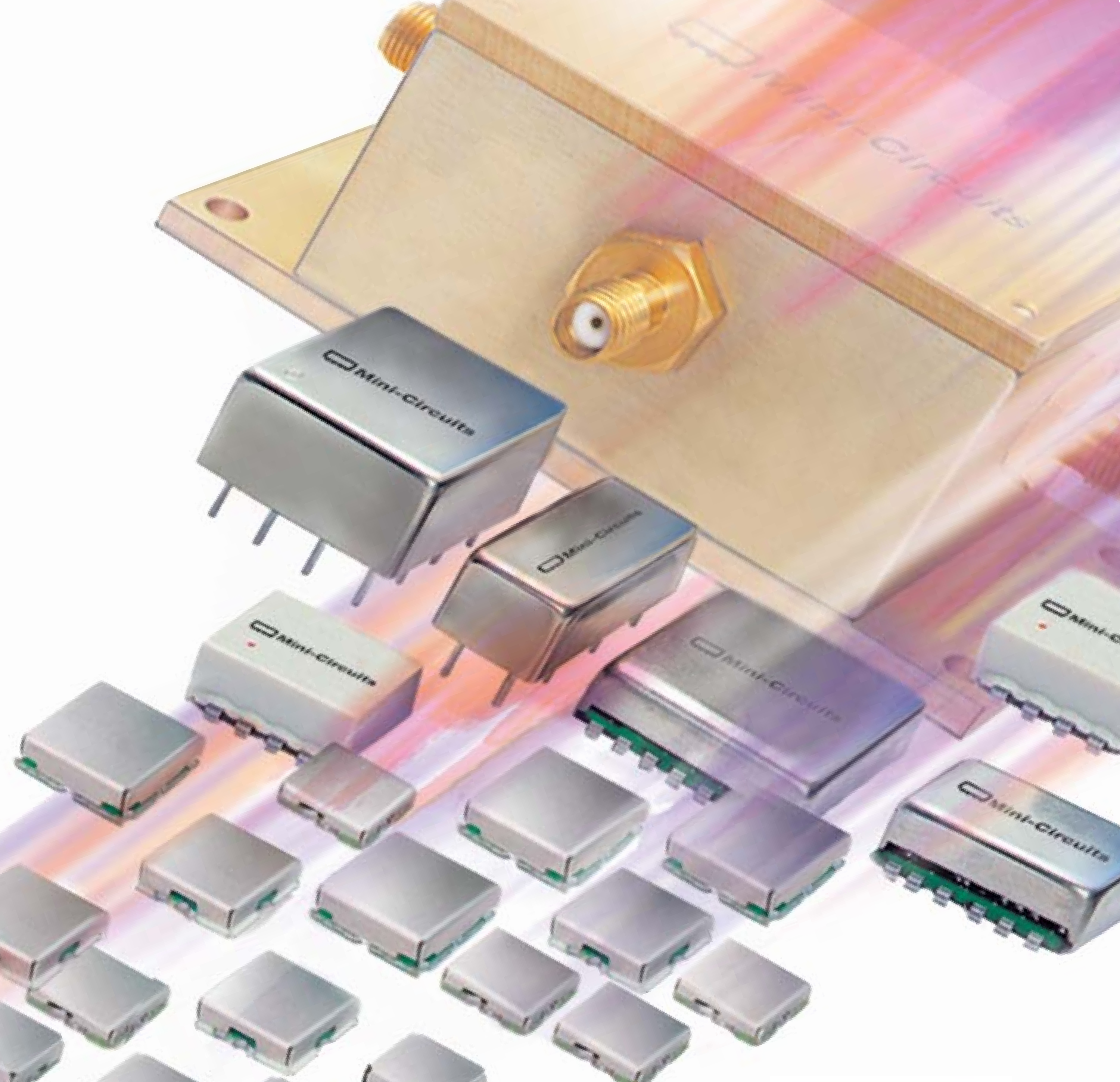
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PRINTED CIRCUIT BOARD MATERIALS FOR MICROWAVE DESIGNS IN AUTOMOTIVE APPLICATIONS

In recent years, in the microwave industry once dominated by defense and aerospace, a market has expanded dramatically to embrace telecommunications and other high volume commercial applications. These changes have had a great influence on the development of microwave materials and how they are processed. The automotive industry is increasingly using microwave technology, as cars and other vehicles adopt more and more wireless devices. From satellite radio and television, through automatic tolling and the transmission of traffic information, to parking aids and adaptive cruise control, modern vehicles are becoming ever more packed with wireless technology, with frequencies varying from 1 to 80 GHz. This article examines the impact of this trend on printed circuit board materials, the demands made on microwave substrates in various automotive applications, and how material selection varies depending on the specific requirements of individual designs.

Microwave laminates, or substrates, have been used in the industry for approximately 50 years. Although they can be thought of as the materials used in microwave printed circuit boards, they do far more than provide mechanical support for components and copper interconnections. In a real sense, these materials form components in their own right, as their characteristics determine the geometry of the circuit, and material selection will substantially affect the circuit performance. ***Figure 1*** shows a broad summary of how these materials have evolved over the past 50 years.

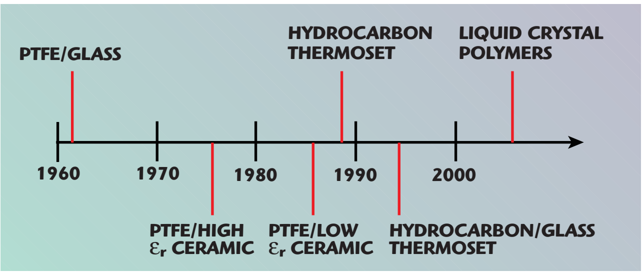
Traditionally, these laminates have been constructed from composites based on a polytetrafluoroethylene (PTFE) resin and some form of reinforcement and/or filler. Ceramic materials such as alumina have been and continue to be used in microwave applications. Continuing pressure to reduce costs in the industry, however, has led to a trend towards traditional PCB processing methods and towards composite laminates, though certainly

JOHN HENDRICKS
Rogers Corp.
Gent, Belgium

not in all applications. PTFE has excellent electrical properties, but is both mechanically and thermally unstable. In the early years, reinforcement was provided by glass, either woven into mats, or in the form of microfibers, which were randomly distributed throughout the PTFE matrix. In the 1970s, laminate manufacturers began to introduce particles of ceramic filler, which could be used to vary relative permittivity, and give the material additional mechanical stability. However, PTFE continued to suffer from electrical properties, which varied over temperature, an issue that was addressed in the 1980s by the addition of new ceramic fillers. PTFE-based materials continue to be used today in a wide variety of applications, but in the 1990s their dominance was challenged by a new generation of hydrocarbon-based materials that offered low loss PTFE-type performance but which could be processed much more like the standard FR4.

KEY MATERIAL PARAMETERS

Traditionally, the two most important electrical parameters are the dissipation factor (tan δ) and the dielectric constant or relative permittivity (ε_r). A low tan δ allows for circuits with low insertion loss and high Q factors in resonant circuits. Commonly available materials have values of ε_r between 2.1 and 10.8, and the choice of higher or lower ε_r is usually made with a mind towards the circuit dimensions. However, the ε_r tolerance is of critical importance, with most materials achieving between ±1 to 3 percent. Over the years, other parameters have gained in importance and materials have evolved to meet those needs. Having a low thermal coefficient of dielectric constant (TCE) indicates that the dielectric constant varies little over temperature. ***Figure 2*** illustrates the different TCEs for various materials. Of increasing importance is the material's thermal coefficient of expansion (CTE). Having X and Y CTEs closely matched to that of copper improves the flatness and dimensional stability of a material, while matching it also in the Z-axis improves the reliability of plated through holes (PTH), as the laminate and the plated copper expand and contract at the same rate through temperature variations. Thermal conductivity remains a key specification in applications where high power is used and thermal management issues provide challenges to the designer. As the use of microwave technology in commercial and consumer applications has increased, there has been more focus on ease of processing. This has long been an issue with PTFE-based materials, which require special through-hole activation prior to plating and demand more careful handling, resulting in a small group of PCB manufacturers specializing in fabricating PTFE circuits. A range of hydrocarbon materials was launched, in order to facilitate the use of larger, general-purpose PCB substrates in higher volume commercial applications. These are compatible with FR4-type processes and complex multilayer designs. They also allow engineers to mix and match microwave materials and FR4 in the same multilayer, enabling the use of the more expensive laminates for higher frequency circuits and antennas, while using less expensive FR4 for lower frequency signals and power distribution.



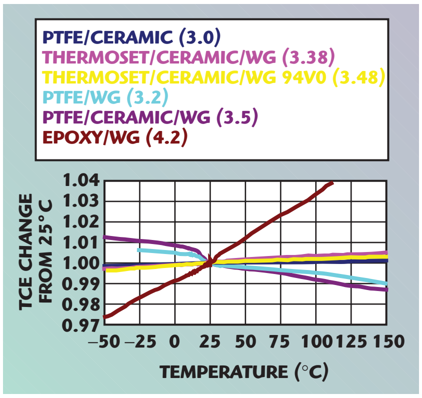
▲ *Fig. 1 Evolution of substrate materials.*

AUTOMOTIVE APPLICATIONS

Microwave technology is being adopted in the automotive industry in a variety of applications and each makes different demands on the materials employed. Examples are electronic toll collection (ETC) and its technological offspring dedicated short-range communication (DSRC) system, long-range radar sensors for adaptive cruise control (ACC), short-range radars for a variety of safety and convenience features, satellite TV and radio, and various other communications technologies, which are being implemented in cars, such as GPS navigation, cellular systems and WiFi.

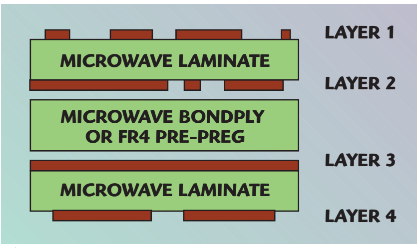
ELECTRONIC TOLL COLLECTION

ETC systems are now being applied worldwide for payment collection from vehicles traveling on or through specific roads, bridges and tunnels. The technology has now settled on 5.8 GHz in Europe and Asia and 5.9 GHz in North America, and is actually an adaptation of the military identification friend or foe (IFF). The system is divided into roadside units or readers, which are usually mounted on gantries over the road, and transponders or tags, which are mounted in the area of the car windshield. As the car passes under the gantry, the tag is interrogated and the driver's bank account is debited by the appropriate amount. The key differences between the tag and reader technologies are driven by volume. Tags are produced in millions per year, readers in thousands. Consequently, cost pressure is far higher on the tags, and this is reflected in their design. Most are relatively simple double-sided PCBs, containing a backscatter antenna, a diode detector and often some kind of IC. Lower performance requirements and short track lengths lead to most designs using simple FR4 glass/epoxy materials. Occasional versions appear where performance dictates using a material with lower loss. In these cases, PTFE materials may be used, but hydrocarbon-based materials tend to be preferred as they pass easily down the production lines of the kind that high volume PCB manufacturers use to produce these components. The ap-



▲ *Fig. 2 Dielectric constant vs. temperature.*

proach to designing readers is somewhat different. Individual designs may be manufactured in quantities of thousands, and most of a system's intelligence is therefore built into these roadside units and this obviously has an impact on design goals. The transceivers require a range of RF circuitry, amplifiers, filters, etc., plus a separate antenna, which is usually also designed on a PCB. Both low loss and tight control of dielectric constant are important, and many designs have settled on PTFE-based materials for these reasons. In an effort to save space and reduce assembly costs, many reader designs have integrated all the RF circuitry and antenna functions onto one multilayer board. ***Figure 3*** shows a typical configuration of a four-copper layer reader, where layer 1 is the RF circuitry, layer 4 is the antenna, and layers 2 and 3 would be additional circuits at lower frequencies. Interconnection of the layers would be through plated through holes. Given the probable temperature fluctuations of systems situated outdoors, a key material consideration would be the Z-axis CTE, and the match between the dielectric material and copper (see ***Table 1***). In these designs, the processing issues surrounding PTFE may not be so much of an issue, as volumes are lower, and specialist PTFE processing facilities may be used, as long as PTFE-based laminates with lower CTEs are selected. Some attention should also be paid to the choice of bondply that is used to bond the two laminates together and sits between layers 2 and 3. If a low loss material is required here, then a bondply system similar to the laminate should be used. However, if the central two layers are predominantly carrying low frequency signals or are ground planes, it may be possible to save money and use a simple FR4 prepreg as a bonding film. In these cases, it may be wiser to consider the more rigid, hydrocarbon-based laminates, due to greater mechanical compatibility with FR4.



▲ *Fig. 3 Typical four-layer PCB layout.*

SATELLITE RADIO AND TV ANTENNAS

While it would be difficult to cover entirely the wide range of antennas now being deployed on cars, two of the applications, which normally require high frequency materials, are those used in satellite radio and TV antennas. While not being fundamentally different in principle to those used outside cars, satellite radio antennas are usually patch antennas designed on thick laminates to achieve the required bandwidth. Typically, an ε_r between 3 and 6 is used to achieve a balance of low cost (high ε_r is more expensive) and compact size. Despite a preference for low loss and tight ε_r control, cost is a primary driver. Part of the challenge is that bandwidth requirements often demand a laminate thickness of between 3 and 6 mm, and conventional materials are laminated from plies that link cost directly to thickness. Therefore, achieving a design with reduced thickness can be highly desirable. There are no particularly stringent processing issues, so PTFE is frequently used, though rigidity is sometimes an issue, as some car manufacturers have elaborate packages that locate satellite

TABLE I

TYPICAL CTEs FOR DIFFERENT MATERIALS

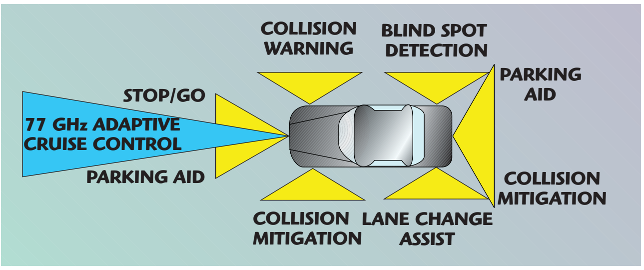
	*Typical Coefficient of Thermal Expansion (ppm/°C)** X-Axis	Y-Axis	Z-Axis
PTFE/woven glass	15	15	200
PTFE/random glass	22	28	173
PTFE/ceramic filler (low ε_r)	17	17	24
PTFE/ceramic filler (high ε_r)	24	24	24
Hydrocarbon/ceramic/woven glass	14	16	35
Copper	17	17	17

*measured from 0–100°C

radio, GPS and cellular phone antennas in the same roof mounted casing. While still in its infancy, satellite TV used in cars is beginning to grow, primarily in the US. While the LNB employed in a car may not be especially different than in a domestic set up, the obvious impracticality of a dish means that electronically steered, roof mounted antennas are essential. Traditional satellite systems operate at around 10 GHz, with newer high definition systems running at over 20 GHz, so using low loss materials with tight ε_r control is essential. Typically, PTFE laminates are used to achieve the lowest loss, though hydrocarbon-based laminates may also be acceptable. Initial systems focus on a multilayer design carrying the antenna elements on top and a feed network on the bottom. Few if any plated through holes are employed. Because of low volumes today, maximum focus is on achieving performance goals. However, these antennas contain few components and processing is relatively straightforward; therefore, the total cost of an antenna/feed combination is heavily dominated by laminate cost. The next generation will be geared to achieving cost targets, which will, by necessity, mean that lower cost materials must be used, if car satellite TV is to become affordable.

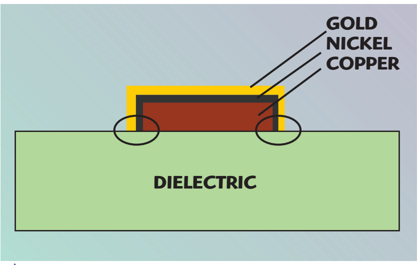
RADAR SENSORS

One of the most interesting growth areas for microwave technology in cars today is radar sensors. For several years now, many of the more exclusive cars have been available with adaptive cruise control, in which the car maintains a constant distance from the vehicle in front, instead of a constant speed, as is the case with conventional cruise control. This is achieved using a narrow band 77 GHz long-range radar system to track the position and speed of the car ahead. More recently, short-range radars operating at 24 GHz have been introduced, which can be used for a variety of functions such as parking assist, braking assist, stop-go systems for use in traffic jams, collision mitigation in which safety systems such as air bags and seat belts are pre-activated an instant before a collision, and various other functions (see ***Figure 4***). There remains some discussion about which frequency bands will remain available in different parts of the world and there is a possibility that, in some areas, these short-range sensors may have to move to 79 GHz, but for the next few years, 24 GHz will dominate. This has a significant impact on the choice of technologies employed in the sensors, particularly the semiconductors, which are mostly GaAs but likely to move to SiGe for new designs. It also has a strong impact on material choice for the PCBs. Reducing cost is key if these sensors are to move beyond the realm of luxury cars and into the mass market. In the past, there has been no real use of the 24 GHz technology for consumer products, though the latest generation of satellite television LNBs operates at similar frequencies in the US. Radar sensors at 24 GHz generally include an MMIC or two, associated RF circuitry, an antenna and digital signal processing. The trend is strongly towards additional integration for reasons of size reduction and lower cost manufacturing. Current designs follow an approach of having a four-layer multilayer board, not unlike those in auto-tolling roadside units. However, the electrical parameters involved are more critical at 24 GHz. The dielectric constant needs to be tightly controlled, as filter tolerances are more critical. The dielectric losses are higher at higher frequencies and copper losses are also more important. At 24 GHz, the skin effect is greater, leading to more current being carried at the base of the copper tracks, so having copper with a smoother surface is advantageous. The effect of copper surface treatment on the performance of a circuit is often

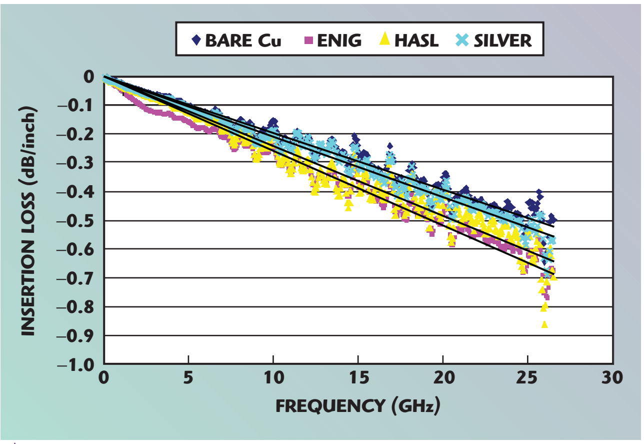


▲ *Fig. 4 Car radar sensor overview.*

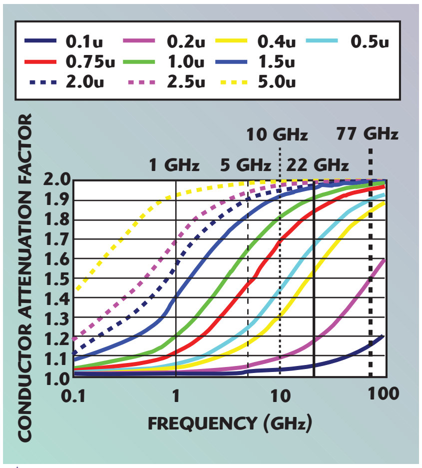
overlooked. This is because at higher frequencies, much of the current flows not only along the bottom surface of the conductor, but a higher proportion of it also flows along the edges. Thus, the current can flow predominantly through the metal, which is plated on top of the copper tracks. ***Figure 5*** illustrates a cross-section of a typical copper track plated with nickel and gold, showing the main area of current flow. Thus, the conductivity of the surface finish can have a significant effect on insertion loss. ***Figure 6*** shows the insertion loss of a 50 Ω line on a 0.020" RO4003 laminate clad with standard foil, using different surface finishes by comparing electroless-nickel-immersion gold, hot-air-solder-leveling, silver and bare copper. It can be seen that the commonly used nickel-gold process, despite its other benefits, has a negative effect on insertion loss at the frequencies used by automotive radar sensors. In principle, applications can be found for short-range radars that would allow for between 2 to 10 sensors per car to be fitted, which translates to a potential for many tens of millions of sensors per year. In such volumes, material cost is critical, as is the cost of manufacturing. High frequency performance may demand high frequency materials, but cost pressures demand that they be used in conjunction with conventional FR4 whenever possible, usually in multilayer boards that employ both materials. Thus, the selection of a microwave laminate will include consideration of its mechanical properties such as CTE and dimensional stability, with a view to matching them as closely as possible to FR4. Furthermore, the potentially high volume of these products means that microwave laminates should be compatible with standard FR4 processing, enabling the use of high volume PCB fabricators, qualified by the automotive industry for all its other rigid board manufacturing. This has resulted in a trend towards the hydrocarbon-based laminates and away from PTFE with its specialist processing requirements. The same cannot be said of PTFE when considering materials for long-range radar sensors operating at 77 GHz. At such high frequencies, losses on hydrocarbon-based materials are often considered too high to be acceptable, and most designs are either on PTFE-based laminates, ceramics, or occasionally on the new generation of liquid crystalline polymer (LCP) materials. Materials with a dielectric constant of 3 or less are chosen because they permit track widths that



▲ *Fig. 5 Current flows on bottom edges of copper tracks.*



▲ *Fig. 6 Effect of surface finish.*



▲ *Fig. 7 Effect of copper roughness.*

can be processed reliably and because they have the lowest dissipation factor. Consideration is also given to the type of reinforcement used in PTFE laminates. The very small wavelengths involved raise the importance of material isotropy, because circuit designs can be sensitive to small local variations in dielectric constant that can be found in woven glass reinforced products. Thus, the trend is towards materials with smaller glass or ceramic fillers that are randomly distributed inside the PTFE matrix. The total absence of any filler or reinforcement is one of the attractions of the LCP product. The previously mentioned issue of copper conductivity becomes more complicated at 77 GHz, where smoothness is commonly regarded as even more critical, but is not necessarily so. ***Figure 7*** shows the theoretical effect of copper roughness on conductor attenuation over a wide frequency range. Most commercially available coppers used on PCB materials vary in RMS roughness from approximately 0.4 µm, for treated rolled copper and reverse-treated electrodeposited copper (ED), to 5 µm for the roughest ED coppers. The shiny side of ED or rolled copper can be as smooth as 0.1 µm RMS. As can be seen from the graph, at 77 GHz almost all copper should behave as though it is essentially rough, due to resistivity saturation effects. However, very recent studies have cast some doubt on this and the best current advice would be to use copper that is as smooth as possible, though the benefit may not be as pronounced as it is at 10 to 20 GHz, for example.

CONCLUSION

In some respects, it would be easy to view current trends in the automotive industry as little more than the adoption of technology that has been used for some years. It is true that applications have existed at K-band and W-band for many years. However, it is clearly the case that automotive applications at 5.8, 24 and 77 GHz, for example, will drive developments in low cost, high volume technology in ways that cellular radio previously did below 2 GHz and satellite TV LNBs did at 10 GHz. This poses challenges for designers seeking to implement previously exotic technology for everyday use, but also for materials companies seeking to develop products that facilitate the commercialization of such designs. Today, some new cars possess technology that until recently was only dreamt of in fighter aircraft. It is reasonable to believe that in 10 years time, this will be true of the majority of cars in production. ■

John Hendricks *received his BSc degree in physics from Manchester University, England, UK, in 1984. He then joined Marconi Defense Systems where he worked as a microwave engineer, before moving to the Test and Measurement Division at Rohde & Schwarz. In 1990, he joined Rogers Corp., where he currently works as the market development manager in the Advanced Circuit Materials Division.*

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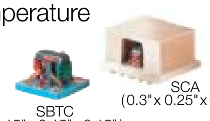

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DESIGN ENABLEMENT FOR RF AND MICROWAVE IC DESIGN: PART I

Editor's Note: *This two-part series from Jazz Semiconductor presents recent developments in design support methodology from a pure-play wafer foundry specialized in RFCMOS and advanced CMOS technologies including BiCMOS, SiGe BiCMOS and high voltage CMOS. In part one, the authors describe how the integration of RF and digital blocks produce the functionality for today's advanced electronics but results in IC complexity that makes shotgun-style prototyping impractical, and how extensive device modeling, simulation and a methodology design enablement tool is imperative for successful analog intensive/mixed-signal IC design.*

The gigahertz era in consumer electronics has catalyzed the convergence of RF and microwave applications with mainstream large-scale semiconductor technology. This merging of technology has brought performance, manufacturability and time-to-market requirements into the forefront of a world once driven solely by design-to-specification. Stand-alone microwave circuits are rapidly moving to analog intensive mixed-signal (AIMS) microwave ICs. Not too long ago, the quick manufacturing cycles of III-IV technologies allowed for countless fabrication iterations of microwave designs before reaching final design and subsequent mass production. These iterations were carried out in prototype vehicles that included tens of individually tweaked versions of a single IC. Later rather than sooner, one of the versions would function, and be selected for production. As these products are plugged into larger scale integrated chips, the high development cost and cycles associated with these technologies make it difficult to survive using this shotgun approach.

When microwave circuits enter the mixed-signal world, they must adapt to function in the mixed-signal process technology. For this adaptation to be successful, the design flow must facilitate the design of optimized microwave modules with the available technology. ***Figure 1*** displays Jazz RF Analog Design Enablement, a novel design platform that delivers robust models and design tools intimately tied to the manufacturing process directly

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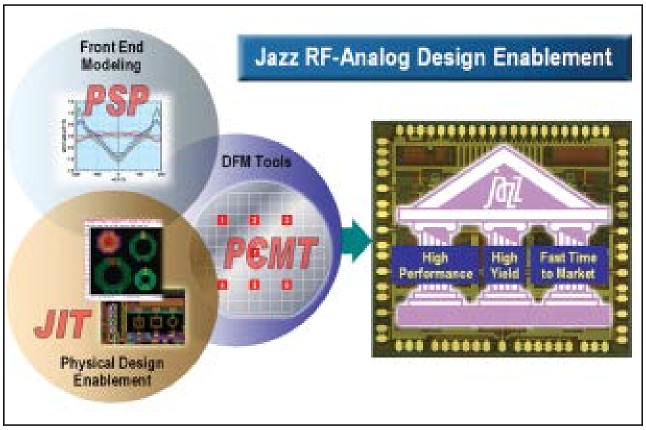
to the IC designer's desk. Application of design enablement to the RF and microwave design space facilitates the innovation of highly differentiated products. The flow starts with a physical, scalable modeling platform combined with a robust statistical infrastructure to simulate design sensitivity to process variation, thus enabling first-time-right semiconductors. The modeling platform resides in a leading commercial IC design environment, which provides scalable parameterized cells for all components with embedded process technology knowledge, facilitating direct design space exploration and optimization. Finally, tools for final loop closure between fabricated silicon and simulation provide a feedback mechanism for continual design improvement.

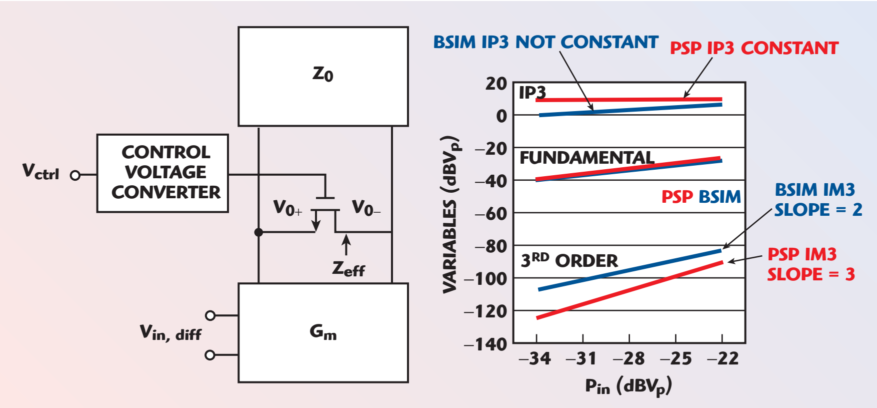
FRONT END DESIGN ENABLEMENT: MODELING METHODOLOGY

The RF IC designer creates a highly complex integrated circuit, which executes complicated functions at various levels of the system. In the end, regardless of the level of abstraction in which an RF system is defined, the semiconductor transistors and integrated passives do the work. Thus, the designer needs to know how these devices perform, in particular how they respond to electrical, magnetic and thermal stimuli. Device models provide this information to the designer. One can think of models as the prescription glasses a designer must be fitted with before the IC design process commences. Different technologies such as RFCMOS, SiGe BiCMOS, or GaAs come with a different prescription, enabling a designer to understand the process and thus make decisions on how to design the particular IC.

An accurate modeling platform consists of a set of physical compact models that are accurately characterized to the semiconductor technology and, just as importantly, are readily available within the IC design environment. The models must not only reflect the nominal process, but also accurately predict the natural process variation of semiconductor technology. All production IC designs are ultimately subject to the semiconductor manufacturing process variation over the life of the product. Hence, the design must be robust and meet performance specifications, or "yield," across the entire process variation space. Therefore, statistical models representing the process variation of the technology must be available within the design environment.



▲ *Fig. 1 High level capabilities required for first-pass microwave/mixed-signal IC design based on Jazz RF-Analog Design Enablement.*



▲ *Fig. 2 RF attenuator schematic and harmonic distortion analysis.*

Physical Compact Modeling

A compact model is a set of analytical equations that describe the electrical, electromagnetic and thermal behavior, implemented in a SPICE-like simulation tool. The models make necessary simplifications from the full physics while retaining sufficient accuracy and reasonable simulation times. As a somewhat simplified assertion, one can state that the simulation time is directly proportional to the complexity of the model. Consequently, the best compact models contain simplifications that retain accuracy while improving speed.

Physically based compact models are based on the fundamental process parameters that control the device behavior, such as oxide thickness for the MOS devices and base doping for an NPN. Additionally, compact models should be formulated based on the geometrical variables including scalable design parameters and process design rules. Examples of scalability include gate length and width of a MOSFET or GaAs FET, emitter length and width of bipolars, and inductor line widths and number of turns. Examples of process design rules include poly to contact, deep trench and active area spacing.

Compact models should be C_∞ continuous over the entire operating range of a device, where C_n continuous means the function and its n^{th} order derivatives are continuous as described by McAndrew.[1] Additionally, models should provide correct asymptotic behavior to the extremes of input stimulus such as voltage or temperature. Such requirements ensure robust simulation convergence behavior and model accuracy in regions not measured during model characterization.

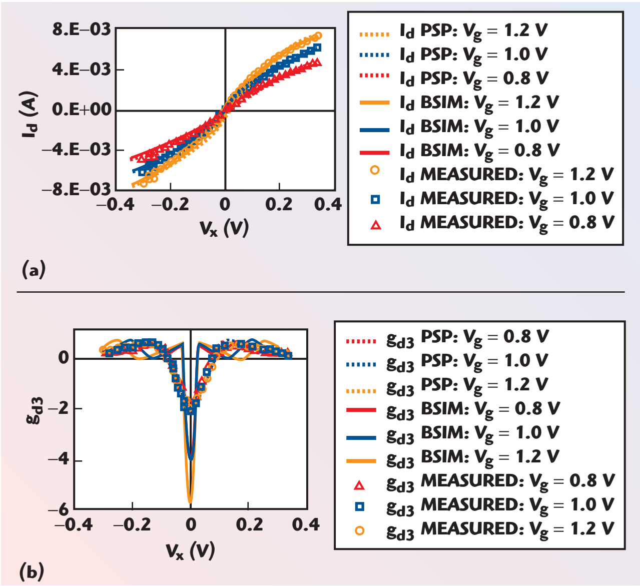
As semiconductor technology has advanced, so has compact modeling. Modern day compact models meet all the requirements previously mentioned providing robust simulation performance and accuracy. Examples of three advanced, state-of-the-art compact models (PSP, MOSVAR and JIT), offered as part of the Jazz Ana-

log Design Environment, are highlighted next.

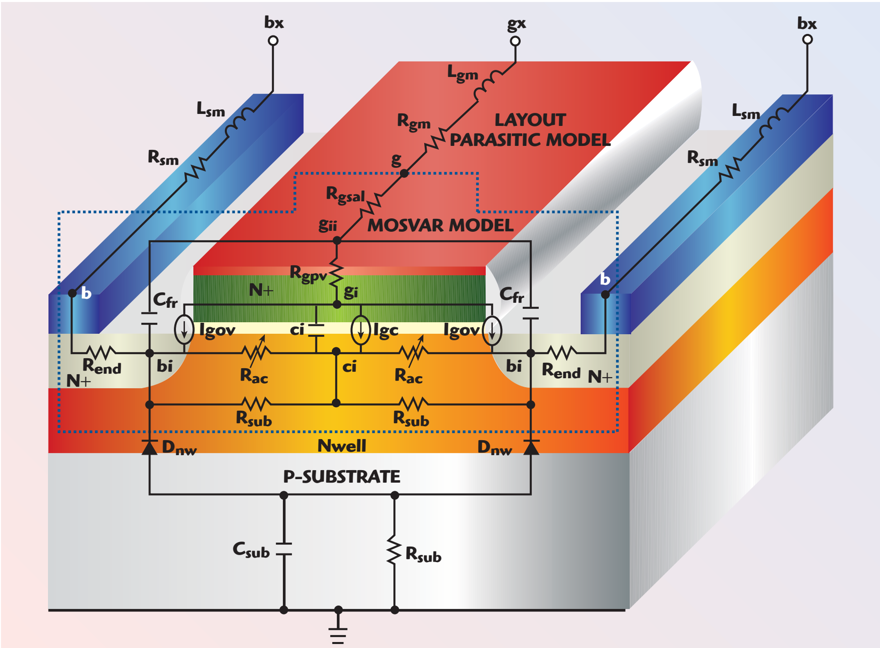
PSP

The PSP model, the next generation standard compact MOSFET model, is an advanced surface potential-based model geared towards 90 nm and below technology nodes.[2] Furthermore, the PSP model remedies many issues with the well-known prior generation model BSIM, making it quite effective for older technologies such as 0.18 µm. PSP provides the best model for RF analog design through complete physical treatment of noise sources including gate and channel noise correlation, and continuous high order derivatives crucial for distortion analysis. An example of the effectiveness of the PSP model for distortion simulation is presented here.

There are several RF circuit blocks that utilize the MOSFET in a passive context such as passive mixers and RF attenuators. ***Figure 2*** shows a simplified diagram of an RF attenuator based on a transconductance amplifier configuration, a circuit block commonly used in RF transceiver design. The GM block combined with the load impedance Z_0 sets the attenuation or gain of the block. A common and effective design technique utilizes an NFET hooked with the drain and source across the differential output signal, DC biasing the device at V_{ds} = 0. The gate voltage is then controlled through automated gain control (AGC) circuitry to modulate the channel resistance, changing the effective load impedance Z_{eff}, thus modulating the



▲ *Fig. 3 0.13 µm NFET Gummel symmetry test; (a) I_d and (b) g_{d3}.*



▲ *Fig. 4 MOS varactor cross-section and model circuit.*

attenuation (or gain) of the block. The figure also shows intermodulation distortion simulations for the attenuator, based on the PSP and BSIM MOSFET model. At low input power levels, the third harmonic (IM3) must exhibit a slope of three based on harmonic power series analysis. The BSIM model simulates a slope of two, which is physically incorrect and leads directly to incorrect simulation of third-order intermodulation distortion, or IP3 analysis. By contrast, PSP exhibits the correct slope of three for IM3 and thus the expected IP3 results.

At the very root of this problem is the discontinuity of the high order derivatives at the $V_{ds} = 0$ point in the BSIM model.[3] ***Figure 3*** shows the results of the well-known Gummel symmetry tests for a NFET in the Jazz SiGe/RFCMOS SBL13 0.13 µm technology. The NFET is swept symmetrically across the $V_{ds} = 0$ point, with the drain current and the third derivatives plotted. The clear third derivative discontinuity in the BSIM model produces the IIP3 slope = 2. PSP displays not only continuous behavior at the third derivative, but tracks the data very reasonably. An RF designer can then design such a key block and others that depend on the accuracy around the $V_{ds} = 0$ point such as RF passive mixers and switches with a high degree of confidence.

MOSVAR

Design of RF/analog and millimeter wave circuits requires accurate, scalable compact models not only for the active transistors but, just as critically, the passive components in a given technology. This includes the MOS varactor, which provides frequency tuning for circuits such as voltage-controlled oscillators (VCO). VCOs provide frequency synthesis and system timing in many modern day RF systems, such as WLAN, WiMAX, UWB, automotive radar and high speed optical communications systems.[4,5,6] The recently developed MOSVAR model shown in ***Figure 4*** is a physically based scalable model for MOS varactors.[7] The model includes a PSP-based analytical surface potential charge formulation and physical geometry and process parameter-based parasitic modeling. The model provides highly accurate simulations of key varactor performances such as capacitance and quality factor Q over voltage, frequency and geometry. Above all, the model provides the physical insights to the designer, enabling design trade-offs such as phase noise vs. oscillator gain.

In a typical VCO tank circuit, an integrated inductor (L) and a MOS varactor (C) set the oscillation frequency. The tank quality factor (Q_{tank}), which directly affects the VCO phase noise, is given by

$$Q_{tank} = \frac{Q_L Q_C}{Q_L + Q_C} = \frac{\omega L}{R_L + \omega^2 LCR_C} \quad (1)$$

derived using the approximations for the tank components:

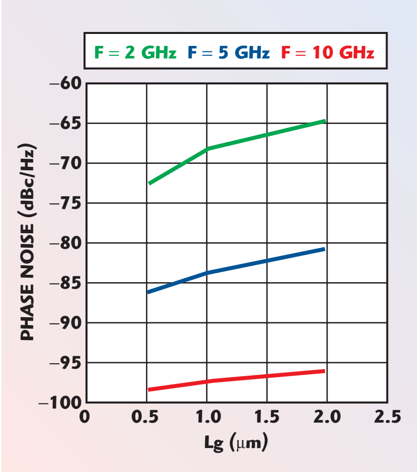
$$Q_L = \omega L/R_L,\ Q_C = 1/\omega CR_C \quad (2)$$

RX (where X denotes L or C) is the resistive loss for each component in the series tank path. Equation 1 shows that at low frequencies, Q_{tank} is controlled by the inductor while at high frequencies Q_{tank} is controlled by the MOS varactor. Leeson's phase noise model[8] provides direct insight into the varactor impact on phase noise (PN). It relates the PN transfer function H(j Δω) to the oscillator parameters by

$$\left|H(j\Delta\omega)\right|^2 = \frac{1}{4\left(Q_{tank}\right)^2}\left(\frac{\omega_0}{\Delta\omega}\right)^2 \quad (3)$$

where

ω = oscillator center frequency
Δω = offset frequency where the phase noise measurement is taken



▲ *Fig. 5 Phase noise dependence on MOS varactor gate length.*

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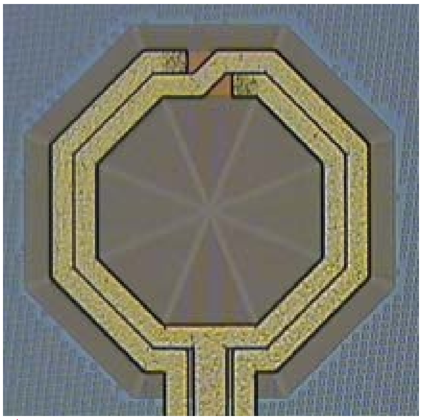
At frequencies where Q_C dominates Equations 1 and 3 show that $|H(j\Delta\omega)|^2 \propto (R_C)^2$. ***Figure 5*** shows PN simulations of the VCO with the MOSVAR model.

PN increases with Lg, as expected due to the increased R_C from the Nwell resistance. In addition, dPN/dL_g increases at higher frequencies above 5 GHz due to the increased influence of Q_C compared to Q_L. The physical, scalable nature of the MOSVAR model provides direct insight into the MOS varactor influence on PN with respect to frequency and geometry, facilitating design of stringent RF and millimeter-wave VCO design criteria such as low phase noise.

Jazz Inductor Toolbox (JIT)

In addition to providing the complimentary tank element to the varactor in VCOs, integrated inductors and baluns are key components to RF and millimeter design where they are heavily used in filtering and impedance matching applications. The Jazz Inductor Toolbox (JIT) provides a comprehensive inductor design environment including scalable compact models and parameterized layout cells, delivering a turnkey design solution to the IC designer.[9] JIT feeds the technology parameters (for example, metal sheet resistance, interlayer dielectric thickness and substrate resistance) directly into a set of comprehensive analytical equations for the self and mutual inductance, parasitic resistance including high frequency skin effects and capacitance. The general void of this in the industry often leaves designers to custom inductor design through a time-consuming iterative process of EM simulation and/or silicon verification.

This inductor toolbox provides a comprehensive, scalable library of inductors applicable to a large design space. The library includes conventional single-ended spirals common to filtering and impedance matching in power amplifiers. Symmetrical inductors enable the use of differential circuit design, well-known to produce improved linearity, noise immunity and common mode rejection ratio (CMRR) in transceiver design. Supported inductor styles include octagonal geometries, which enhance Q performance through reduction in parasitic resistance and capacitance. Additionally, scalable patterned ground shields provide additional Q boost combined with enhanced noise isolation critical to RF systems. ***Figure 6*** shows a microscope photograph of a symmetric inductor over a ground



▲ *Fig. 6 Microscope image of octagonal inductor over ground shield.*

shield. Designers can also leverage a scalable passive library for characterization of transmission lines and other components such as tees and bends. As the infrastructure includes high frequency effects, the broadband output models produce low risk and rapid RF design validation.

CONCLUSION

In the first part of this series, the role of microwave circuits as primary building blocks of communications systems and their expansion into new industries and applications such as AIMS is considered. We examined how the lines separating microwave and consumer commodity products have vanished. Under these conditions, new breeds of microwave products are leveraging semiconductor technologies that decisively allow for integration of high value functionality in a cost-effective manner. As these analog-only circuits evolve into integrated AIMS solutions, a design flow that delivers robust models and tools intimately tied to the manufacturing process is requisite in the pursuit of performance, manufacturability and time-to-market. As an example of such a flow, the Jazz RF Analog Design Enablement has been presented as a state-of-the art methodology that promotes the design of first-time-right optimized microwave modules. In the second part of this series, examples of modeling methods, physical design and loop closure tools will be showcased as illustrations of design enablement. ■

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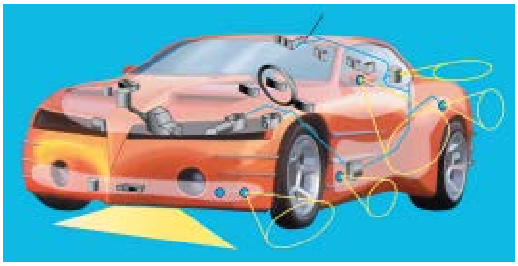
FREQUENCY CONTROL IN TRANSPORTATION APPLICATIONS

The first time frequency control devices were used in an automobile was in the 1930s when car radios from the Galvin Manufacturing Corp. were installed. Galvin Manufacturing was later renamed Motorola (the prefix "motor" was chosen because of the company's early involvement in the automotive industry) and later the automotive products division was sold to Continental. Then in 1952 Blaupunkt became the first company to offer FM car radios. Twenty years later analogue-based ECUs (Engine Control Units) utilized frequency control devices as the system clock while digital ECUs became a reality around 1986. Since then the utilization of frequency control devices in the transportation industry has exploded. Today there could be over 30 frequency control devices in every new automobile (see ***Figure 1***).

Communications systems for transportation applications have come a long way since those modest beginnings. Each new application seems to have more critical specifications than the last one. A tire pressure monitoring system (TPMS), which includes four RF transmitters and a receiver, provides the safety that would be seriously compromised by false reads. Clearly in this instance, failure cannot be tolerated. With the growth of drive-by-wire applications, frequency controls are also being used as the gateway for communication not only in the wireless devices, but in wired systems as well.

Fig. 1 Automotive subsystems requiring frequency control devices.



Current examples of in-car frequency control applications include safety and drive train applications, infotainment, security and convenience applications. Common safety and drive train systems employing frequency control devices include: ESC (Electronic Stability Control), TPMS (Tire Pressure Monitor Systems), collision avoidance and smart cruise control radar, ABS (Anti-locking Braking Systems), airbag, and ECU. Infotainment applications include navigation systems, GPS (Global Positioning Systems), satellite radio, TV media centers and hands-free mobile phones. Security and convenience applications include components and subsystems such as RKE (Remote Keyless Entry), immobilizers, DVR (Digital Video Recorder), rearview camera and parking assistance.

Communications outside the vehicle is also playing a big role in improving current and future traffic management systems, helping to ease automobile congestion. Smart vehicles will be much more aware of their environment, alerting drivers about their immediate

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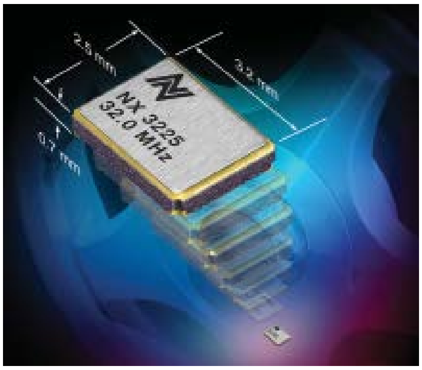
surroundings (vehicle proximity warning) as well as major congestion and alternate routes. Ideally, these smart vehicles will reduce the time that cars spend stuck in traffic jams and possibly reduce their overall carbon emissions and contribution to greenhouse gases. Current examples of Smart Vehicle Frequency Control Applications include: GPS/navigation systems, VICS (Vehicle Information and Communication System), commercial vehicle support systems, AHS (Automated Highway Systems), IVC (Inter-Vehicle Communication), ETC (Electronic Toll Collection), ASV (Advanced Safety Vehicle), highway video monitoring, automated driving infrastructure, emergency vehicle support systems and road-to-vehicle communication infrastructures.



▲ *Fig. 2 A 3.2 × 2.5 mm quartz crystal for use in TPMS applications.*

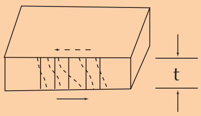
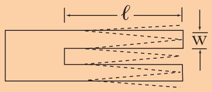
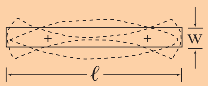
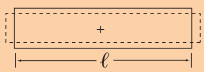
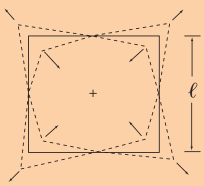
CONSIDERATIONS WHEN SELECTING FREQUENCY CONTROL DEVICES

The following are leading factors in determining the requirements for a frequency control device in automotive applications. Given the safety liabilities and costs involved in a warranty claim, reliability is the number one concern in transportation applications. If the microprocessor (MPU) is the brain of the automotive application, the crystal would be the heart. The clock keeps the system in check allowing the MPU to perform computations with a stable reference signal. Therefore, it is often critical to include the frequency control device manufacturer in the very early stages of the project. Most frequency device suppliers have many years of experience to guide system integrators. Some can even offer "oscillation margin analysis" where the application is brought to the lab for testing and design tweaks are implemented to help ensure optimal performance. Quartz-based frequency control components offer many advantages critical to demanding automotive applications including stability over temperature range and excellent aging hysteresis (stable repeatable performance over time). Quartz is also hard and can be processed consistently from lot to lot, yet it is not brittle, which gives it excellent shock and vibration resistance.

Environmental conditions must be taken into consideration when specifying the proper frequency control devices for the application. Automotive environments are infamous for their grueling requirements, often looking for –40° to +125°C operating temperature ranges while operating

TABLE I

BASIC CHARACTERISTICS OF QUARTZ CRYSTALS

Mode of Vibration	Cut	Frequency Range (kHz)	Frequency Formula (kHz)	Capacitance Ratio (Typical)
Thickness-shear 	AT Fundamental	800 ~ 5000 2000 ~ 80000	1670/t 1670/t	300 ~ 450 220
	AT 3rd Overtone AT 5th Overtone AT 7th Overtone AT 9th Overtone	20000 ~ 90000 40000 ~ 130000 100000~200000 150000 ~ 230000	$1670 \times \frac{n}{t}$	$n^2 \times 250$ n: Overtone Mode
	BT Fundamental	2000 ~ 35000	2560/t	650
Length-width-flexure 	+2°X	16 ~ 100	$700 \times w/\ell^2$	450
Length-width-flexure 	XY NT	1 ~ 35 4 ~ 100	$5700 \times t/\ell^2$ $5000 \times w/\ell^2$	600 900
Length-extensional 	+5°X	40 ~ 200	$2730/\ell$	140
Face-shear 	CT DT SL	250 ~ 1000 80 ~ 500 300 ~ 1100	$3080/\ell$ $2070/\ell$ $460/\ell$	400 450 450

during high shock and vibration in various humidity conditions. Needless to say, special consideration must be taken in the design and manufacturing of devices that can handle these rigorous elements. The products must be beefed up by using properly engineered materials and assembly techniques to meet these demands. This attention to detail can have an impact on the cost of the component. Product specification should be driven by the application of the product. For example, a device used under the hood would require tougher environmental specifications than an infotainment application placed inside of the vehicle.

Safety applications require extra special treatment to avoid situations such as a failure in an airbag deployment or an improper reading from a TPMS leading to an accident. For safety applications the frequency control devices must be designed to higher than normal standards, once again utilizing special materials and production techniques. These components are run in a special batch process marking them and separating them from other standard components. Components for safety applications must receive a 100 percent inspection for physical, electrical and performance characteristics, which ensures their conformance.

Proper package selection is key to ensuring the use of mainstream components that will provide a reliable supply. The largest user of frequency control devices is the mobile phone industry. They drive the volume and package size. Today's phones keep getting thinner and thinner while delivering more features than ever. This trend will continue to force smaller and smaller components to be developed. What might be a popular size today will not necessarily be mainstream in a few years. The manufacturers of frequency control components continue to make investments in the production tooling of these smaller packages. So as the volume demand for the smaller packages raises the price point drops, and as the volume demand decreases for the larger packages pricing will go up and lead to an end-of life product. Due to their small size and excellent environmental characteristics the 3.2 × 2.5 mm quartz crystal has become a very popular frequency control device in TPMS applications (see ***Figure 2***).

Selecting a crystal or oscillator for the application must also be considered. Oscillators such as XOs (crystal oscillators), TCXOs (temperature-compensated crystal oscillators), VCXOs (voltage-controlled crystal oscillators) and OCXOs (oven-controlled crystal oscillators) deliver an all-in-one device oscillation signal. They provide users with an easy solution to fulfill their clock system requirements. The other method of fulfilling clock system requirements is to utilize a crystal and build your own oscillation circuit. Either method can be effective depending on the application. In higher volume with lower stability requirements developing a PLL could provide an overall unit cost savings when compared to utilizing an oscillator. For lower volume applications, oscillators can be cost

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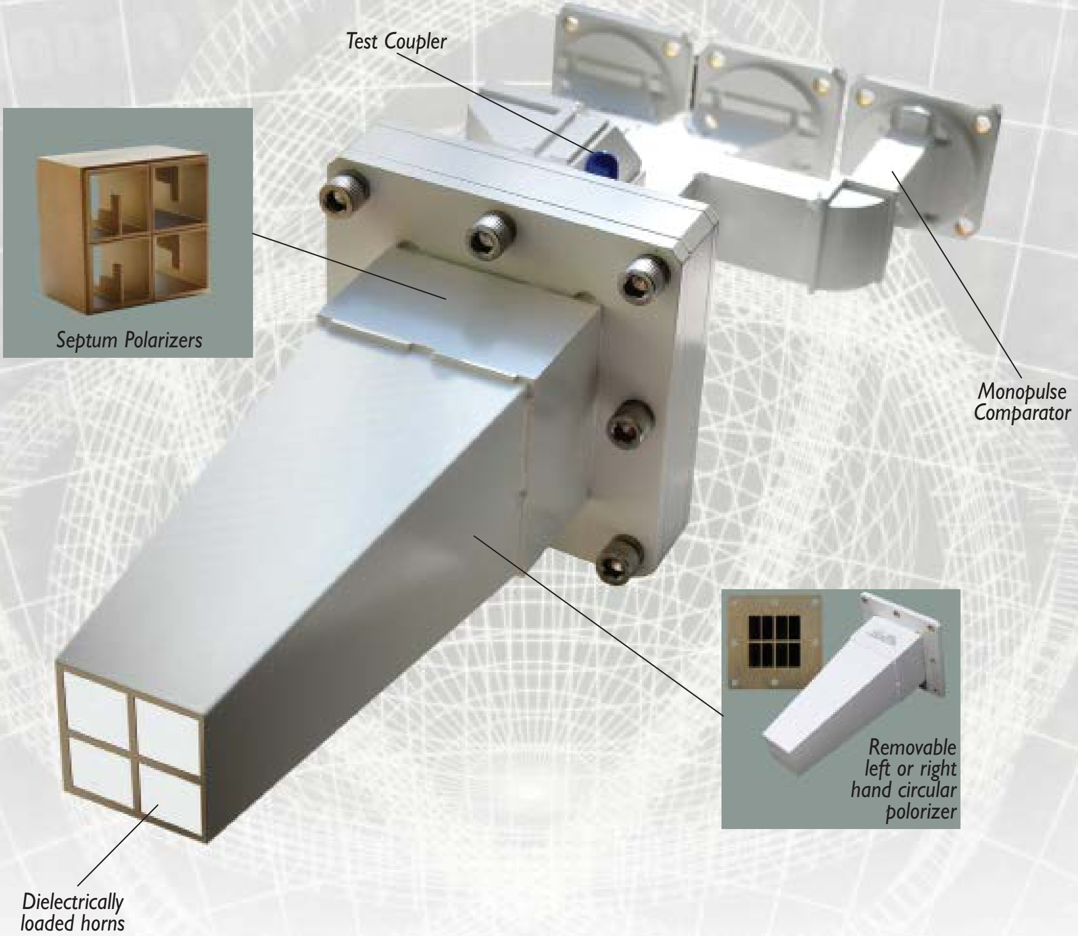

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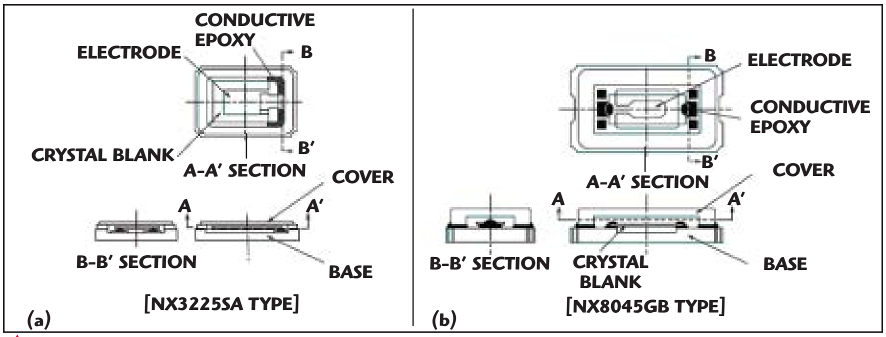

▲ *Fig. 3 Internal structure of a hermetically sealed crystal unit.*

effective when calculating design and development time. Oscillators also offer the advantage of being more stable because of their ability to adjust to changing conditions.

THE BENEFITS OF QUARTZ CRYSTAL

A crystal wafer mechanically vibrates at several modes, as shown in ***Table 1***. To pick up desired vibration energy effectively, the system supporting the crystal wafer is very important. An example of the typical internal construction for a thickness-shear mode crystal unit at the minimum displace point of mechanical vibration on the wafer is shown in ***Figure 3a***. The holder is hermetically sealed to prevent deterioration of the crystal unit's performance, as shown in ***Figure 3b***.

Because crystal units are widely used for their stable oscillation frequency, superior temperature characteristics are required. However, as with ordinary materials, a crystal flake cut as a quartz unit is influenced by temperature change, causing its oscillation frequency to change. The level of change in the oscillation frequency (frequency-temperature characteristics) varies depending on the cutting azimuth.

Cutting angles differ depending upon the applications (oscillation frequencies and electrical characteristics). ***Table 1*** shows vibration modes, frequency ranges and capacity ratios (typical values).

Taking the most popular AT-cut crystal wafer, for example, it operates in a plane, which makes an angle of 35°15' to the Z-axis and the wafer thickness is approximately 0.06 mm in the case of 28 MHz fundamental-wave thickness shear vibration.

Figure 4 shows three different temperature characteristics for different cutting angles. Curve 2 provides the smallest rate of frequency change against temperature change near normal temperatures; therefore, crystal units represented by this curve have excellent characteristics suited for most usual applications. On the other hand, over a wider temperature range of –55° to + 105°C, curve 1 shows better characteristics. It is necessary to determine the most appropriate temperature characteristics taking into consideration applications and required operating temperature ranges.

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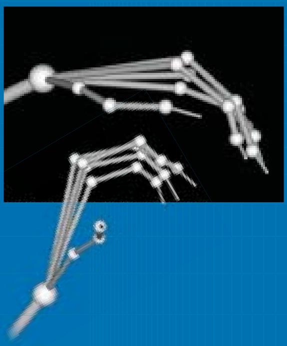

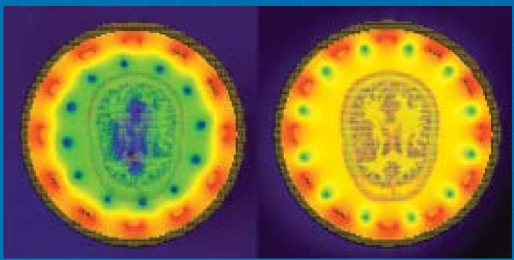

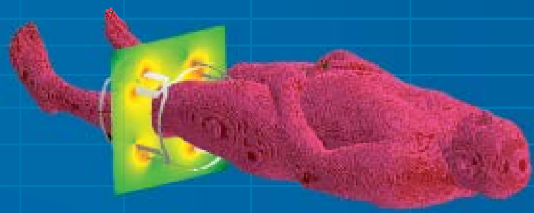

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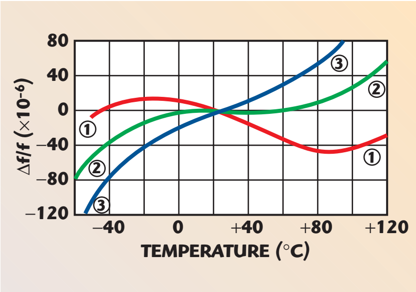

▲ *Fig. 4 Frequency vs. temperature characteristics of an AT-cut crystal unit.*

Cutting angle allowance is determined by operating temperature range and allowable frequency tolerance.

A quartz crystal unit's high Q and high stiffness (small C1) make it the primary frequency and frequency-stability determining element in a crystal oscillator. The Q values of crystal units are much higher than those attainable with other circuit elements. In general-purpose crystal units, Qs are generally in the range of 104 to 106. A high stability 5 MHz crystal unit's Q is typically in the range of two to three million. The intrinsic Q, limited by internal losses in the crystal, has been determined experimentally to be inversely proportional to frequency (that is, the Qf product is a constant for a given resonator type). For AT- and SC-cut resonators, the maximum Qf = 16 million when f is in MHz. An oscillator built from a quartz crystal resonator has an advantage over one designed with a tank circuit built from discrete Rs, Cs and Ls in that the crystal is far stiffer and has a far higher Q than can be achieved using normal discrete components.

CONCLUSION

The use of frequency control devices in automotive applications is just beginning to hit its stride. Looking back at car radios and early ECUs, no one could have imagined today's applications. These same frequency control devices will ensure that GM's OnStar system will be able to give authorities the location of a stolen vehicle and slow the vehicle before shutting the engine down. This system incorporates external communication with internal communication. Infotainment options are available on all vehicles, with some of these components found as standard equipment. Soon you will be able to download movies via satellite selecting programming that will keep passengers entertained. Concepts to enhance safety and ease road traffic such as Advanced Cruise-assist Highway Systems (AHS) and Advanced Safety Vehicle (ASV) seem futuristic now, but engineers are working diligently on these applications. These programs look to develop technology that will lead to safer driving, aiming to reduce accidents, enhance transport efficiency, improve environmental conditions, and reduce burdens on drivers by enhancing their convenience and comfort. Over the past decade, research and development has been promoted jointly with the AHS Research Association, formed by the 21 enterprises possessing leading-edge technologies. Soon these systems will be as common as air bags. The future looms large for increased use of crystals and oscillators in the entire transportation industry. ■

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COMPUTATION OF FIELDS AND SAR FOR MRI WITH FINITE-DIFFERENCE, TIME-DOMAIN SOFTWARE

Editor's note: *RF and microwave technology has been utilized in numerous medical applications, such as the study of electromagnetic radiation on the human body. Mobile handset and antenna manufacturers have performed Specific Absorption Rate (SAR) measurements and/or simulation with various test systems and software tools at microwave frequencies for a number of years. As we look to how our technology is addressing problems in the fields of industry, science and medicine,* Microwave Journal *finds numerous examples of microwave engineering being applied to the lower-end of the high frequency spectrum (from 3 MHz to a few hundred megahertz), such as magnetic resonance imaging (MRI), plasma generation for semiconductor processing equipment and laser drivers. One such example is the following invited application note from REMCOM Inc.*

In most fields today, electronic devices must meet strict certification requirements to ensure that humans are not exposed to excessive levels of radiated energy. If sufficiently high levels of power, quantified as the Specific Absorption Rate (SAR), are dissipated in human tissue, the result could be tissue heating and damage. Should a device that has reached the prototyping stage fail to pass SAR certification, a redesign will be required, costing both time and money. Through advanced software tools, designs can be iterated and validated for compliance, ensuring a good product before any prototypes are built. To adequately analyze this type of design, a fully three-dimensional approach for simulating the propagation of electromagnetic fields is required.

The SAR analysis for an MRI system, presented in this article, is based on the XFDTD® product from REMCOM Inc., which utilizes a finite-difference, time-domain (FDTD) method. In FDTD, the geometry under consideration is discretized into small block-shaped voxels. This approach works well with complex electronic devices and also preserves the configuration of the tissues within the human body. It has been recognized as the preferred method for making SAR calculations[1] and has been widely used in a variety of applications.

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Performance Table for New HF/VHF ISM – To 450 MHz Devices

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Part Number	Test Frequency (MHz)	Voltage (V)	Rated Power (W)	Package	θ_{JC} °C/W	Typical Gain (dB)	Typical Efficiency (%)
MRF6VP11KH	10-150	50	1000	Flanged Ceramic	0.03	26	71
MRF6V2010N	10-450	50	10	Single-ended Plastic	3.0	23.9	62
MRF6V2150N	10-450	50	150	Single-ended Plastic	0.24	25	68.3
MRF6V2300N	10-450	50	300	Single-ended Plastic	0.24	25.5	68

Performance Table for New ISM Band – 2.45 GHz Devices

Derived from Freescale's industry-leading cellular infrastructure portfolios, the MW6IC2420NB, MRF6S24140H and MRF6P24190H devices operate at 28 V and achieve high levels of performance for 2.45 GHz applications.

Part Number	Test Frequency (MHz)	Voltage (V)	Rated Power (W)	Package	θ_{JC} °C/W	Typical Gain (dB)	Typical Efficiency (%)
MW6IC2420NB	2450	28	20	Single-ended Plastic	1.8	19.5	27
MRF6S24140H	2450	28	140	Flanged Ceramic	0.29	13.2	45
MRF6P24190H	2450	28	190	Flanged Ceramic	0.22	13.2	46.2

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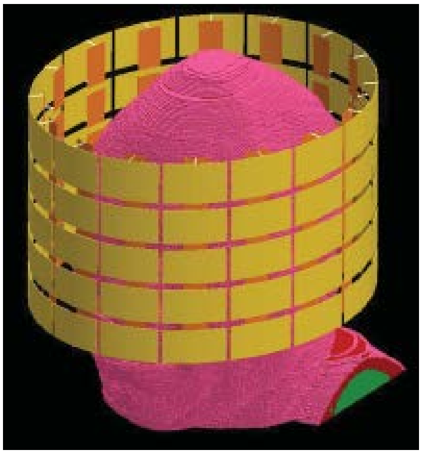
XFDTD USE FOR MRI

In magnetic resonance imaging (MRI) systems, the field propagation and distribution in the human patient is important for good image quality in addition to the safety requirements. These quantities are difficult to measure in living human subjects, so simulation has become a useful method for research in the MRI field. As far back as 1998, researchers at the Center for NMR Research at Penn State College of Medicine used simulation to determine SAR and B1 fields from birdcage coils at several frequencies in realistic human head models. Studies have done similar work to investigate the field homogeneity and SAR in higher frequency MRI systems and with different coil configurations. For example, in 2003 DeMeester[6] compared using body and head transmit coils to determine which gave lower SAR while still producing an acceptable B1 field. In fact, researchers developing MRI systems have used simulations to:



▲ *Fig. 1 An image from XFDTD of the human head surrounded by an 80-element coil.*

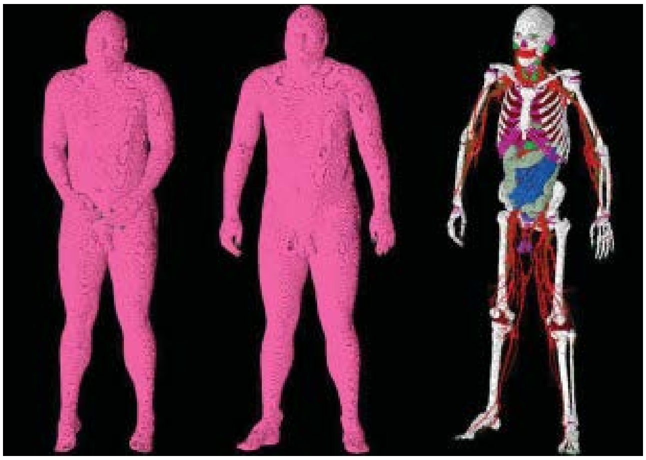
- Study and improve coil and shield designs[7–9]
- Find optimum transmit and receive arrays and waveforms to improve homogeneity[9,10]
- Investigate issues of dielectric resonance[12–15]
- Study the impact of metallic implants such as wires[16] and electrodes for electroencephalography (EEG) recording[17] on SAR

In addition to SAR, the temperature rise in the tissues is of particular interest, since it is the heating of tissues that causes the damage. Evaluation of the power absorbed in SAR does not take into account the cooling effects by blood flow and air movement. Work by Collins, et al.[18] describes a technique to compute the temperature rise caused by absorbed power in the form of SAR. This technique, based on the Pennes bio-heat equation, can be achieved through simulation provided the software includes the appropriate thermal module, such as the one recently added to XFDTD®.

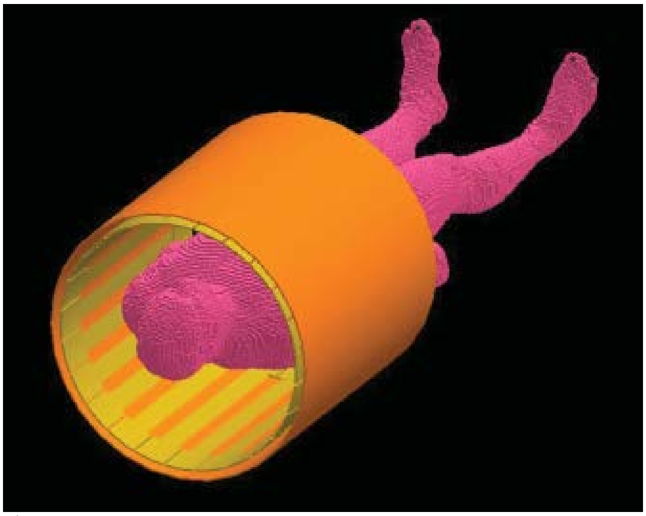
A continuing advance in simulation technology has allowed researchers to investigate extremely challenging problems. For instance, recent use of the XFDTD software included an MRI system, involving complex imaging devices made of arrays of elements with adjustable magnitude and phase such as the case[19] where an 80-element coil made of five vertical elements in 16 columns is simulated on a human head (see ***Figure 1***). The importance of simulations can be summed up by the comments of Christopher Collins of the Center for NMR Research at Penn State College of Medicine, who attributes the use of the XFDTD product in particular as "a valuable tool in the field of MRI for applications ranging from groundbreaking fundamental discoveries and demonstrations to engineering and safety assurance. It is now something of an industry standard in our field."

HUMAN BODY DATA

In simulations involving MRI systems, a detailed dataset of the human body tissues is necessary for accurate results. These detailed datasets are available as meshes (available from REMCOM) based on the scans from the Visible Human male and female projects. These meshes are available in resolutions as fine as one millimeter, although the data may be rescanned in the software to any necessary voxel size. The highest resolution meshes contain 39 distinct tissues including 24 tissues in the head. The original Visible Human data that is available for the XFDTD product has the body in a supine position with the arms crossed over the body. Unfortunately, this position is inappropriate for some MRI applications and will not yield SAR results that correspond with the MRI system's actual use. Therefore, it is critical that researchers are able to manipulate the data including the re-positioning of the body into more desirable poses (see ***Figure 2***). At left is the data in the original position, while at right is the data after processing by Varipose. The data is shown with all tissues present and again with the outer layers

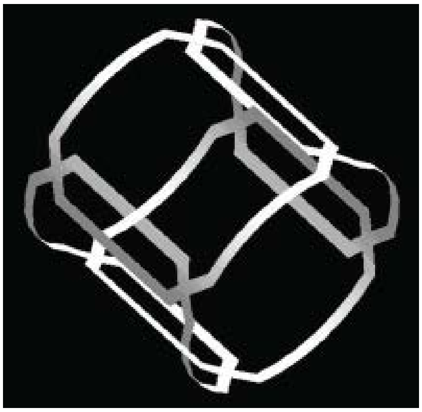


▲ *Fig. 2 Three-dimensional views of the human male data.*



▲ *Fig. 3 Simulation geometry of a human male in 5 mm resolution in a large MRI coil.*

(skin, fat, muscle) removed to reveal the internal structure. All the limbs on the body, including the fingers, may require repositioning. It is also important that the internal tissue connections are maintained during repositioning in order to ensure continuity. To improve the simulation speed, it may also be desirable for the body data to be cropped to include only those parts of interest for a particular application, such as separating the head or arm into a file of its own.

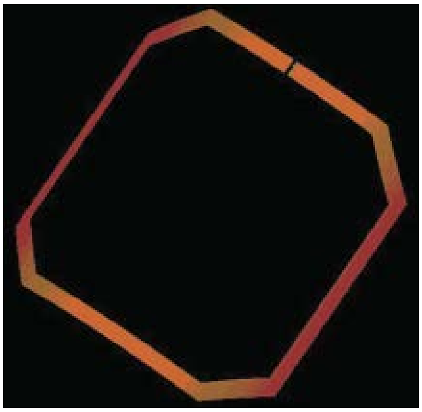


▲ *Fig. 4 A four-element coil.*

An example of a commercial tool with the ability to manipulate the body model data is a separate product from REMCOM known as Varipose®.

MRI COIL SIMULATION

One area where the use of simulation tools can provide significant cost and time savings is coil design. Engineers making coil designs need to tune the coils by applying appropriately placed capacitors to get a resonance at the desired frequency. Using a prototyping approach, this can lead to several expensive models being built until proper values for the capacitors are found and the coil is tuned at a high level of Q. With simulation, the coil can be tuned with a few simple steps. While whole body simulations with a large MRI coil (such as the one shown in ***Figure 3***) can be computed, a simple coil example will be performed here to demonstrate the technique. An example of a four-element coil is shown in ***Figure 4***, where identical coil elements are placed with a slight overlap. This coil measures approximately 280 mm in diameter with a length of 250 mm and may be placed over a knee for imaging. Here, it will be tuned for use at 64 MHz. This coil and tuning approach were generously provided by Fahad Alradady of MR Medical Solutions of Pittsburgh, PA. To begin the tuning process, start with a single coil element, as shown in ***Figure 5***. A single cut is placed in the coil and a parallel combination of a voltage source and a wisely chosen capacitor are placed in the gap. For this case, a

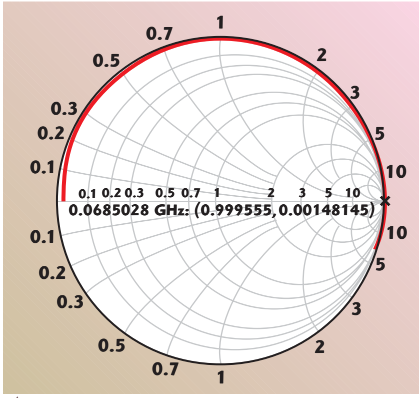


▲ *Fig. 5 A single coil element.*

capacitor value of 7 pF was chosen. Although this coil is designed for receive-only use, by reciprocity it can be simulated in transmit mode for tuning. The coil is simulated with a broadband input of a Gaussian pulse to find the series resonance of the base coil. Following the simulation, the return loss for the coil is plotted on a Smith chart, shown in ***Figure 6***, to find the resonant frequency of the coil. The resonance is located at the point where the return loss is purely real, at approximately 68.5 MHz, which is slightly above the desired 64 MHz for the coil. With the resonant frequency value and the applied capacitance of 7 pF, the inductance of the coil structure can be computed. This is done by first computing the reactance due to the capacitor as

$$X_c = \frac{1}{j\omega C} = -331.9\ \Omega \qquad (1)$$

Since at resonance the inductive reactance will equal the negative of the capacitive reactance, the inductance of the coil loop may be computed as



▲ *Fig. 6 Return loss of a single coil plotted to determine the resonant frequency.*

$$X_L = j\omega L$$
$$\therefore L = \frac{X_L}{\omega} = 771\ \text{nH} \qquad (2)$$

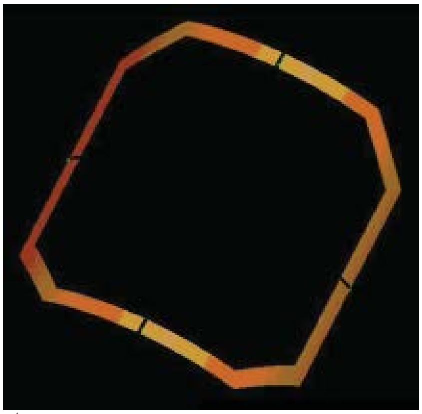
Since the desired frequency for the coil is 64 MHz, and the inductance of the loop is known, the inductive reactance at 64 MHz may be found and then from this value the necessary capacitance may be computed to resonate the coil. This is done by first computing the reactance at 64 MHz for the coil inductance, or

$$Z_{L64} = j\omega L = j2\pi(64\ \text{MHz})(771\ \text{nH}) = 310\ \Omega \quad (3)$$

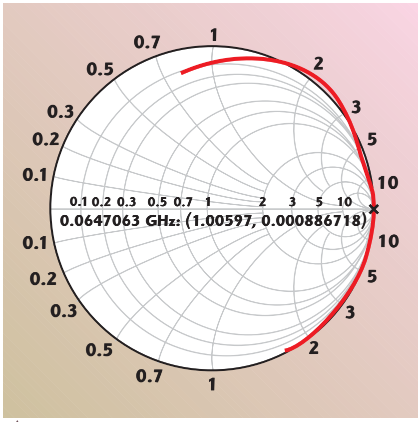
To resonate the coil, the capacitive reactance must equal the negative of the inductive reactance, so the required capacitor value may be found as

$$X_{C64} = -310\ \Omega = 1/j\omega C$$
$$C = 1/\omega X_{C64} = 8\ \text{pF} \qquad (4)$$

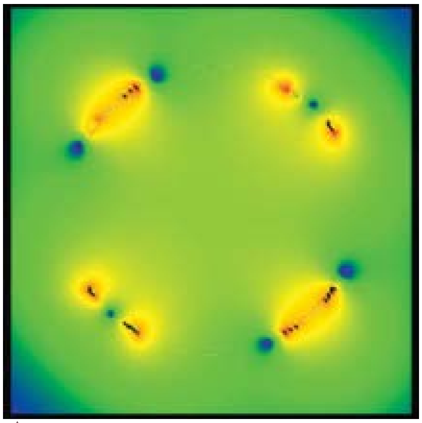
To best resonate the coil at 64 MHz, the capacitance value should be distributed around the loop. The number of divisions of the capacitance should be based on the wavelength of the signal. In human tissue, the wavelength will be approximately 50 cm, so four gaps around the loop are determined to be appropriate to properly distribute the capacitance. Since the total capacitance needed to resonate the loop was found to be 8 pF, each elemental capacitance, connected in series, should be set to 32 pF. The resulting coil with the four capacitances attached is shown in ***Figure 7***. The coil with the four capacitive elements is simulated again with a broadband Gaussian pulse to determine the resonant frequency. The resulting return loss is shown in ***Figure 8*** where the resonance can be seen to have shifted to the desired 64 MHz. At this point, a single coil has been tuned. This procedure of cutting gaps and adding capacitors should be performed for the other three elements of the total four-element coil. In order to minimize coupling between the elements, a tank circuit is added at the feed point capacitor by adding an appropriate inductor to form a high impedance at 64 MHz making the coil seem invisible to the adjacent elements. Once this is done, the full coil is ready to be simulated at the design frequency to determine the quality of the field distribution. Following a simulation with a sinusoidal input at the desired 64 MHz, the magnetic field and magnetic flux density distributions across the center of the coil may be observed. A properly designed coil should give a homogeneous field across the coil and have nulls in the field centered between the coil overlaps. The resulting magnetic field through the center cross-section of the coil, shown in ***Figure 9***, indicates that the coil is still not perfectly tuned. A well-tuned coil will have a strong null in the magnetic field between the coil elements. This null is visible in the upper right and lower left hand corners where a low field value (single blue dot) may be seen between the two coil elements, indicating minimal coupling. In the upper left and lower right hand corners, there is still some coupling between the adjacent coil elements, which is disturbing the magnetic field distribution and pro-



▲ *Fig. 7 Single coil resonated with four separate capacitors.*



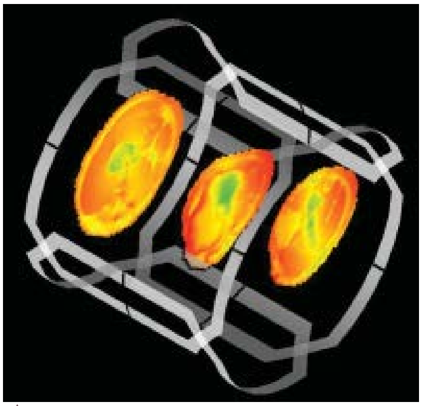
▲ *Fig. 8 Return loss of the single coil with capacitors adjusted for resonance at 64 MHz.*



▲ *Fig. 9 Magnetic field through the center cross-section of the coil.*

ducing nulls at the outer edges of the elements. To reduce the coupling, the spacing between the elements requires some adjustment to make the field more homogeneous. After the coil is properly tuned, a simulation of the loaded coil in use on a leg may be performed. The positioning of the coil is shown in ***Figure 10***, where the knee is centered in the coil. The actual simulation is performed on a section of the leg in the vicinity of the coil. Note that the coil may need further tuning once it is under loaded conditions. This step is not discussed here, but it would involve optimizing the return loss when the leg is present in the coil. The resulting SAR distribution through the leg may be computed and observed to ensure that the device is within design specifications. The SAR in several leg sections is shown in ***Figure 11***. In addition to the values shown here, the temperature rise in the tissue resulting from the SAR, the rotating B fields (B+/B–), the electric fields and the currents in the simulated geometry may also be displayed.

▲ *Fig. 10 Positioning of the coil, centered on the knee.*



▲ *Fig. 11 Computed SAR in several leg sections.*

CONCLUSION

Research and development of MRI systems requires powerful software tools to evaluate and optimize designs. For a number of years, researchers in the MRI area have made use of FDTD software for computing the fields internal to the body, which are nearly impossible to measure experimentally and to design structures such as coils. The simulation procedure allows the coil designer to get quick feedback on the performance of the device, without the time or cost of producing numerous prototypes. The further ability to simulate the structure in practical use, such as the coil around a body part, permits the designer to optimize the device under loaded conditions and ensure that the regulated limits such as SAR are within thresholds. Improvements in software accountability for actual human body characteristics (such as heat transfer due to blood flow) provides enhanced accuracy with the capability of supporting body data re-positioning

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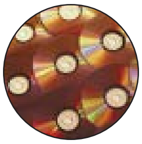
Christopher Penny *is a cofounder of REMCOM Inc. He has extensive experience in the development of the XFDTD® software package. He has also worked as the principal investigator for several US Government Small Business Innovative Research (SBIR) contracts, including one that led to the Varipose® software product.*



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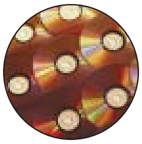

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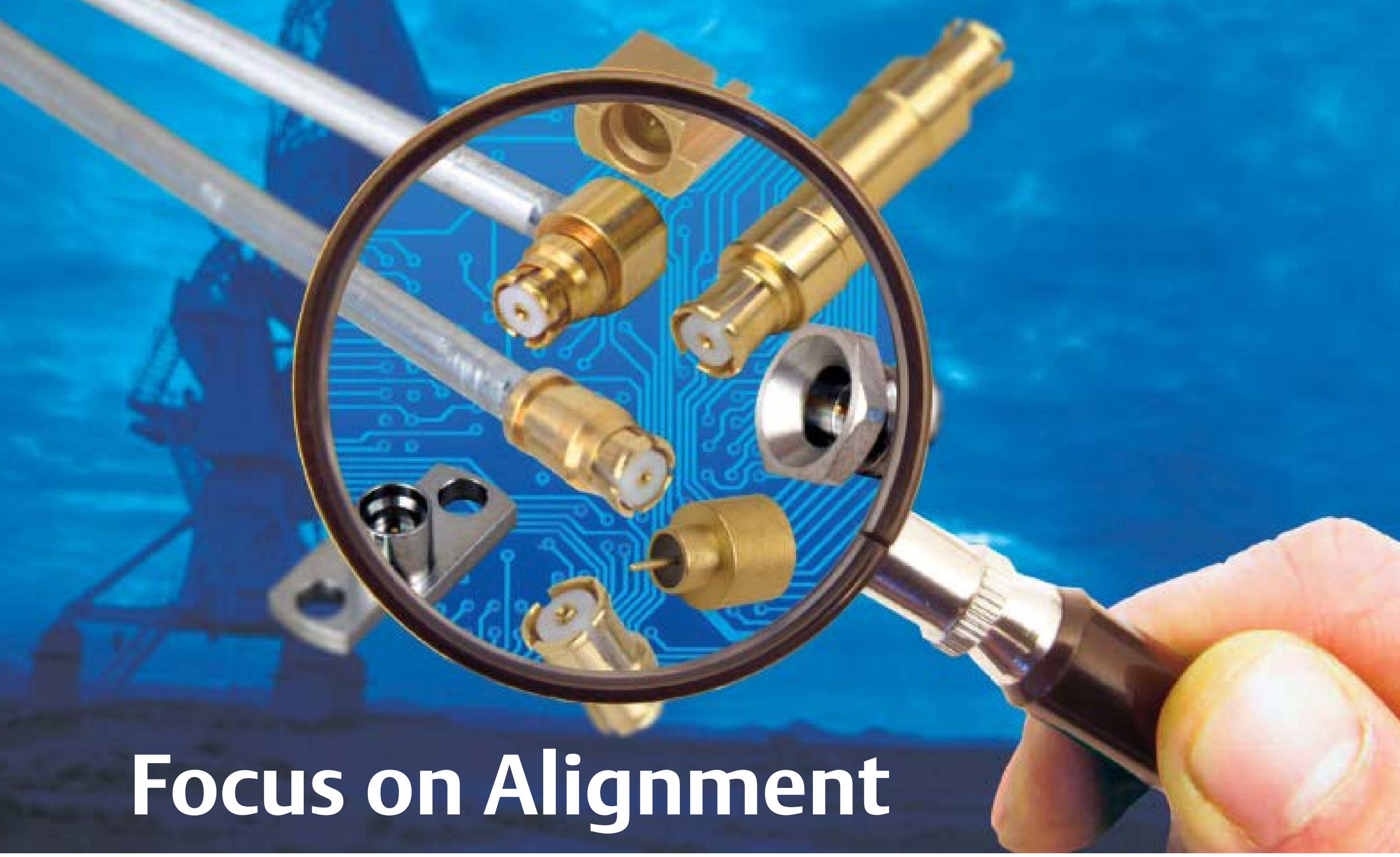

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EuMW 2007: The Perfect 10

The 10th European Microwave Week in Munich, Germany, in October commemorated and celebrated the past, while looking forward and heralding the future. To mark its first decade, EuMW lauded the RF and microwave industry's camaraderie, endeavour and achievements, while focussing on the efforts needed to further technological and commercial development and take the industry forward. The Week benefited from the globalisation of the RF and microwave industry with the US, Asia and Eastern European states having an increasingly significant presence and influence on both the conference content and participation in the *European Microwave Exhibition*.

As an international showcase for leading manufacturers in the RF, microwave, integrated circuit, wireless and radar industries, EuMW provided an invaluable and dynamic platform for the presentation and introduction of the latest technological developments and a forum for discussing current trends and exchanging scientific and technical information.

THE CONFERENCES

EuMC 2007

The *European Microwave Conference* marked its third visit to Munich with 66 regular oral sessions, 22 of which were joint sessions with the associated conferences, EuMIC, ECWT and EuRAD. This large number was a particular aim, in accordance with the EuMW concept of integrating the four conferences and uniting their respective communities. In addition, there were three poster sessions and various workshops designed to encourage technical exchanges on specific topics in the microwave arena.

Richard Mumford
Microwave Journal *European Editor*

ECWT 2007

Like EuMW, the *European Conference on Wireless Technology* celebrated its 10th anniversary. Over that period it has established itself as the premier European forum for wireless technology. This technology was once synonymous with mobile phone systems but has developed beyond that in recent years, with advances in technology being the enabling force behind many innovations in communications using microwave and mm-wave signals. This year's conference grew to accommodate these new concepts within the framework of a top class technical programme. Importantly, joint sessions with the EuMC and EuMIC gave delegates an intensive update on the latest developments.

EuMIC 2007

The technical programme for the 2007 *European Microwave Integrated Circuits Conference* included more than 100 technical papers spanning more than 20 sessions. Demonstrating the conference's global appeal it included contributions from all over the world, particularly the Far East. A significant number of sessions were joint sessions with EuMC and ECWT. The programme featured two invited talks in the plenary session, several workshops and short courses, and was completed by the now traditional *Foundry Round Table Discussions*.

EuRAD 2007

The 4th *European Radar Conference* consisted of 65 oral presentations arranged over 18 sessions, along with 17 poster papers. Contributions came from authors from around the world, covering a wide range of topics from broadband radar, sophisticated radar signal and data processing, including STAP to SAR interferometry and imaging, both from a scientific as well as from an application-related perspective. A special attraction was the focused sessions, which were on the topics of millimetre-wave imaging, communication by radar, broadband radar and short-range automotive sensing.

SPONSORS

The 10th European Microwave Week would not have been such a success without the support and encouragement of commercial sponsors. Through continued support many have become synonymous with the event and are expected features. That is the case with Platinum Sponsors Agilent whose contribution to the Week and particularly the *Welcome Reception* has made it a social highlight. Rohde & Schwarz sponsored the registration where visitors collected delegate bags courtesy of Ansoft. WIN Semiconductors provided the badge cords and Mician the visitor bags. The very welcome coffee breaks were sponsored by Mimix Broadband, EADS, Rohde & Schwarz and Microwave Marketing, while the ever popular Cyber Café sponsored by CST provided that essential link with the outside world. In the real café area EADS provided the delegate lunch boxes.

AMSTERDAM 2008

From 26 to 31 October 2008 European Microwave Week will return to its origins and the RAI Centre, Amsterdam, The Netherlands, the venue of the very first EuMW in 1998. When the city last paid host to the event in 2004 the European Radar Conference was launched. This event has gone from strength to strength and sits well with the other three conferences. Just like the industry it represents EuMW adapts and evolves to encompass new technologies. In 2008 the subject areas covered will include microwave and opto-electronic devices and circuits, packaging and interconnects, antennas, propagation and EMI, radar, sensors and wireless technologies, measurement and instrumentation, and telecommunication, transportation and medical systems. Indeed the Week promises to be as diverse as Amsterdam itself. It is the ideal city for mixing business with pleasure and every effort is being made to make it a memorable event. The Call for Papers has gone out, so if you would like to contribute or find out more about EuMW 2008 visit: www.eumweek.com. ■

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PLUG-AND-PLAY POWER SOLUTION MODULES FOR L- AND S-BAND PULSED RADAR APPLICATIONS

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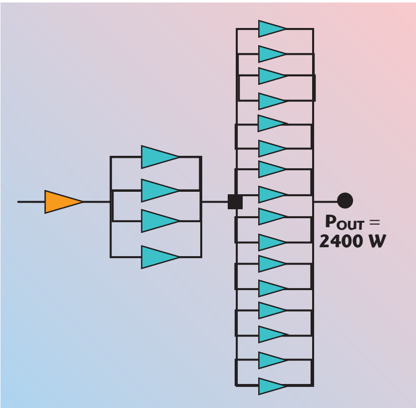
Fig. 1 A 2 kW amplifier using a traditional approach.



NEED FOR MULTI-KILOWATT SYSTEMS WITH 1 kW OR 2 kW AS BUILDING BLOCKS

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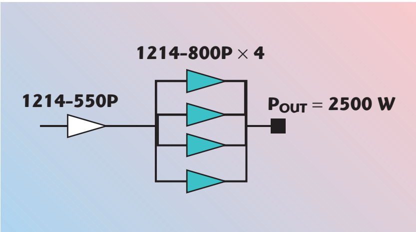
impedance of this kind of discrete transistor is at the 1 to 2 Ω range; thus, users need to design external input and output matching circuits to transform such low impedance to 50 Ω in order to be compatible with other RF components in the system. Such tasks require specific knowledge, skill sets and experience in the RF/microwave field, and are quite time consuming. Once the individual transistor is matched to a 50 Ω system, the user needs to design both a multi-way power splitter at the input and a multi-way combiner at the output to accomplish driving the inputs and combining the outputs, respectively, of the stage of four and stage of 16 paralleled transistors. The overall module efficiency after such high number of combinations decreases from 50 percent to 35 to 40 percent because of the loss of the 16-way combiner. In addition, the size of such modules tends to be very large; the biasing network and low frequency filtering circuitry for 16 transistors adds another dimension to the overall module complexity. The resulting module is labor intensiveness for production assembly and tuning.

PSM SOLUTION AND BENEFITS

The new PSM Series is designed to provide substantial reductions in system design time, real estate and complexity. Most importantly, users can achieve cost savings in both the design and the manufacturing phases of their system amplifiers while providing considerably higher efficiency, reduced power amplifier size and better system reliability in mission critical applications. Designers can use just one 550, 700, or 800 W PSM to replace up to four 220 W transistors that are commonly designed in parallel at the output of L-band power amplifiers. ***Figure 2*** shows a 2 kW amplifier designed with 1214-800P devices.



▲ *Fig. 2 A 2 kW amplifier using the PSM approach.*

The L-band Power Solution Module Series consists of three model types: the 1214-800P, 1214-700P1 and 1214-550P. They provide a "50 Ω IN-50 Ω OUT" fully matched across the 1200 to 1400 MHz band, high power amplifier stage for pulsed radar systems. These high performance class-C modules are designed for unparalleled performance, delivering peak power outputs greater than 550, 700 and 800 W at 50 percent collector efficiency, under a pulse format of 300 µs, 10 percent long-term duty cycle. Their user-friendly feature provides users with plug-and-play capability that requires no additional tuning or complicated impedance matching.

The PSM product family uses a Microsemi proprietary chip design, effective power combining, and advanced state-of-the-art automated assembly and testing. Its design and manufacturing advantages result in superior performance in power output, gain, efficiency and footprint, while achieving outstanding module consistency and repeatability in high volumes.

TABLE I

L-BAND PSM KEY PRODUCT FEATURES

Frequency coverage (MHz)	1200 to 1400
Medium pulse format	300 µs, 10%
Ouput power (W)	> 550, > 700, > 800
Power gain (dB)	> 8 min
Collector efficiency (%)	> 50
Operation	Class-C
Compact size (mm)	81.3 × 50.8 × 5.3 (3.2" × 2" × 0.21")

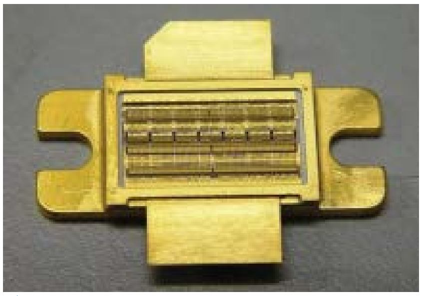
POWER SOLUTION MODULE BENEFITS:

- Extremely easy to use—50 Ω IN-50 Ω OUT —plug and play
- Significantly reduced design cycle—No complex RF impedance matching work required
- Reduced system size—PSM devices are compact
- Reduced system complexity—fewer combining stages required; no matching necessary
- Improved system performance—high efficiency, reliability and repeatability
- Eliminates system production transistor assembly and RF tuning time
- Greatly improves production yield—reduces transistor scrap
- Reduces system components inventory
- Custom-designed PSM to customer's specifications available

PSM KEY SPECIFICATIONS AND DESIGN APPROACH

The NPN silicon bipolar junction transistor used in the PSM is designed and fabricated at Microsemi PPG - RF Products Division. ***Table 1*** lists the L-band PSM's key features. The transistor has an interdigitated geometry with very tight emitter-to-emitter pitch to increase the emitter periphery-to-base area ratio, which on this chip is about 8 mil. The emitter periphery and epitaxial material was chosen to provide nominal power of 100 W per chip biased at 50 V. Double layer gold metallization is used to lower the output capacitance (COB) and also results in achieving excellent MTTF for the L-band frequency range. Nichrome emitter ballast resistors are used for better linearity.

The transistor chips are attached to a 40 mil thick metallized beryllium oxide (BeO) substrate over a 60 mil thick CuW flange. The packaged transistors are internally matched with input and output metal-nitrate-metal (MNM) capacitors that are also fabricated at Microsemi PPG-R. The input matching network consists of a two-stage low pass impedance matching transformer design by using the series inductance of bond-wires and capacitance of shunt MNM capacitors soldered to the metallized ground plane. Output matching consists of the shunt inductive bond-wires connected from the isolated collector-die attachments area to DC blocking capacitors, which are also mounted on the metallized



▲ *Fig. 3 A single-ended L-band packaged transistor.*

TABLE II
SINGLE-ENDED SOURCE AND LOAD IMPEDANCE

Frequency	Z_S (Ω)	Z_L (Ω)
1200 MHz	1.75–j2.2	1.50–j2.10
1300 MHz	1.75–j1.60	1.35–j2.00
1400 MHz	1.76–j1.20	1.1–j1.80

ground plane. All bond-wires are straight and in-line, which allows fully automatic wire bonding for mass production and consistency. All together there are 369 wire bonds. ***Figure 3*** shows the inside of the single-ended transistor. These transistors are hermetically solder-sealed for the highest reliability.

The single-ended input and output impedances achieved with the internal matching design are shown in ***Table 2***. The source impedance Z_S and load impedance Z_L are measured using a TRL technique and are oriented away from the transistor.

This Power Solution Module is designed on Roger Corp.'s RT/Duroid copper-backed boards. The compact size of the 1214-800P PSM (81.3 mm × 50.8 mm × 5.3 mm) makes it very attractive for users who have constraints on system mechanical dimensions. The surface of the board is also electro-plated to prevent the oxidation of the copper boards.

The power combining technique used in this power amplifier is a Wilkinson divider/combiner. Impedances of the input and output of the single-ended transistors are first transformed to a 25 Ω intermediate impedance. This impedance is subsequently transformed to 50 Ω through the Wilkinson divider/combiner. The two RF choke sections are set to be quarter-wave length at 1300 MHz. Two 50 Ω high power AlN resistors, one for each side of the divider/combiner circuit, are used to provide isolation between the two single-end transistors. The isolation is more than 20 dB according to computer simulation. To achieve higher output power and high efficiency the transistors are configured in common base mode and class-C biased. The 800 W Power Solution Module described here is shown in ***Figure 4***.

RF MEASUREMENTS AND PERFORMANCE

To facilitate the demonstration of PSM performance, a test fixture was built where SMA connectors could be attached to the input and output of the RF terminals. Two high voltage 4000 μF storage capacitors are also soldered to the biasing circuits, one on each side of the PSM. Finally, a heat dissipating aluminum fin is mounted on the bottom of the PSM and an air-cooling fan is used to cool the PSM during test.

▲ *Fig. 4 The 1214-800P 800 W power solution module.*

The performance of this 800 W PSM tested under 300 μs pulse width, 10 percent duty cycle biased at 50 V is shown in ***Figures 5*** and ***6***.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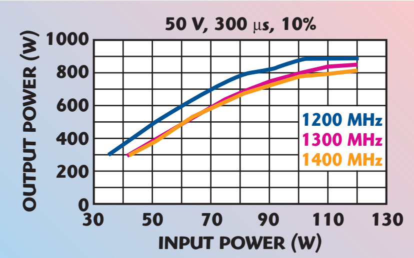
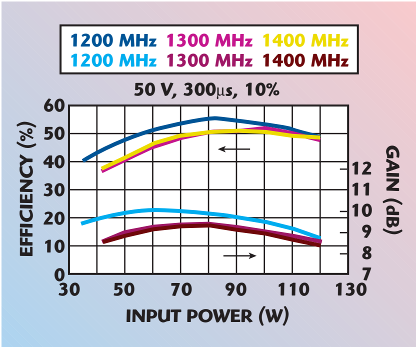


▲ *Fig. 5 Output power vs. input power for the 1214-800P PSM.*

The output power is measured at the middle of the pulse, which is 150 µs into the pulse for this case. As shown, 800 W of output power is obtained with input power drive at about 110 W, which corresponds to 8.6 dB power gain at frequency of 1400 MHz. At 1200 MHz, 893 W of output power was measured at the same input drive, which is 9.1 dB gain. The output gain flatness for this power module is less than 0.5 dB measured at this fixed input drive. The collector efficiency is around 50 percent at P_{in} = 110 W. A snapshot of a typical pulse shape at 1300 MHz is shown in ***Figure 7***. The typical amplitude droop is under 0.3 dB, an indicator of excellent thermal design. The return loss across the frequency of 1200 to 1400 MHz is better than –12 dB.

PSM FAMILY FOR S-BAND PULSED RADAR APPLICATIONS

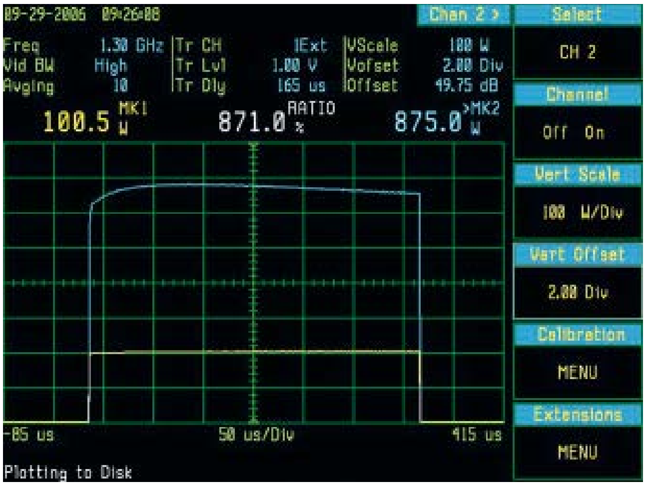
The demand for a similar product for S-band pulsed radar applications has been increasing. The PSM family also consists of three platform products that cover the popular 2700 to 3400 MHz frequency range: 2731-200P, 2729-300P and 3134-180P, as listed in ***Table 3***.



▲ *Fig. 6 Gain and efficiency vs. input power for the 1214-800P PSM.*

DESIGN PHILOSOPHY AND MASS PRODUCTION CAPABILITY

Consistency is at the heart of



▲ *Fig. 7 Typical pulse shape at 1300 MHz.*

TABLE III

S-BAND PSM KEY PRODUCT SPECIFICATIONS

Model number	2731-200P	2729-300P	3134-180P
Frequency coverage (MHz)	2700 to 3100	2700 to 2900	3100 to 3400
Medium pulse format	200 μs, 10%	200 μs, 10%	100 μs, 10%
Output power (W)	> 200	> 300	> 180
Power gain (dB)	> 7 min	> 7	> 7
Operation +36 V	Class-C	Class-C	Class-C
Compact size	50.8 × 35.6 × 5.3 mm (2" × 1.4" × 0.21")	50.8 × 35.6 × 5.3 mm (2" × 1.4" × 0.21")	69.9 × 38.1 × 5.3 mm (2.75" × 1.5" × 0.21")

chip development discipline. Thermal die simulation and thermal scan analysis guide die design to eliminate hot spots, produce thermally balance die with targeted low junction temperatures that permit consistent die operation and the utmost reliability. Fully automated die attach, wire bonding and assembly assures precise construction and tight tolerances of all critical elements and dimensions. Automated RF test guarantees repeatable RF performance. As a result, the consistency and repeatability of critical parameters for phase array radar applications, such as output power, gain and insertion phase from lot to lot are able to achieve extremely tight distribution in volume production.

CONCLUSION

Power solution modules have been described that feature a plug-and-play concept that has built-in impedance transformation networks with 50 Ω terminal impedance at both input and output. Users can easily drop in the PSM to their system power module without any further impedance design work and enjoy the benefits of faster design cycle time, simplified power module complexity, reduction of system size, improvement in system reliability, elimination of production tuning, improvement of transistor yield, and reduction of inventory of components count in addition to the obvious enhancement of higher power and higher efficiency.

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RS No. 301

FREQUENCY CONVERTERS FEATURING MILLIMETER-WAVE MEASUREMENTS WITH HIGH DYNAMIC RANGE AND MULTIPLE PORTS

The demand for products and systems that can operate at higher frequencies is increasing with the higher frequency bands being utilized for important applications such as vehicle distance radar (77 GHz) and aerospace and defense applications (94 GHz). This creates demand for higher frequency measurement and testing. To address this need Rohde & Schwarz has extended the frequency range of its high-end vector network analyzers to 75 to 110 GHz (W-band), with the introduction of the R&S ZVA-Z110 frequency converter, which is available for the R&S ZVA24, R&S ZVA40 and R&S ZVT20.

A key consideration was to make the frequency converters easy to use and help users save time, which is why it was designed so that no additional hardware is necessary if an adequate four-port vector network analyzer is used to operate a pair of converters. Also significant was the fact that in recent years, multi-port measurements have become more and more important, which is why the R&S ZVA-Z110 is the first to offer full multi-port and balanced measurement in the W-band.

THE CONVERTER

To illustrate how the frequency converter operates, ***Figure 1*** shows a transparent CAD representation of the converter together with its block diagram where: (1) is a source multi-

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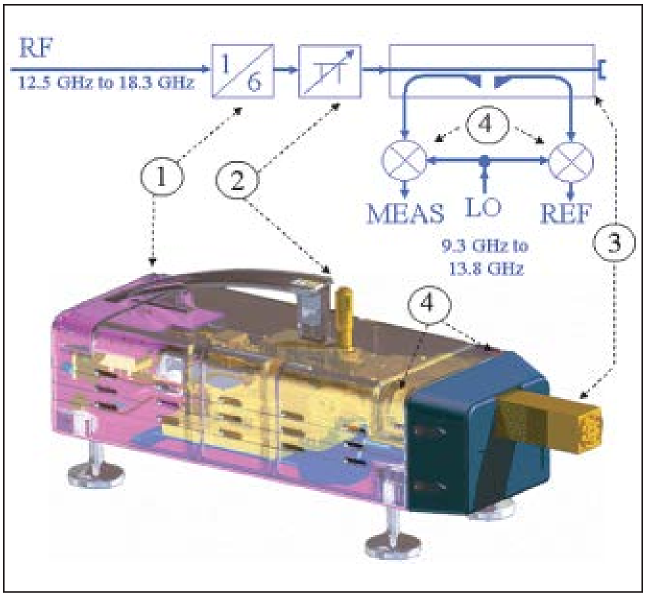


▲ *Fig. 1 Transparent CAD representation and block diagram of an R&S ZVA-Z110 converter (test port adapter removed).*

plier; (2) is an adjustable waveguide attenuator; and (3) is the directional coupler, which separates the reference and measurement channels. These channels are down-converted using (4) two harmonic mixers. Using the example of a 90 GHz bandpass filter consider the S-parameter measurement of a filter.

STEP 1: CONFIGURATION AND SET UP

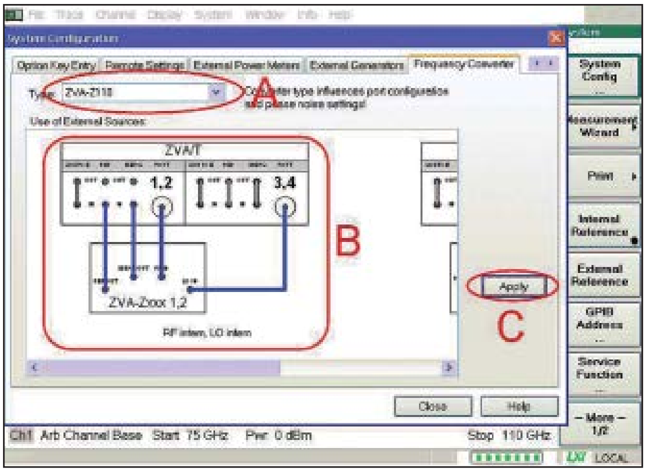
Configuration is as easy as ABC, as ***Figure 2*** illustrates. In this figure A is – select the converter type; B is – choose the cabling scheme; and C is – click, apply and connect the converters to the analyzer (see ***Figure 3***). The frequency axis becomes 75 to 110 GHz (indicated at the bottom of Figure 2). In addition, all measurement parameters for the converters are set automatically (for example, multiplication factors of RF and LO, optimum power levels, redefinition of preset, connector type WR10 and the R&S ZV-WR10 waveguide calibration kit is defined and selected).

STEP 2: CALIBRATION

In this example the calibration is performed using the TOSM calibration technique and the R&S ZV-WR10 waveguide calibration kit (shown in the foreground of Figure 3). The kit supports several other calibration techniques such as TRL, UOSM, TOM, TRM and OSM. A sliding match can be included in the kit. The sliding match can be used to raise directivity and load match up to typically 42 and 40 dB. Due to radiation effects that occur at an open end of a waveguide, the open standard, which is known from coaxial calibration kits, has to be replaced by an offset short. The offset short consists of a shim (acts as a λ/4 transformation around the middle of the frequency band) and a short standard.

STEP 3: MEASUREMENT

Figure 3 shows the complete set up using an R&S ZVA24 vector network analyzer and two R&S ZVA-Z110 converters to measure a 90 GHz bandpass filter. Measure-



▲ *Fig. 2 Configuration dialog.*

ments on high rejection filters require high dynamic range. These frequency converters set a new standard for dynamic range of typically > 110 dB and can easily satisfy the needs for filter measurement. This enables the user to increase the measurement bandwidth to 1 kHz, for example, gaining high sweep velocity.

Besides filter measurements, several other applications can be carried out:

- Tests on low noise amplifiers that can be performed without any problems due to the integrated W-band attenuator, making it possible to provide the low stimulus levels that are essential for this type of measurement.
- The use of the converters in production lines that are dedicated to compact design and fast sweeps. For instance, in particle-sensitive environments, e.g. for a wafer prober, the passive cooling concept without a fan is an additional advantage.
- Multi-port and balanced applications at millimeter-wave frequencies.

MULTI-PORT MEASUREMENT

Up to now, multi-port and balanced measurements have been restricted to about 50 GHz. Nevertheless,

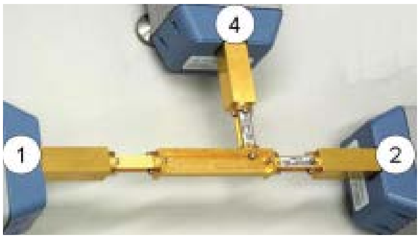
▲ *Fig. 3 Complete millimeter-wave set up measuring a 90 GHz bandpass filter, together with the R&S ZV-WR10 waveguide calibration kit.*

there are a number of applications within the W-band that use balanced circuits or devices featuring multiple ports (for example, the vehicle distance radar and aerospace and defense applications mentioned earlier). The R&S ZVA-Z110 frequency converters and the R&S ZVT20 vector network analyzer have been designed to provide a flexible solution for up to six measurement ports.

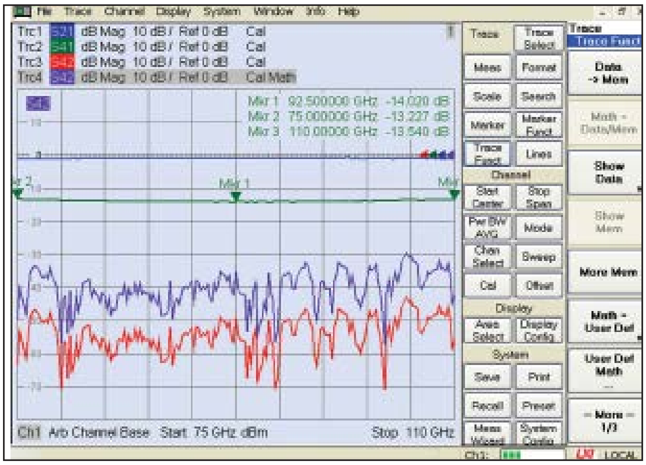
Consider a three-port measurement of a directional coupler. The first question is why use three test ports? The answer is that with three converters and a suitable network analyzer, a three-port coupler can be measured in a single test sequence (see ***Figure 4***). This saves time and allows measurement of all 3 × 3 S-parameters of the coupler, eliminating the need for reconnections and the use of several two-port calibrations. Instead, a full three-port calibration is possible, resulting in more accurate results.

MEASUREMENT SET UP

The R&S ZVT20 allows the user to drive up to four frequency converters, without using an external generator. This solution is compact (no additional hardware) and offers fast measurement speed. With this application



▲ *Fig. 4 Three-port measurement.*



▲ *Fig. 5 Measurement result of a three-port coupler.*

three converters are sufficient. Test ports 5 and 6 provide the LO signal for the converters. In addition, if needed, external Wilkinson dividers can be used to distribute the LO signal to all converters.

UOSM CALIBRATION

The advantage of the UOSM calibration technique is that it gets along with an unknown through as a calibration standard. This unknown through has to fulfill only one requirement: reciprocity. The unknown through, therefore, does not need to have good matching or low loss. Even low priced waveguide sections, bends and twists with standard flanges meet the reciprocity requirement and can serve as unknown throughs.

Any significant modification to the test port orientation after calibration may cause a (avoidable) loss in accuracy. Therefore, an H-plane bend is used in this example to establish the throughs between waveguide test ports 1 and 4, and test ports 2 and 4. The through between waveguide test ports 1 and 2 is made by direct connection of the two test ports.

The measurement results for the directional coupler are shown in ***Figure 5*** and are measured using a measurement bandwidth of 1 kHz. *Trc1* shows the insertion loss, *Trc2* the coupling loss, *Trc3* the isolation and *Trc4* is the directivity calculated by means of trace mathematics from *Trc3* and *Trc2*.

CONFIGURATION ISSUES

An R&S ZVA or R&S ZVT vector network analyzer with an upper frequency limit of at least 20 GHz can be used to operate the converters, so long as the direct generator/receiver access and converter control software options are adopted. Another configuration issue is whether an external generator is necessary.

In the second example (coupler), a four-port R&S ZVA can be used alternatively if the converters' LO signal is

TABLE I

KEY SPECIFICATIONS

Frequency range (GHz)	75 to 110
Waveguide designator	WR10
Connector type	precision waveguide flange compatible to UG387/U-M
Test port output power (dBm)	+2 with +7 dBm at RF IN
Accuracy of output power (dB)	< 4 (with 0 dB power attenuation)
Manual power attenuation (dB)	0 to 25
Dynamic range (dB)	95 (typ. 110)
Input power at RF IN, LO IN (dBm)	+5 to +10 (ideally +7)
Plug-in power supply	100 to 240 V, 47 to 63 Hz
Dimensions (W × H × D) (mm)	360.5 × 110 × 114
Number of feet	4, 3 or 0

provided by an R&S SMF100A signal generator and distributed to all converters (for example, by a four-port power splitter). The external generator has to be controlled by the R&S ZVA. This causes a growth in sweep time, which can be minimized by the use of the generator's listed sweep mode. As a general rule, the number of converters operated by the network analyzer can be increased if the external generator is used to provide the LO signal.

For example, six frequency converters can be operated using an R&S ZVT20, an R&S SMF100A and a suitable LO distribution network. Also, a two-port R&S ZVA24 vector network analyzer, which is normally not sufficient to drive a converter (at least four ports are required), can be complemented by an R&S SMF100A to operate one or two converters. ***Table 1*** shows the key specifications of the R&S ZVA-Z110.

CONCLUSION

The fact that equipment and systems are being employed at higher frequencies for an increasing number of applications has created a demand for the R&S ZVA-Z110 frequency converter to extend measurement options into the 75 to 110 GHz (W-band) range. As this article has demonstrated its implementation opens up greater possibilities for vector network analyzers.

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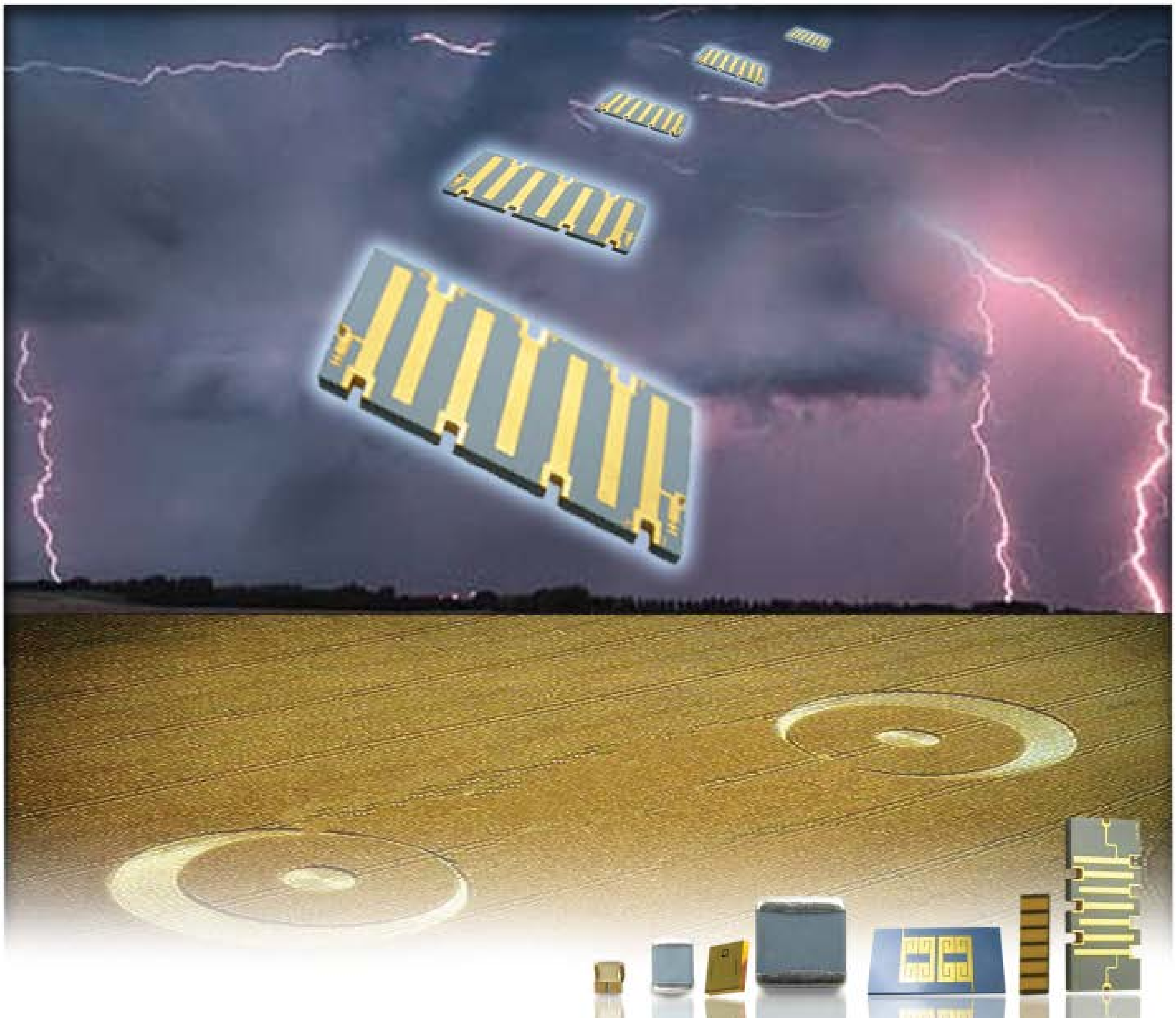
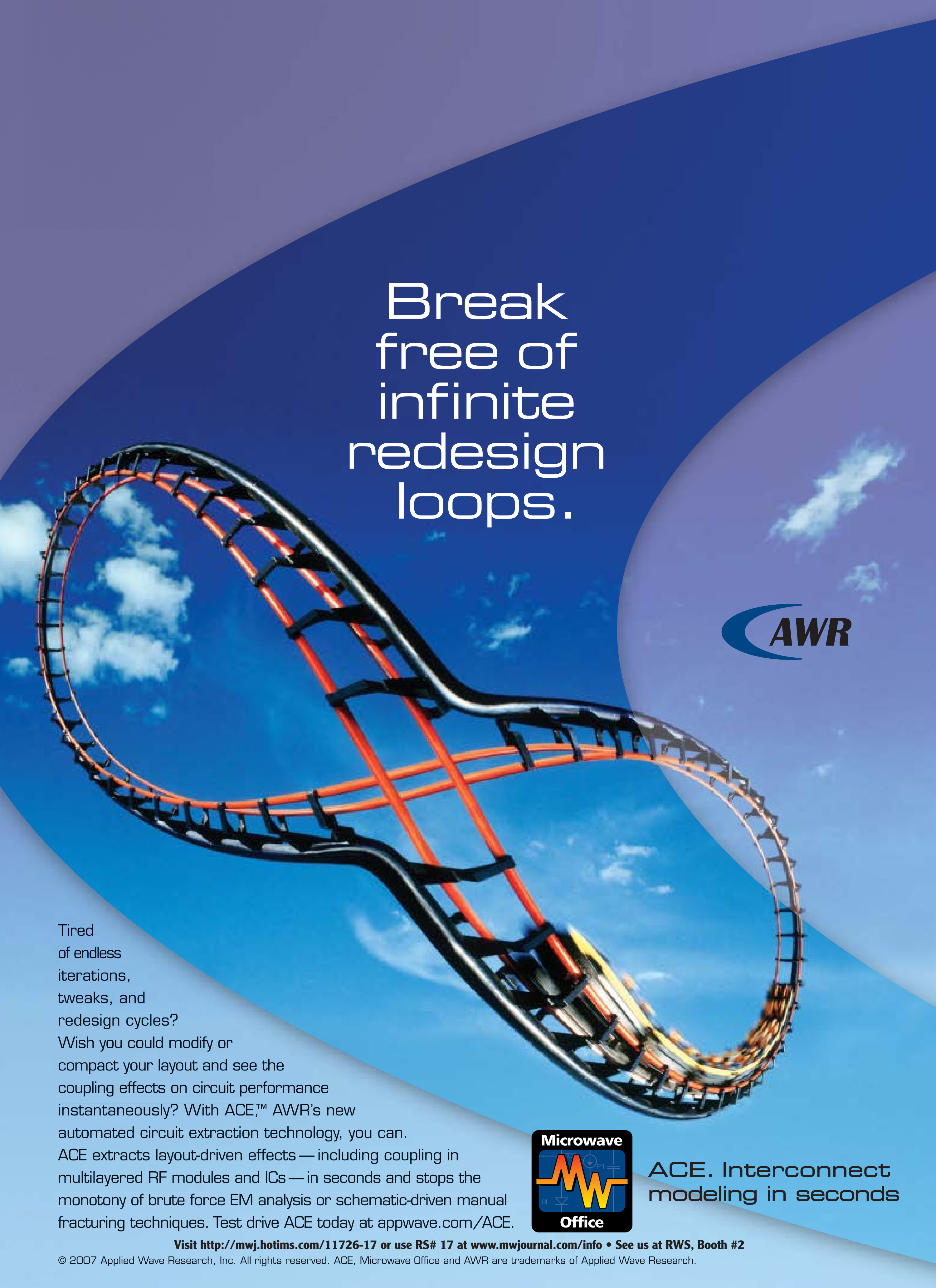
FURTHER READING

Readers wanting more information can access data sheets and application notes from http://www.rohde-schwarz.com.

For readers generally interested in the field of vector network analysis the book *Fundamentals of Vector Network Analysis* is recommended and available via the book shop at http://www.books.rohde-schwarz.com.

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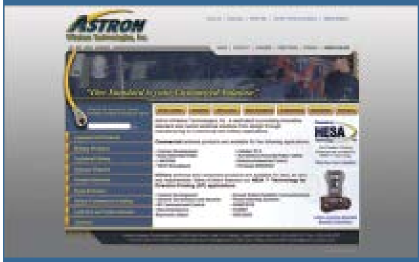

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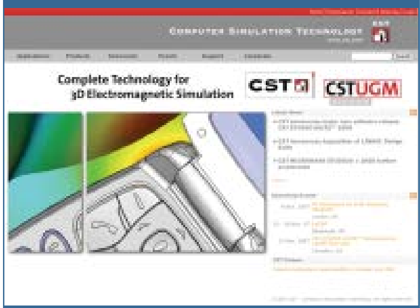

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- GUARANTEED DELIVERY
- SWEPT TEST DATA SUPPLIED WITH EVERY UNIT

Visit www.planarelec.com for full listing of amplifiers.

Ultra-Broadband

Freq. Range (GHz)	Gain (dB)	Gain Flatness (+/- dB)	NF (dB)	OP1dB (dBm)	OIP3 (dBm)	VSWR In/Out	Max. CW RF Input (dBm)	DC Current @ +12VDC (mA)	Model Number	Cost ($ USD) 1-10	11-20	20+
0.03-20	14	2.5	3.0	14	26	2.0:1	23	75	PUB-14-30M20G-14-LCA	850	750	650
0.03-20	15	2.5	3.0	20	30	2.0:1	23	180	PUB-15-30M20G-20-LCA	950	850	750
0.50-20	14	1.75	3.0	14	26	2.0:1	23	75	PUB-14-500M20G-14-LCA	750	650	550
0.50-20	15	1.75	3.0	20	30	2.0:1	23	180	PUB-15-500M20G-20-LCA	850	750	650

Broadband

Freq. Range (GHz)	Gain (dB)	Gain Flatness (+/- dB)	NF (dB)	OP1dB (dBm)	OIP3 (dBm)	VSWR In/Out	Max. CW RF Input (dBm)	DC Current @ +12VDC (mA)	Model Number	Cost ($ USD) 1-10	11-20	20+
2-20	15	1.75	3.0	12	24	2.0:1	23	75	PBB-15-220-12-LCA	750	650	550
2-20	28	2.25	3.0	12	24	2.0:1	23	150	PBB-28-220-12-LCA	850	750	650
2-18	10	1.75	4.0	16	26	2.0:1	23	75	PBB-10-218-16-LCA	650	550	450
2-18	15	2.0	3.0	20	30	2.0:1	23	180	PBB-15-218-20-LCA	800	700	600
2-18	20	2.0	4.0	16	26	2.0:1	23	150	PBB-20-218-16-LCA	800	700	600
2-18	28	2.5	3.0	20	29	2.0:1	23	250	PBB-28-218-20-LCA	850	750	650

Octave Band

Freq. Range (GHz)	Gain (dB)	Gain Flatness (+/- dB)	NF (dB)	OP1dB (dBm)	OIP3 (dBm)	VSWR In/Out	Max. CW RF Input (dBm)	DC Current @ +12VDC (mA)	Model Number	Cost ($ USD) 1-10	11-20	20+
2-4	10	1.0	4.0	10	18	2.0:1	10	75	POB-10-24-10-LCA	450	350	300
2-4	15	1.0	3.5	15	26	2.0:1	23	75	POB-15-24-15-LCA	500	450	350
2-4	17	1.0	3.5	22	34	2.0:1	23	180	POB-17-24-22-LCA	550	450	400
2-4	28	1.25	3.5	15	26	2.0:1	23	150	POB-28-24-15-LCA	550	450	400
4-8	10	1.0	3.0	10	18	2.0:1	10	75	POB-10-48-10-LCA	450	350	300
4-8	15	1.0	3.0	15	26	2.0:1	23	75	POB-15-48-15-LCA	500	450	350
4-8	16	1.0	3.0	22	32	2.0:1	23	180	POB-16-48-22-LCA	550	450	400
4-8	28	1.25	3.0	15	26	2.0:1	23	150	POB-28-48-15-LCA	550	450	400
8-18	10	1.5	3.0	8	16	2.0:1	10	75	POB-10-818-8-LCA	600	500	400
8-18	15	1.5	3.0	13	25	2.0:1	23	75	POB-15-818-13-LCA	650	550	450
8-18	15	1.75	3.0	20	26	2.0:1	23	180	POB-15-818-20-LCA	700	600	500
8-18	28	1.75	3.0	13	24	2.0:1	23	150	POB-28-818-13-LCA	750	650	550

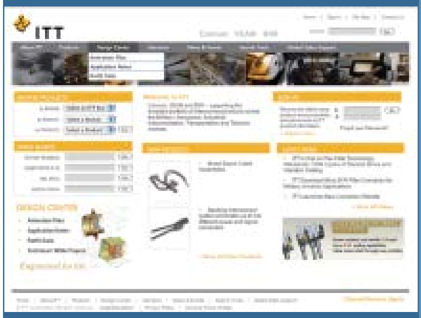
Low Noise

Freq. Range (GHz)	Gain (dB)	Gain Flatness (+/- dB)	NF (dB)	OP1dB (dBm)	OIP3 (dBm)	VSWR In/Out	Max. CW RF Input (dBm)	DC Current @ +12VDC (mA)	Model Number	Cost ($ USD) 1-10	11-20	20+
1-2	18	1.0	1.5	15	28	2.0:1	0	65	PLN-18-12-15-LCA	500	400	300
2-4	18	1.0	1.5	15	28	2.0:1	0	65	PLN-18-24-15-LCA	550	450	350
4-8	17	1.25	1.75	15	28	2.0:1	0	65	PLN-17-48-15-LCA	600	500	450
6-8	32	1.25	1.0	2	10	2.0:1	10	40	PLN-32-68-2-LCA	650	550	450
8-10	32	1.25	0.8	2	10	2.0:1	10	40	PLN-32-810-2-LCA	650	550	450
8-12	25	1.0	1.8	10	18	2.0:1	20	75	PLN-25-812-10-LCA	700	600	500
10-12	30	1.5	0.8	2	10	2.0:1	10	40	PLN-30-1012-2-LCA	650	550	450
1-10	17	1.5	2.0	15	28	2.0:1	0	65	PLN-17-110-15-LCA	750	700	650

Typical specifications shown

5715 Industry Lane, Unit 11, Frederick, MD 21704 USA • PHONE (301) 662-5019 • FAX (301) 662-1731
EMAIL: sales@planarelec.com • WEB SITE: www.planarelec.com

TOLL FREE NUMBER: 1-877-PLANAR1



Connector Web Site

This new connector web site has been launched by ITT to provide designers and customers with comprehensive information and design know-how. The completely redesigned site focuses on the company's industry-leading brands—Cannon, VEAM and BIW. Easy-to-use navigation tools enable users to search by product, brand and market, while a Design Center hosts an array of application notes, technical papers and product demonstrations in Macromedia Flash format.

ITT Electronic Components,
666 East Dyer Road,
Santa Ana, CA 92705

www.ittcannon.com

ICs, Modules and Subsystems

This comprehensive, versatile web site has recently added new product pull-down menus and RoHS-compliant component pages. The web site details full specifications for over 480 products, application notes, quality assurance and product support tools, including Product Cross Reference, Parametric Search, PLL Phase Noise and Mixer Spur Chart Calculators, and expanded e-commerce. The company's new Designer's Guide, product selection guide, newsletter and CD can also be requested from the site.

Hittite Microwave Corp.,
20 Alpha Road,
Chelmsford, MA 01824

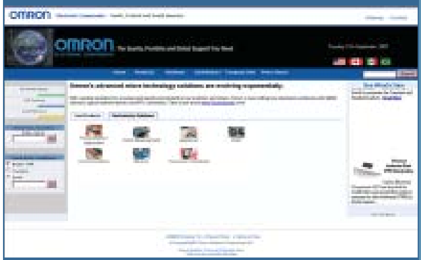
www.hittite.com

Mixers, Multipliers and Frequency Converters

This web site features the company's comprehensive line of microwave mixers, multipliers and mixer-based frequency converters. By combining superior engineering expertise with proven strategies for managing high volume, low cost production, Marki Microwave has grown to be a premier supplier of microwave mixers worldwide. Marki's 2007-2008 product catalog is available upon request at info@markimicrowave.com.

Marki Microwave Inc.,
215 Vineyard Court,
Morgan Hill, CA 95037

www.markimicrowave.com



Components Web Site

The new web site was built to provide a true e-Marketing vehicle for the company, while offering effective tools and resources to its customers. The new components site allows customers to quickly search for solutions by product type or specific industry. The homepage also provides immediate access to the entire Omron library of published documents, RoHS compliance information, cross reference searching, a CAD drawing database, and distributor inventory and contact information.

Omron Electronic Components LLC,
55 Commerce Drive,
Schaumburg, IL 60173

www.components.omron.com

Microwave Cable

Semflex, a wholly-owned subsidiary of Emerson Network Power Connectivity Solutions, designs and manufactures high performance microwave flexible coaxial cable and custom cable assemblies for the military/aerospace, commercial application and test instrumentation markets. The company also manufactures custom connectors, adapters, phase trimmers and other components to meet special interconnect requirements. Semflex Inc. is ISO 9001/2000 registered and also meets the requirements of MIL-I-45208.

Semflex Inc.,
5550 E. McDowell Road,
Mesa, AZ 85215

www.semflex.com

RF Interconnect Products

Trompeter, a wholly-owned subsidiary of Emerson Network Power Connectivity Solutions, is a best-in-class producer of RF interconnect products, including RF connectors, cross-connects, patching, cable assemblies and related tools for coaxial, twinax and triax applications markets worldwide. The company's web site features downloads of BNC installer training videos. Trompeter is ISO 9001/2000 registered and also meets the requirements of MIL-I-45208.

Trompeter,
5550 E. McDowell Road,
Mesa, AZ 85215

www.trompeter.com

Simple Solutions to Complex Switch Problems

Whether you need the benefits of total integration or a high performance custom switch, Aeroflex gives you the choice. The combination of PIN / MMIC diode switches, power dividers, and digital control circuitry in the compact 4x4 non- blocking Matrix multifunction assembly shown, with blind mate connectors and modular construction eliminates cables and crossover's . This modular packaging provides the flexibility to quickly adapt to new circuits, such as switched filters. The miniature 70 dB isolation SPDT switch that is shown provides optimum loss, isolation, with custom phase and power related performance all up to Ka band.

Aeroflex/KDI is a provider of custom PIN/MMIC switched products, including Matrices, Phase Shifters, Attenuators Time Delay Units, from a 10 MHz to 40GHz.

For more information contact us at **973-887-5700 x500** or e-mail **sales@aeroflex-kdi.com**

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REV:0824-1

New Product Slideshow

AR RF/Microwave Instrumentation's homepage now features a new product slideshow that features the latest AR products. Currently highlighted is information on the company's 10 to 20 GHz amplifier series, the "Subampability" Concept, FM7004 free software upgrade, signal generator offerings, and the 4 to 8 GHz amplifier series.

AR RF/Microwave Instrumentation,
160 School House Road,
Souderton, PA 18964

www.ar-worldwide.com

Filters, Duplexers and Integrated Assemblies

K&L Microwave's redesigned web site features improved product navigation and an integrated quote cart that enhances the customer's ability to review available products, simplify identification and specification of custom design solutions, and speed direct communication with the factory.

K&L Microwave,
2250 Northwood Drive,
Salisbury, MD 21801

www.klmicrowave.com

Cavity, Lumped Element and Ceramic Filters

Lorch Commercial and Wireless (LCW), a division of Lorch Microwave, has recently revamped its site to feature complete product information on cavity, lumped element and ceramic filters. The site includes standard frequency ranges, typical specifications, outline drawings, reflow profiles and contact information.

Lorch Commercial and Wireless,
PO Box 2070,
Salisbury, MD 21802-2070

www.lorchwireless.com

A signal analyzer for everybody

You may need to get more than one

Agilent EXA signal analyzer

The Agilent EXA is the first new economy-class signal analyzer that's fast enough for manufacturing and functional enough for development.

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Visit http://mwj.hotims.com/11726-11 or use RS# 11 at www.mwjournal.com/info • See us at RWS, Booth #12

4 to 8 GHz Solid-state Amplifier

AR RF/Microwave Instrumentation has increased its offering of broadband amplifiers with a new family covering 4 to 8 GHz. This family includes models available in 15, 35, 60, 90 and 120 W. This amplifier family is suitable for wireless test applications and EMC testing for automotive requirements, and also the new IEC 61000-4-3 standard.

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

RS No. 216

Miniature Frequency Synthesizers

The LT series of frequency synthesizers operates with minimal phase noise degradation at random vibration levels exceeding 14 g's RMS, 20 Hz to 2 kHz. Shielded aluminum housings are surface-mountable, and can be optionally hermetically sealed for use in stringent environments. The products are offered with optional RoHS compliance, lead (Pb)-free and tin-mitigated designs. Ideally suited for use as local oscillators in UAV, re-entry vehicle (sounding rockets) and military ballistics applications. The LT series exhibits negligible microphonics under shock.

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

RS No. 217

Low Profile Bandpass Filter

This low profile bandpass filter is ideal for applications where cable connections are necessary, while maintaining a "z" dimension that is comparable to many surface-mount applications. Measuring at 1 in^2, with a "z" height of 0.25", the filter features high performance flexible RF cable assemblies available with "SMP," as well as other similar types of RF connectors. This allows fast integration, without the necessity of solder reflow that is typical of most surface-mount configurations. The filters are available in center frequencies ranging from 1000 to 6000 MHz, with 3 dB bandwidths, which can be specified at greater than 100 percent of center frequency.

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

RS No. 219

High Reliability Mixers

The ADE-R3GLH+ series of high reliability mixers features proven, time tested, diode quads in a hermetically sealed package and operates in a frequency range from 2000 to 2700 MHz with an LO power of 10 dBm. It has a low conversion loss of 5.2 dB and an L-R isolation of 35 dB typical over the entire band. It has a wide IF bandwidth of DC to 700 MHz, making it suitable for applications such as I&Q modulators/demodulators, phase detectors and up/down converters. It is usable in applications such as WiMAX, WCDMA, WLAN, ISM and radar. This mixer is packaged in a low profile (0.112") package and is aqueous washable. It is priced only marginally higher than its non-hermetic (quad) counter part to make it attractive for use in a wide range of applications.

Mini-Circuits,
Brooklyn, NY (718) 934-4500,
www.minicircuits.com.

RS No. 220

Antenna Line Monitor

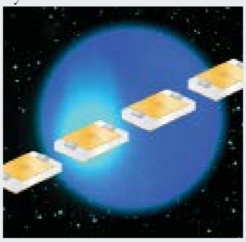
An exceptionally high directivity (typically 40 dB) dual directional coupler that operates over the full frequency range of 380 to 2170 MHz provides the ultimate in precision for this new in-line power meter/antenna monitor. Model CD-A09 monitors forward power with a ±0.5 dB accuracy over a dynamic range of 2 to 500 W of average power, with an insertion loss of less than 0.2 dB. It resolves antenna VSWR changes as small as 1.15. With PIM under 160 dBc and minimal insertion loss, the unit has little or no impact on system performance, regardless of modulation protocol. The unit has user settable alarm thresholds and is provided with Windows friendly utility software for local monitoring with the option for remote monitoring capability.

R&D Microwaves LLC,
East Hanover, NJ (908) 212-1696,
www.rdmicrowaves.com.

RS No. 221

Low Pass Filters

These thin film low pass filters are the company's newest addition to its high frequency product line. Subminiature case size (0.150 × 0.100 × 0.025) low pass filters are available on 99 percent alumina substrates constructed using high stability thin film planar technology, and 50 ohm terminations available for either solder or epoxy mounting. These devices are available with passband cutoffs at 5.5, 7 and 8 GHz. These filters offer a maximum rejection of greater than 16 dB, and VSWR characteristics of less than 1.4 with an insertion loss of less than 0.5 dB. Price: < $1.90. Delivery: stock to eight weeks ARO.



State of the Art Inc.,
State College, PA (800) 458-3401,
www.resistor.com.

RS No. 222

Lab Brick® Signal Generators

Covering 50 MHz to 4 GHz in three models, these miniature devices deliver a true phase-locked RF signal with full output power control just like expensive, full sized, RF signal generators but at a fraction of the price. Each unit measures 4.9" × 3.14" × 1.59" and weighs less than one pound. Lab Brick® Signal Generators are powered and controlled by a PC or laptop via any USB port. The graphical user interface (GUI) features intuitive controls with a large, uncluttered display making these devices simple to use. Lab Brick Signal Generators eliminate the need for sharing bulky pieces of test equipment in the engineering lab.

Vaunix Technology Corp.,
Haverhill, MA (978) 662-7839,
www.labbrick.com.

RS No. 223

Microminiature Round Cable

This microminiature round cable is designed for medical applications. When size and electrical integrity are critical, GORE™ Microminiature Round Cable provides one of the smallest, most durable medical cable solutions. A variety of medical devices can benefit from GORE Microminiature Round Cable including electrophysiology products and small diameter flexible endoscopes, where real estate is a premium and reliability is paramount. Through the use of GORE High Strength Toughened Fluoropolymer (HSTF) and low dielectric constant expanded PTFE (ePTFE) material, this cable maintains its performance through device flexure, abrasion during routing, or tracking and sterilization.

W.L. Gore & Associates,
Elkton, MD (800) 445-4673,
www.gore.com.

RS No. 224

COMPONENTS

10 to 20 GHz Switch

The model SW-2184-1 Option 1020 is a SPST switch without an integral driver. These switches are broadband, nominally 2 to 18 GHz. The Option 1020 has been tuned and adjusted to perform over the bandwidth of 10 to 20 GHz with a minimum isolation of 70 dB at a maximum insertion loss of 2.5 dB with a VSWR of 1.9 maximum. The rise and fall times are 10 ns typically. Size: 0.95" × 0.79" × 0.51". Weight: < 1.5 oz.

American Microwave Corp., Frederick, MD (301) 662-4700, www.americanmicrowavecorp.com.

RS No. 225

2:1 Mismatch Connector

The model 552-266-021 is a 50 ohm, 2:1 VSWR mismatch with an N male connector (other impedance values, mismatch values and connector types are available). This mismatch reflects 12 percent of the incoming signal (–12 percent reflection coefficient). BroadWave mismatches provide a quick method for checking the performance of an RF or microwave system and are ideal for test applications. This device operates in a frequency range from DC to 1000 MHz. The average power is 2 W with an operating temperature range of –55° to +75°C.

BroadWave Technologies Inc., Franklin, IN (317) 346-6101, www.broadwavetech.com.

RS No. 251

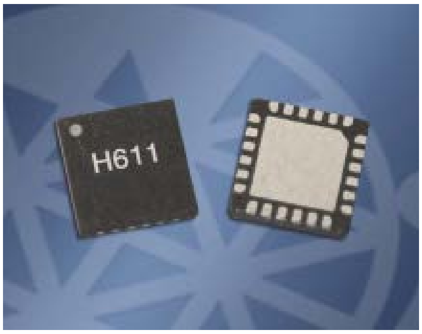
Waveguide Junction Isolator

The model IMW320 is a WR62 waveguide junction isolator with an integrated bandpass filter and coaxial adapter that has been qualified to handle 50 W average power in a fully screened military flight environment. This Iso-Filter features typical insertion loss of < 0.40 dB, isolation of 23 dB minimum and 1.15 maximum VSWR over the 13.5 to 15.5 GHz bandwidth. Attenuation of signals outside the passband exceeds –60 dB. This integrated package provides enhanced electrical specifications through computer modeling and the company's vast library of proven designs.

Channel Microwave Corp., Camarillo, CA (805) 482-7280, www.channelmicrowave.com.

RS No. 226

Ultra Wideband Log Detector



The HMC611LP4(E) logarithmic detector/controller is fabricated in a SiGe BiCMOS process, and converts RF signals at its differential input to a proportional output DC voltage. The HMC611LP4(E) is pin-compatible with the previously released HMC602LP4(E) and delivers an extremely high ±1 dB dynamic range of greater than 60 dB from 50 MHz to 5.8 GHz, 54 dB dynamic range at 8 GHz with outstanding stability of 1 dB total error from –40° to +85°C. In logarithmic detection mode the HMC611LP4(E) provides a nominal logarithmic slope of –25 mV/dB and a nominal intercept of 12 dBm up to 5.8 GHz.

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

RS No. 227

Harmonic Absorptive Filter

This C-band high power rectangular waveguide harmonic reject absorptive low pass filter handles 350 kW peak power, offers –65 dB rejection of second harmonic, in excess of –55 dB rejection of third harmonic, less than –0.20 dB insertion loss and –26 dB return loss at all ports across the passband. The filter measures 25" × 6.5" × 3" in size. Units are available eight to ten weeks ARO. Made in the USA.

Leusin Microwave LLC, Hampstead, NH (603) 329-7270, www.leusin.com.

RS No. 254

Surface-mount Combline Filter

This family of surface-mount combline filters operates in a frequency range from 5 to 15 GHz, with a 3 to 20 percent bandwidth and exceptionally low insertion loss of 0.5 to 1.5 dB combined with a return loss of 14 dB minimum/17 dB typical and a package size of 0.75" to 2.25" L × 0.5" W × 0.5" H. These filters meet military environmental specifications.

Lark Engineering Co., San Juan Capistrano, CA (949) 240-1233, www.larkengineering.com.

RS No. 228

AWS Cavity Duplexer

The model WP-100069 is a duplexer that covers the full advanced wireless services (AWS) frequencies. The WP-100069 duplexer exhibits less than 0.5 dB of insertion loss across the passbands of 1710 to 1755 MHz and 2110 to 2155 MHz while providing greater than 80 dB of rejection. The unit measures 5.0" × 4.0" × 2.3" and is available from stock. Other mechanical configurations and weatherproofing options are available.

Lorch Commercial and Wireless (LCW), Salisbury, MD (866) 729-8509, www.lorchwireless.com.

RS No. 229

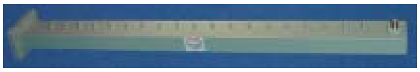
Bandpass Filter

The model 6DMX-1150/X45-MP is a six-pole ultra Hi "Q" temperature stable bandpass filter. Center frequency is 1150 MHz and insertion loss is < 3.0 dB. Attenuation is 50 dB minimum at 1100 MHz and 1200 MHz. VSWR is 1.5 typical. Size: 1" × 0.50" × 0.35".

Lorch Microwave, Salisbury, MD (410) 860-5100, www.lorch.com.

RS No. 230

WR75 Bandpass Filters



These high selectivity dual post bandpass filters offer 20 MHz ripple bandwidth, 24 MHz at –3 dB, and rejection of at least –40 dB at 28 MHz. A waveguide-to-coax (SMA) adapter is

incorporated in the filter body. Similar filters are available in WR112 and WR137.
M2 Global Technology Ltd., San Antonio, TX (210) 561-4800, www.m2global.com.

RS No. 252

Hybrid Ring Divider/Combiners

These two high power, hybrid ring divider/combiners are designed to cover wireless

bands from 0.810 to 0.960 GHz and 1.700 to 2.000 GHz with average RF power handling capability of 1000 W (5 kW peak). Other high power, hybrid ring models are available in frequencies spanning from 0.810 to 6.000 GHz for narrowband applications. These divider/combiners are made in the USA, offer a 36-month warranty and are available from stock to four weeks ARO.
MECA Electronics, Denville, NJ (973) 625-0661, www.e-meca.com.

RS No. 231

CDMA Transmit Filter

The part number 10CX9-854.5-X61N11 is a CDMA transmit band filter. This unit is centered at 854.5 MHz with a flat passband of 824 to 885 MHz. Passband insertion loss comes in at less than 1 dB, a passband return loss of greater than 15 dB and has 50 dB of attenuation at 890 to 925 MHz. This unit sized at only 2.75" high × 4.55" wide × 11.1" long has type N connectors, but can be fitted with most any RF connector.
Reactel Inc., Gaithersburg, MD (301) 519-3660, www.reactel.com.

RS No. 232

Switch Matrix

The model 18A1NAG is a DAC/ADC switch matrix that supports the high level of integration required during qualification testing for digital and analog assemblies operating at microwave frequencies. This RF switch matrix, within the test setup, allows for multiple channel testing with minimal test equipment resources. The switch matrix will route the input signal source and outputs of the DUTs to the communications analyzer for eye diagram measurements as well as bit error rate (BER) test. The approach allows for maximum use of test instruments and full coverage of DUTs without manually hooking and unhooking cables.
Renaissance Electronics Corp., Harvard, MA (978) 772-7774, www.rec-usa.com.

RS No. 233

Waveguide Broadwall Coupler

This standard range of multi-hole broadwall directional couplers operate in a frequency range from 40 to 2.6 GHz in standard waveguide sizes. The electrical characteristics of high directivity and coupling flatness are achieved by using a precise machined coupling hole pattern and a precision load in the secondary arm. Non-standard configurations or selected electrical parameters are available on request.
RLC Electronics Inc., Mount Kisco, NY (914) 241-1334, www.rlcelectronics.com.

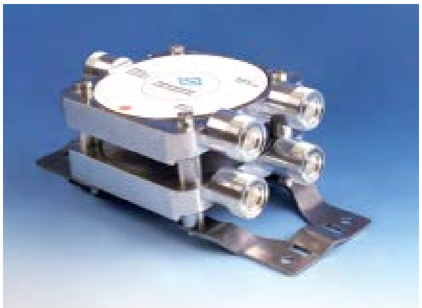
RS No. 253

IF Amplifier Assembly

This custom LO amplifier and IF distribution assembly is designed for an airborne military radar application. The unit includes three sets of in-phase three-way power dividers combined with a high OIP3 IF amplifier and RF switching circuit. A unique feature of the assembly is the packaging concept that incorporates nine floating push-on RF connectors, which interface with three different modules.
Rodelco Electronics Corp., Ronkonkoma, NY (631) 981-0900, www.rodelcocorp.com.

RS No. 234

Stripline Diplexer



The GSM900/GSM1800/UMTS stripline diplexer combines the compact size of a stripline diplexer with the advantages of the lower insertion loss of a cavity diplexer. The two-part housing is assembled using a new laser welding technology and the filter structure is a new innovation, which uses a patented mixed dielectric with high air content to significantly reduce insertion loss. As a result the product achieves a typical intermodulation level of less than –170 dBc, even under the most difficult conditions and in extreme weather.
SPINNER GmbH, Munich, Germany +49 89 12601 0, www.spinner.de.

RS No. 235

Jitter Attenuators

The models VFJA400 and VFJA401 are integrated clock/PLL timing modules for synchronization in SONET

and SDH network elements. The VFJA400 and VFJA401 offer the user the ability to select one of four preset input frequencies from 8 kHz to 200 MHz and 200 MHz to 800 MHz, respectively. Both timing modules provide an ultra low jitter (0.2 ps RMS from 12 kHz to 20 MHz) synchronized LVPECL output frequency from 10 to 200 MHz. A lock detect indicates when the output signal is frequency locked to the input. Operating with a +3.3 V power supply, both devices typically consume less than 150 mW.
Valpey Fisher Corp., Hopkinton, MA (508) 435-6831, www.valpeyfisher.com.

RS No. 236

Directional Coupler

This ultra-broadband directional coupler covers UHF thru EHF operating in a frequency range from 1 to 42 GHz. This coupler offers coupling of 20 dB ±1 with a frequency sensitivity of 1.3 dB maximum. The coupler also exhibits a maximum insertion loss of 1.5 dB with an input port and coupled port return loss of 15 dB typical. Worst case directivity within the bandwidth is 12 dB, but it is typically 15 dB across the full band. The coupler is manufactured with no internal components and is designed to meet all MIL-SPEC requirements and is RoHS compliant and non-magnetic with a durable epoxy paint exterior finish.
Vanguard Microwave Solutions Inc., Newark, NJ (973) 494-8027, www.vanguardmicrowave.com.

RS No. 237

AMPLIFIERS

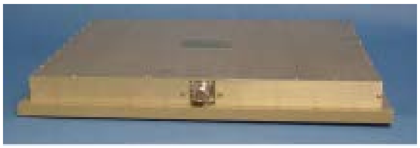
Solid-state Power Amplifier

The model BCPA-500-2500-25J is a multi-octave, broadband, solid-state power amplifier (PA) suitable for delivering reliable output power over the instantaneous frequency range from 500 to 2500 MHz. The PA is ideal for military communications and jamming platforms as well as commercial applications. This PA utilizes the latest in gallium nitride (GaN) HEMT device technology. The model is suitable for both linear and compressed amplifier applications.

Advanced RF Amplifiers,
a division of BC Systems Inc.,
Setauket, NY (631) 751-9370,
www.bcpowersys.com.

RS No. 238

High Power Amplifier



The model L0618-46 is a wideband, high power amplifier that operates in a frequency range from 6 to 18 GHz. This model offers P_{sat} of 46 dBm (40 W) minimum at 25°C from 6 to 17.5 GHz and P_{sat} of 45.5 dBm (35.5) minimum at 25°C from 17.5 to 18 GHz. This high power amplifier offers P1dB of 44 dBm typical, gain of 47 dB minimum and power supply of +12 V at 52 A typical. Size: 13" × 15" × 1.5".

Microwave Power Inc.,
Santa Clara, CA (408) 727-6666,
www.microwavepower.com.

RS No. 239

Linear Power Amplifier

The model XP1031-QK is a surface-mount packaged four-stage GaAs MMIC linear power

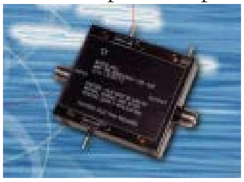
amplifier that offers +35 dBm OIP3 and 23 dB small-signal gain. This power amplifier covers 37 to 42 GHz and comes in a high performance, RoHS compliant, 7×7 mm SMT package, offering excellent RF and thermal properties. The device is ideal for wireless communications applications such as point-to-point radio, LMDS, SATCOM and VSAT applications, and can be used in conjunction with Mimix's XR1008-QB receiver and XU1006-QB transmitter to form a complete SMT 38 GHz transceiver solution.

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

RS No. 240

Broadband Power Amplifier

The model AMF-2B-00030300-150-32P is a broadband power amplifier. This model is a

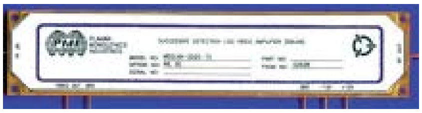


2 W amplifier, offering 20 dB of gain from 30 MHz to 3 GHz. The 24 V voltage required is also internally gated by an external –5 V to minimize any chance of damage. Its compact, 2" × 2" × 0.5" housing has two SMA connectors and can be bolted on a heatsink. It draws 600 mA maximum and has a typical noise figure of about 8 dB and an input match of 1.5 maximum.

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

RS No. 241

High Speed Compact SDLVA



The model MSDLVA-2020-70 Options 48 and SE successive detection log video amplifiers (SDLVA) operate in a frequency range from 4 to 8 GHz (other frequencies are available). This unit has high speed and uses GaAs technology in a compact size. The dynamic range is 80 dB. The VSWR is 1.6 typical and the TSS is –73 dBm typical. The logging range is –65 to +15 dBm. Frequency flatness is ±1 dB typical. The size is 4.6" × 0.98" × 0.24" and power supply of +12 V at 570 mA is typical and –12 V at 155 mA is typical.

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

RS No. 242

SOFTWARE

RF Design Software

This new version of LINC2 Pro RF and microwave design, synthesis and simulation software suite is now

available. Version 2.70 release Z2 offers enhanced schematic capture, including an all new snap-to-grid feature for easy placement and alignment of components on the schematic page. Circuits can be entered manually or created automatically by a number of circuit synthesis modules. LINC2 Amp Pro features advanced amplifier synthesis. The LINC2 Amp Pro wizard-like GUI quickly and effortlessly guides the user through the process of entering the specifications for the automatic synthesis of a wide variety of amplifier circuits, including single or multistage amplifiers, balanced amplifiers, push-pull amplifiers and low noise amplifiers.

Applied Computational Sciences (ACS),
Escondido, CA (760) 612-6988,
www.appliedmicrowave.com.

RS No. 243

SOURCES

Parallel Programmable Frequency Synthesizer

The model LMPL_GP_1500_0500_1 is a parallel programmable frequency synthesizer that features one octave frequency from 1000 to 2000 MHz. This synthesizer offers a 12 bit parallel frequency control, high harmonic rejection, auto-switching internal and external reference, buffered reference output, visual indicators for LD and EXT/IN and a single DC supply of +15 VDC. Size: 3" × 3" × 1" metal housing.

General Electronics Devices,
San Marcos, CA (760) 591-4170,
www.gedlm.com.

RS No. 218

Voltage-controlled Oscillator

The model CVCO55CW-0200-0400 is a voltage-controlled oscillator (VCO) that operates from 200 to 400 MHz with a control voltage range of 0 to 5 V. This VCO features a typical phase noise of –105 dBc/Hz at 10 kHz offset and has excellent linearity. The model CVCO55CW-0200-0400 is packaged in the industry standard 0.5" × 0.5" SMD package. Input voltage is 5 V, with a maximum current consumption of 25 mA. Pulling and pushing are minimized to 2 MHz and 2 MHz/V, respectively. Second harmonic suppression is –10 dBc typical. Price: starts at $10.39 each.

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

RS No. 244

Coaxial Noise Source

The NW2G-CS coaxial noise source is available in 6, 15 and 30 dB excess noise ratios (ENR). The NW2G-CS is ideal for noise figure measurements and built-in test applications. The unit features a small profile housing of 0.75" by 0.5" by 1.25" excluding connectors, ideal when space is at a premium. The unit features flatness better than ±1.0 dB over the frequency range 10 kHz to 2 GHz and comes with calibrated cardinal ENR frequencies. The NW2G-CS is available with a variety of connectors. Standard operation is from +28 VDC with a 20 mA maximum current draw. The NW2G-CS is economically priced and delivery is typically from stock.

Noisewave Corp.,
East Hanover, NJ (973) 386-1119,
www.noisewave.com.

RS No. 245

PLL Synthesizer

The model PSA1450F-LF is a fast switching and wideband fractional N PLL synthesizer in a small surface-mount package (0.8" × 0.6"). The design scheme enables the achievement of spurious levels as low as –80 dBc. The PSA1450F-LF provides excellent phase noise with –90 dBc/Hz at 1 kHz offset and –100 dBc/Hz at 10 kHz offset when operated with a low phase noise reference of 32 MHz. Above all, it has a switching speed of < 6 µs for a 40 MHz frequency hop. The PSA1450F-LF operates with a DC voltage of 5/15 V, I_{cc} 20/40 mA and delivers high and flat output power of 6 ±2 dBm over the 800 MHz band. It has an operating temperature range of 0° to 70°C. Price: $69.95 each. Delivery: six to eight weeks.

Z-Communications Inc.,
San Diego, CA (858) 621-2700,
www.zcomm.com.

RS No. 246

SUBSYSTEM

Microwave VME Tuner

The M/A-COM TU-6401 is a new lightweight low power SIGINT microwave tuner designed

for signal search and collection applications. The TU-6401 provides simultaneous narrowband and wideband IF (intermediate frequency) outputs centered at 160 MHz (100 MHz bandwidth) and 1 GHz (500 MHz bandwidth). The tuner's frequency range operates from 0.5 to 18 GHz and features an RF downconverter, which is integrated with a direct digital synthesizer to uncouple tuning speed from phase noise, creating the fastest high performance tuner on the market today.

M/A-COM Inc.,
Hunt Valley, MD (410) 329-7900,
www.macom.com.

RS No. 247

SYSTEM

L-band Transceiver

The model 15172 is a transceiver that provides a compact, cost-effective solution for interfacing systems that employ a 70 MHz intermediate frequency (IF) to single-band, tri-band or quad-band block converters in military satellite communications systems. This model upconverts or downconverts signals between the 70 MHz IF and the entire band from 950 MHz to 2 GHz. In addition, it provides the ability to set the output frequency at any point within the band with step sizes as small as 20 kHz and as broad as 1 MHz, rather than providing one or two step sizes typical of other transceivers. The model 15172 combines these features with exceptional signal purity, including phase noise performance that exceeds the requirements of MIL-STD-188-165A. Size: 6" × 8" × 1.5". Weight: 4 lbs.

Narda Microwave-East,
Hauppauge, NY (631) 231-1700,
www.nardamicrowave.com/east.

RS No. 248

TEST EQUIPMENT

Signal Generator

New Products

The MG37020A is a fast-switching microwave signal generator that utilizes an advanced VCO-based hardware architecture to achieve best-in-class frequency switching speed of 100 µsec per point. The fast switching speed, and a number of other high performance specifications and design advantages make the MG37020A well suited for integration into automated test systems used in defense signal simulation and manufacturing ATE where minimum test time and maximum throughput is critical. The innovative VCO-based architecture integrates advanced RF hardware, enhanced computing, and digital interfaces that minimize command and trigger delays.

Anritsu Co.,
Morgan Hill, CA (800) 267-4878,
www.anritsu.com.

RS No. 249

Harmonic Phase Reference

The NM200 is a 20 GHz harmonic phase reference comb generator that produces a precisely characterized repetitive output pulse when a sine wave between 600 MHz and 1.2 GHz is applied. This repetitive pulse consists of a fundamental tone and multiple harmonics up to 20 GHz and the phase relationship between these tones is stable and well known with a given uncertainty up to 20 GHz. It can be used as a unique calibration element to eliminate the phase distortion of any setup, such as a large-signal network analyzer, which is used to characterize active components in a nonlinear mode of operation.

NMDG NV,
Bornem, Belgium +32 3 890 46 12,
www.nmdg.be.

RS No. 250

Microwave Journal CALL FOR PAPERS

To see one's work in print is the rightful reward of every creative engineer and scientist. The editors of *Microwave Journal* invite you to submit your technical manuscripts for consideration to be published in one of our upcoming issues. Technical articles, application notes and tutorial articles based on the monthly editorial themes are encouraged. Editorial themes include wireless, radar and antennas; RF components and systems; test, measurement and CAD; amplifiers and oscillators; semiconductors, MMICs and RFICs; satellite and mm-wave applications; communications and wireless applications; passive components; and control devices and modulation.

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NEW LITERATURE

LIGHTWAVE CATALOG

This catalog provides detailed product and application information on Agilent's latest solutions for photonic testing of next-generation low cost optical devices and digital microwave solutions (BERTs, DCAs) for high speed devices. It covers photonic and transceiver measurement solutions that offer industry-leading performance for fastest time-to-market in next-generation photonics.

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

RS No. 200

MILITARY DIVISION CD

The new video features the company's RF antenna technology for military and government applications ranging from 2 MHz to 90 GHz; the miniaturized Direction Finding systems (HESA™ proprietary technology); its customized flexibility for most mobile, shipboard, submarine and airborne applications; and antenna solutions for SATCOM, EW, EMC, EMI, SIGINT, mapping, reconnaissance and general surveillance requirements.

Astron Wireless Technologies Inc.,
Sterling, VA (703) 450-5517,
www.astronwireless.com.

RS No. 201

PRODUCT SELECTION GUIDE

The October 2007 product selection guide summarizes over 625 products including 105 new products. Also featured are Hittite's newly acquired Velocium advanced GaAs MMIC products covering DC to 86 GHz. The addition of the Velocium product line expands Hittite's product offerings for automotive radar, long and short haul communications, fiber optics, test equipment, radar imaging, space and military applications.

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

RS No. 202

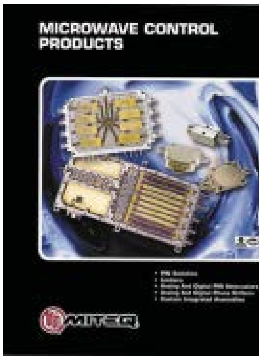
SHORT FORM CATALOG

This short-form catalog and product catalog on CD-ROM have recently been updated and include new product highlights, updated data sheets with more comprehensive information and measurement curves, RoHS program information, application features and notes, company and facility overviews, ordering information and a complete listing of international sales representative and distribution networks.

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

RS No. 203

MICROWAVE CONTROL PRODUCTS

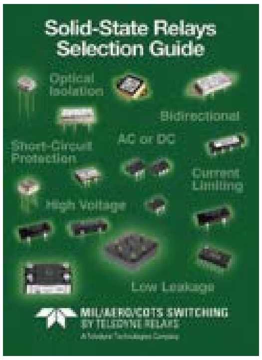


This 120-page microwave control products catalog features PIN diode switches, limiters, analog and digital PIN attenuators, analog and digital phase shifters, and custom integrated assemblies. Specification definitions, ordering information, outline drawings, typical test data and block diagrams are also included.

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

RS No. 204

SELECTION GUIDE



This solid-state relays selection guide features the company's military, aerospace, COTS and HRIP (high reliability industrial parts) applications. The catalog features 76 families in a tabular format designed in an easy to use format to quickly assist engineers in choosing a product. The 20-page digest provides detailed information about the relays, which include AC, DC and bidirectional relays with output ranging from 0.25 to 10 amps.

Teledyne Relays,
Hawthorne, CA (800) 284-7007,
www.teledynerelays.com.

RS No. 205

PIN DIODE SWITCHES

FEATURES:

- Multioctave bands 0.2 to 18 GHz
- Reflective or Absorptive
- Current or TTL control
- Low insertion loss
- High isolation

Frequency Range (GHz)	Model Number	Insertion Loss (dB, Max.)	Isolation (dB, Min.)	VSWR (Max.)	Rise/Fall Time (ns, Typ.)	On/Off Time (ns, Typ.)	On/Off Time (ns, Max.)	DC Power Positive/Negative (mA, Max.)
SPST								
0.2 – 2	SW1-002020RN1NF	1.7	70	1.6:1	10/10	20	35	35/70
2 – 8	SW1-020080RN1NF	2	80	1.7:1	10/10	20	35	35/70
4 – 12	SW1-040120RN1NF	2.2	80	1.7:1	10/10	20	35	35/70
2 – 18	SW1-020180RN1NF	3	80	2:1	10/10	20	35	35/70
1 – 18	SW1-010180RN1NF	3	70	2:1	10/10	20	35	35/70
SP2T								
0.2 – 2	SW2-002020RN1NF	1.5	70	1.6:1	10/10	20	35	60/60
2 – 8	SW2-020080RN1NF	1.8	80	1.7:1	10/10	20	35	60/60
4 – 12	SW2-040120RN1NF	2.2	80	1.7:1	10/10	20	35	60/60
2 – 18	SW2-020180RN1NF	2.8	80	2:1	10/10	20	35	60/60
1 – 18	SW2-010180RN1NF	3	70	2:1	10/10	20	35	60/60
SP3T								
0.2 – 2	SW3-002020RN1NF	1.6	70	1.6:1	20/20	150	180	85/85
2 – 8	SW3-020080RN1NF	1.9	80	1.7:1	20/20	150	180	85/85
4 – 12	SW3-040120RN1NF	2.4	90	1.7:1	20/20	150	180	85/85
2 – 18	SW3-020180RN1NF	3	80	2:1	20/20	150	180	85/85
1 – 18	SW3-010180RN1NF	3.1	70	2:1	20/20	150	180	85/85

Note: The above models are all reflective switches. Absorptive models are also available, please contact MITEQ.

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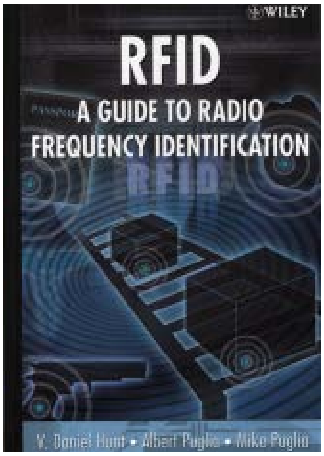
RFID: A Guide to Radio Frequency Identification



V. Daniel Hunt, Albert Puglia and Mike Puglia
Wiley Interscience • 238 pages; $ 60
ISBN: 978-0-470-10764-5

Radio frequency identification (RFID) technology is a wireless communication technology that enables users to uniquely identify tagged objects or people. This book provides a broad overview and guide to RFID technology and its application. It is an effort to do the initial "homework" for the reader interested in better understanding RFID tools. It is written to provide an introduction for business leaders, supply chain improvement advocates and technologists to help them adopt RFID tools for their unique applications, and provide the basic information for better understanding RFID. The book describes and addresses the following:

- How RFID works, how it is used and who is using it.
- The history of RFID technology, the current state-of-the-art and where RFID is expected to be taken in the future.
- The role of middleware software to route data between the network and the IT system within an organization.
- The use of RFID technology in both commercial and government applications.
- The role and value of RFID industry standards and the current regulatory compliance environment.
- The issues faced by the public and industry regarding the deployment of RFID technology.

The most important impediments in the development of RFID technology are resolving consumer privacy issues, overcoming the higher costs of developing and deploying RFID technology compared with traditional bar code technology, and technological immaturity and integration with legacy data management systems. Also important is the need for RFID tag and system robustness, the lack of application experience, end-user confusion and skepticism, insufficient training and education on RFID applications, and the scope, utilization and cost of data management tools.

To order this book, contact:
John Wiley & Sons Inc.
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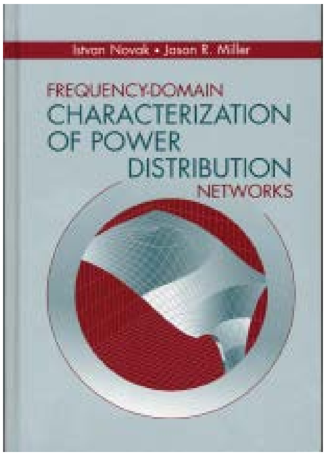
Frequency-Domain Characterization of Power Distribution Networks



Istvan Novak and Jason R. Miller
Artech House • 360 pages; $129, £72
ISBN: 978-1-59693-200-5

This book focuses on the frequency domain characterization of power distribution networks. Design approaches and design methodologies of power distribution networks and semiconductor (silicon) power distribution, as well as time domain characteristics are not covered in this book. Power distribution network characterization in electronic systems encompasses many disciplines from control-loop theory to material science, from assembly technology to metrology. Chapter 1 starts with the explanation of why frequency-domain characterization is the focus. The pros and cons of frequency- and time-domain characterizations are summarized. Exceptions are pointed out when time-domain is needed. The modeling approach used in the subsequent chapters is outlined. Chapter 2 is devoted to frequency-domain power-distribution simulations using various approaches, including MATLAB, SPICE and field solvers. Simulations are correlated to measurement results to help the reader understand how the simulation parameters and settings impact accuracy. Chapters 3 and 4 focus on characterizing and modeling vias, via arrays, planes and laminates. Chapters 5, 6 and 7 describe in greater detail proper measurement practices. From selecting the right probe or cable to calibrating an instrument, these chapters cover all aspects of how to make accurate PDN measurements. Chapter 8 is devoted entirely to the characterization and modeling of bypass capacitors, starting with the simplest model and working through various complexity levels to frequency dependent causal models. Chapter 9 focuses on the characterization and modeling of inductors, DC-DC converters and systems.

To order this book, contact:
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S4W2	S4W5	N4W5	4	±0.40
S5W2	S5W5	N5W5	5	±0.40
S6W2	S6W5	N6W5	6	±0.40
S7W2	S7W5	N7W5	7	-0.4, +0.9
S8W2	S8W5	N8W5	8	±0.60
S9W2	S9W5	N9W5	9	-0.4, +0.8
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S20W2	S20W5	N20W5	20	-0.5, +0.8
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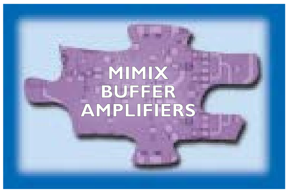

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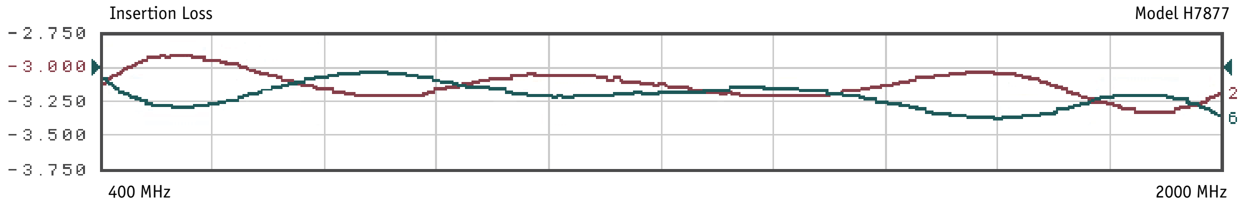

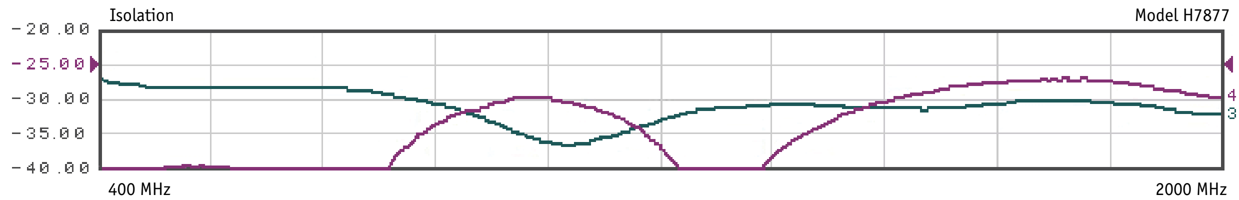

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