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August 2014

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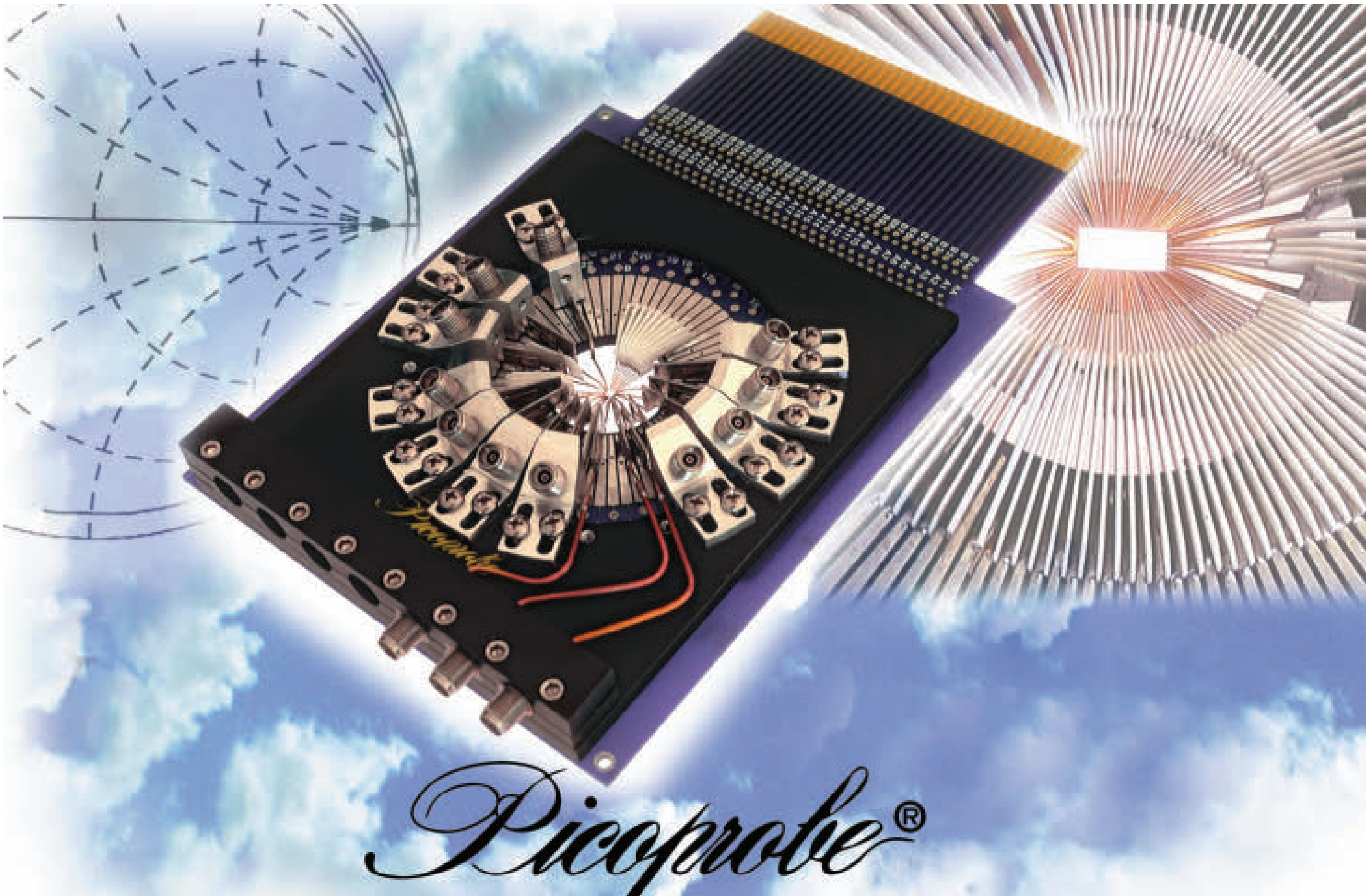

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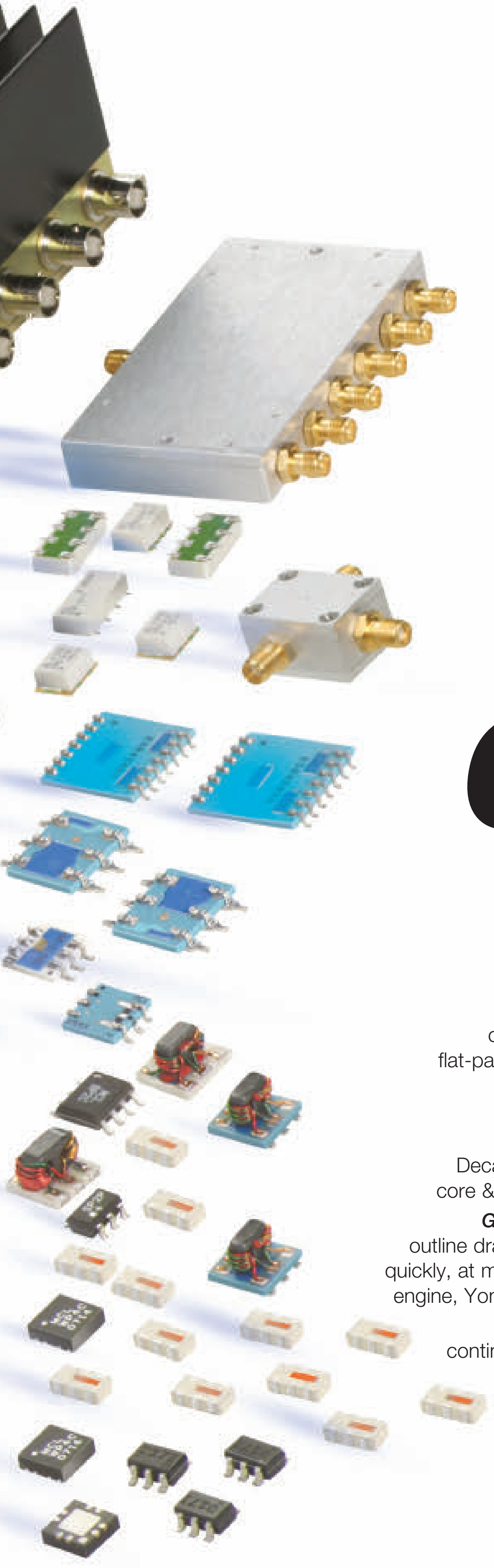

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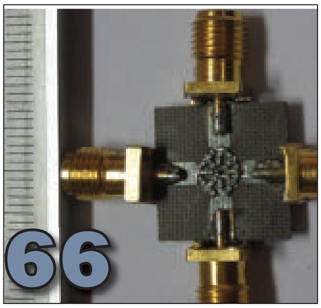

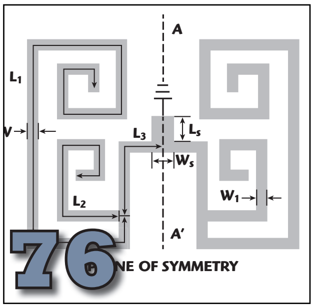

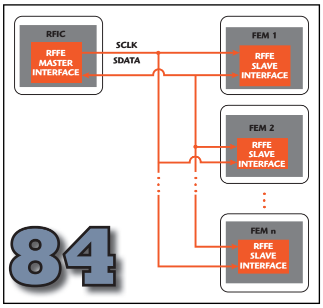

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Refer to page 136 for this month's participants

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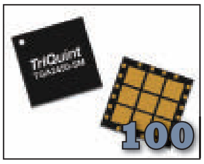

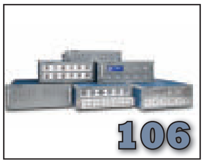

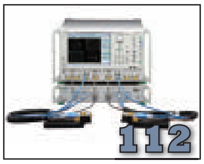

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GaAs will continue to dominate RF [24 votes] (14%)

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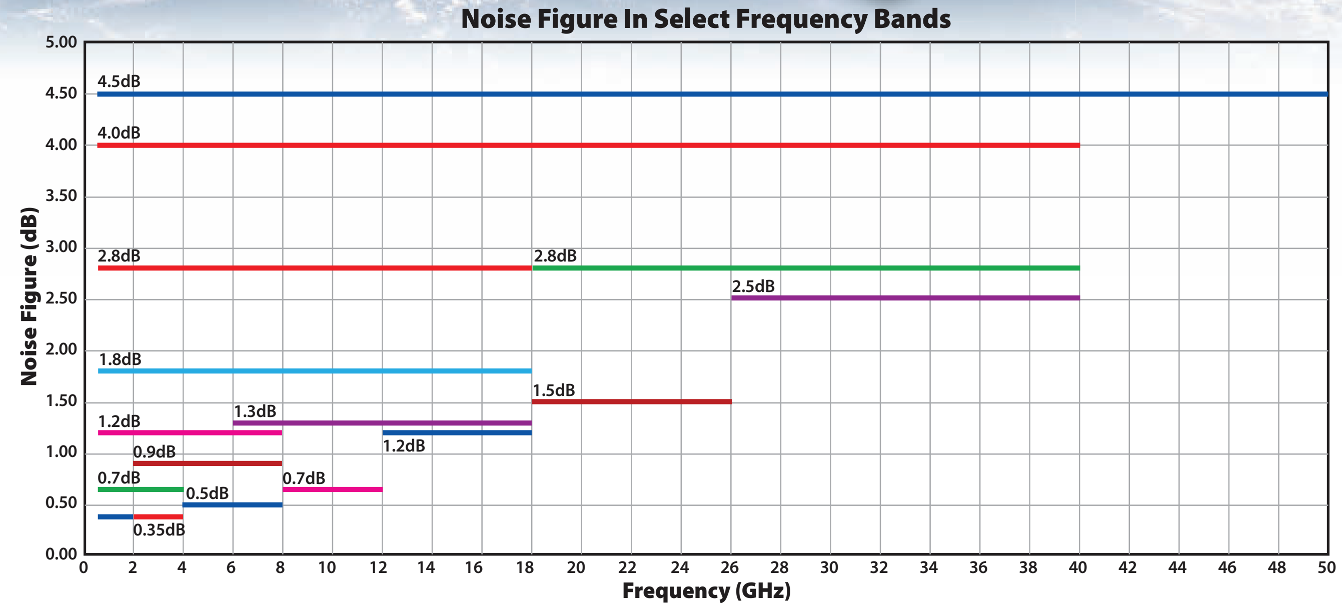

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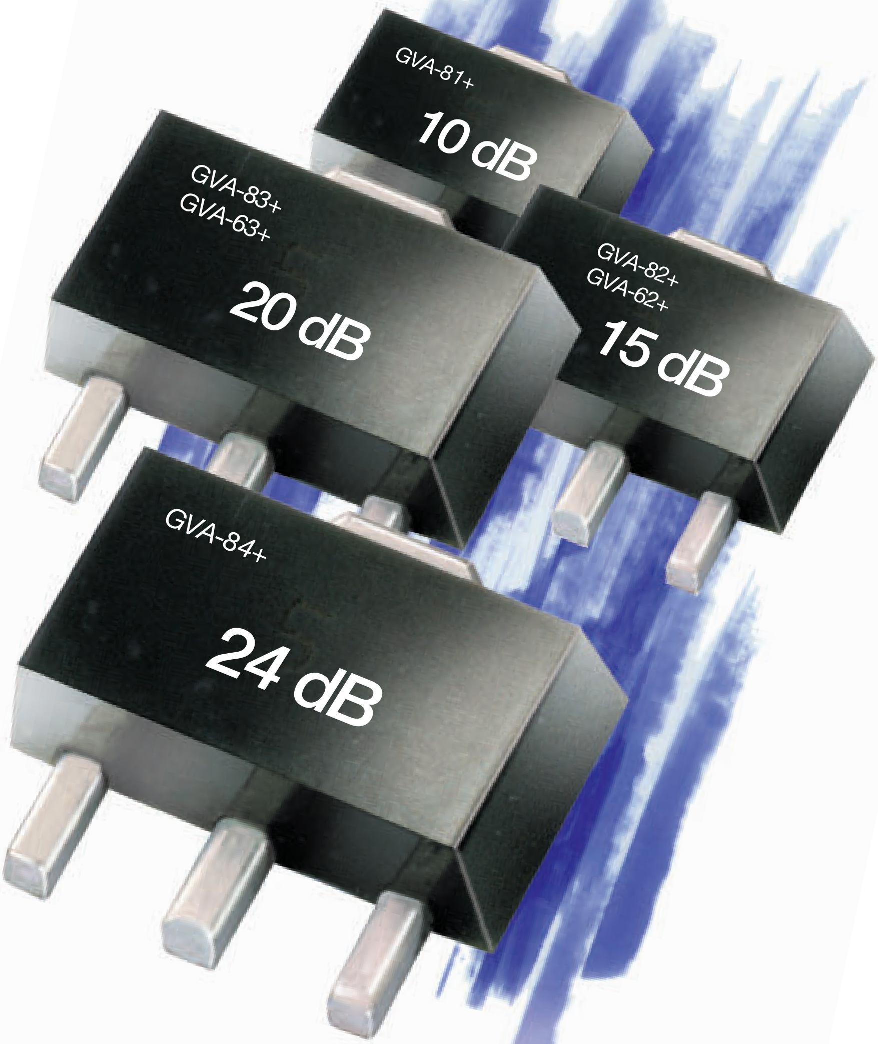
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SEPTEMBER 2014

SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
31	1 ← ICUWB 2014 – 2014 IEEE International Conference on Ultra-Wideband, 1-3 September 2014 - Paris, France	2 Paris, France	3 →	4 **Webinar:** DynaFET: Advanced Model for GaN/GaAs HEMTs Sponsored by KEYSIGHT TECHNOLOGIES	5	6
7	8 ← ION GNSS+	9 ← 4G World; ← Super Mobility Week. **Webinar:** Accelerating Custom Test Solutions Sponsored by Mini-Circuits	10 **Webinar:** RF Components for Aerospace/Defense Sponsored by NATIONAL INSTRUMENTS. 4G World Las Vegas, NV	11 ION GNSS+ Sept. 8-12, 2014 Tampa, FL. Super Mobility Week Las Vegas, NV →	12 →	13
14 ← IRMMW-THz Tucson 2014	15 ← IEEE AUTOTEST 50th Anniversary 2014	16 IRMMW-THz Tucson, AZ. **Webinar:** UltraCMOS Technology Sponsored by Peregrine Semiconductor	17 IEEE AUTOTEST St. Louis, MO. **Webinar:** Design of Broadband GaN RF PAs Sponsored by NATIONAL INSTRUMENTS, CREE	18 → **Webinar:** Validation, Maintenance and Repair of Satellite Earth Stations Sponsored by KEYSIGHT TECHNOLOGIES	19 →	20
21	22	23	24 **Webinar:** Sponsored by TECH-X	25	26	27
28	29	30	1	2	3	4

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EDI CON 2015
October 31, 2014

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August 25–30, 2014 • Copenhagen, Denmark
http://congress2014.metamorphose-vi.org

RFIT 2014
IEEE International Symposium on Radio-Frequency Integration Technology
August 27–30, 2014 • Hefei, China
www.rfit2014.org

SEPTEMBER

ICUWB 2014
IEEE International Conference on Ultra-Wideband
September 1–3, 2014 • Paris, France
www.icuwb2014.org

ION GNSS+ 2014
September 8–12, 2014 • Tampa, FL
www.ion.org

Super Mobility Week 2014
September 9–11, 2014 • Las Vegas, NV
www.supermobilityweek.com

4G World 2014
September 9–11, 2014 • Las Vegas, NV
www.4gworld.com

IRMMW-THz 2014
39th International Conference on Infrared, Millimeter and Terahertz Waves
September 14–19, 2014 • Tucson, AZ
www.irmmw-thz2014.org

AUTOTEST 2014
September 15–18, 2014 • St. Louis, MO
www.ieee-autotest.com

OCTOBER

EuMW 2014
European Microwave Week
October 5–10, 2014 • Rome, Italy
www.eumweek.com

The 2014 Defence, Security and Space Forum at European Microwave Week
October 8, 2014 • Rome, Italy
www.eumweek.com

MILCOM 2014
October 6–8, 2014 • Baltimore, MD
www.milcom.org

AMTA 2014
36th Antenna Measurement Techniques Association Meeting & Symposium
October 12–17, 2014 • Tucson, AZ
www.amta2014.org

ITC/USA 2014
October 20–23, 2014 • San Diego, CA
www.telemetry.org

MWP/APMP 2014
International Topical Meeting on Microwave Photonics (MWP)
9th Asia-Pacific Microwave Photonics Conference (APMP)
October 20–23, 2014 • Sapporo, Japan
www.mwp2014.com

IME/China 2014
9th International Conference & Exhibition on Microwave and Antenna
October 29–31, 2014 • Shanghai, China
www.imwexpo.com

NOVEMBER

APMC 2014
Asia-Pacific Microwave Conference
November 4–7, 2014 • Sendai, Japan
www.apmc2014.org

DECEMBER

Precise Time and Time Interval Systems and Applications
December 1–4, 2014 • Boston, MA
www.ion.org/ptti

JANUARY

Radio and Wireless Week
January 25–28, 2015 • San Diego, CA
www.radiowirelessweek.org

MARCH

Satellite 2015
March 16–19, 2015 • Washington, DC
www.satshow.com

APRIL

EDI CON 2015
Electronic Design Innovation Conference
April 14-16, 2015 • Beijing, China
www.ediconchina.com

Passing the Torch

David Vye, Microwave Journal *Editor*

Seven years ago, I was invited to join *Microwave Journal* as editor and manager of business development. I came on board just in time to help the team navigate its way through three disruptive events. The first was the end of the long-standing relationship between the International Microwave Symposium and Horizon House/*Microwave Journal* as exhibition manager. The second was the start of the great recession. The third event was brought on by shifting attitudes toward print advertising in the age of the internet.

Fortunately, the microwave industry had the resiliency to withstand the recession and the *Microwave Journal* team was able to maintain and strengthen the loyalty of our readers and advertisers through a renewed commitment to editorial excellence. We took the lead in using social and electronic media by developing webinars, videos and industry-focused enewsletters. By leveraging the various strengths of these diverse mediums, we have greatly improved how we deliver technical content to the high-frequency engineering community.

No longer tied to our responsibilities for managing the IMS exhibition, we turned our resources and attention to the global expansion of our brand by launching a *Microwave Journal China* print magazine (circulation 10,000) and electronic media in late 2011. As other print magazines shrunk in size and circulation, *Microwave Journal*'s formula of peer-reviewed, industry driven technical content – written by engineers for engineers – has allowed us to expand and solidify our value to our readers.

Then we did something that I am most proud of. We created EDI CON; an event that applied our well-established editorial standards to an industry driven technical conference and our business principles to an exhibition. The result was an event that truly brought attendees and vendors together. Today, EDI CON is on track to becoming the leading design event of its kind in China. Furthermore, we have developed a model that is scalable and can be replicated in any geographical location that best serves the needs of the industry – vendors and engineers alike.

Over the last couple of years, we have witnessed a shift in how engineers acquire information – from those who are providing content, to how it is delivered. Equally important are the time constraints placed on working engineers to investigate solutions outside their knowledge base to meet both their work challenges and their own professional development needs. This content is increasingly being provided by industry. Timely, relevant information is essential to engineering and commerce, which explains why organizations gaining traction in competitive marketplaces are stacking their marketing decks with technologists. This trend is certainly helping vendors and engineers communicate better.

In a specialized field such as ours, industry provided content is a major source of information guiding engineering and business decisions. Leveraging technical content to influence business brings me to an important announcement. After seven great years at *Microwave Journal*, I have accepted an opportunity to practice these principles as business development manager with ANSYS. In this position, I will be responsible for identifying and creating business opportunities. In attracting new business, my tool of choice will be the placement of timely and relevant technical content where engineers find such information – i.e., *Microwave Journal* and EDI CON. I look forward to viewing the industry from a different vantage point, getting closer to where the rubber meets the road, facilitating new networks and helping others understand and utilize the power of the press.

By necessity, *Microwave Journal*'s editorial focus is devoted to high-frequency engineering. Yet the Journal's audience needs to be aware of broader eco-systems where microwave products are integrated with technologies from other engineering disciplines. In addition, since hardware development itself extends beyond pure electrical design, engineers also need a working knowledge in areas such as power management, thermal dynamics and material science. In my new role I expect to "get schooled" in broader product development issues and look forward to sharing what I learn through future contributions to *Microwave Journal* as a consulting editor.

I look forward to my new relationship with *Microwave Journal*. It has been a great pleasure to serve both readers and advertisers, hopefully to everyone's satisfaction. Thanks to its superb staff and management and the support of its readers and contributors, *Microwave Journal* will continue to be one of this industry's finest institutions and a leading authority on frequency matters. And I'll see you all around the circuit. ■

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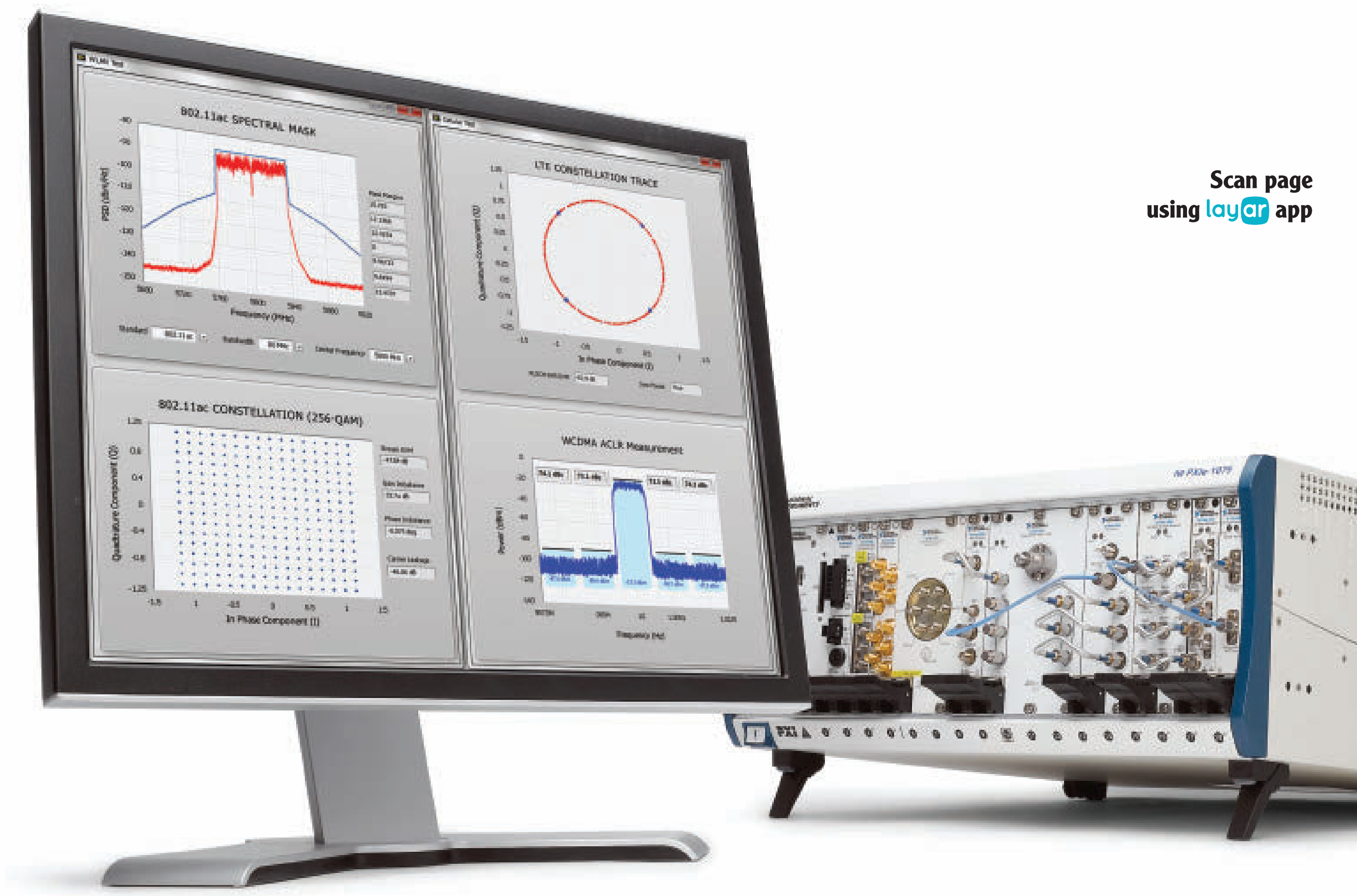

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Antenna Design Challenges for New-Generation Nano Satellites

David Farr and Bill Henderson
Haigh-Farr, Bedford, N.H.

The commercialization of space is well underway with companies such as SpaceX, Boeing, ULA and Orbital Sciences developing and providing launch vehicles and spacecraft being used by both government entities, as well as private, commercial customers. Large satellites are being launched from these vehicles and while they are still of prime interest because of shear capacity, depth of functions and expected service life, a new generation of compact satellites and launch vehicles are being developed that allow the academic and commercial sectors to produce useful science at significantly lower cost and with shorter realization times.

NASA is also contributing to this movement, as it has produced the Nanosatellite Launch Adapter System (NLAS) enabling small satellites to be launched as secondary payloads on major launch vehicles. Meeting size and space restrictions for small satellite devices presents engineering challenges to deliver the desired performance capabilities within these confines. A major area of concern is the availability of reliable communications to and from Earth, as well as between other compact satellites launched as a group. The antennas required to do so are, of course, a key element of the analysis of this problem. This article will explore the issues considering both where we are now and what we believe will be the future, and will evaluate the challenges facing standardization of the satellite's infrastructure and communication capabilities with a focus on antennas.

When looking at developing antennas for the compact satellite market, there are two areas that pose significant challenges: the actual physical size of the satellites, and the size and weight restrictions of the launch vehicle. Delivering a robust antenna that can fulfill the mission and survive the harsh environment of space within these size and weight constraints is the goal. The small satellites themselves offer much smaller surface area for antenna placement. Miniaturized or small satellites are of low mass and small in size, usually less than 1,100 lbs. While all such satellites can be referred to as small satellites, different classifications are used to categorize them based on size, with the largest ones being a mini-satellite (220 to 1,100 lbs.), micro-satellite (22 to 220 lbs.) and nano-satellite (2.2 to 22 lbs.); down to as small as a pico-satellite (0.22 to 2.2 lbs.) and femto-satellite (3.5 oz.). For purposes of this discussion we will focus on nano, micro and mini-satellites, or a weight range of 2.2 to 1,100 lbs.

The key to success in this emerging market for antenna companies, is taking their well-proven space-qualified designs and manufacturing techniques for costly, high-end satellite

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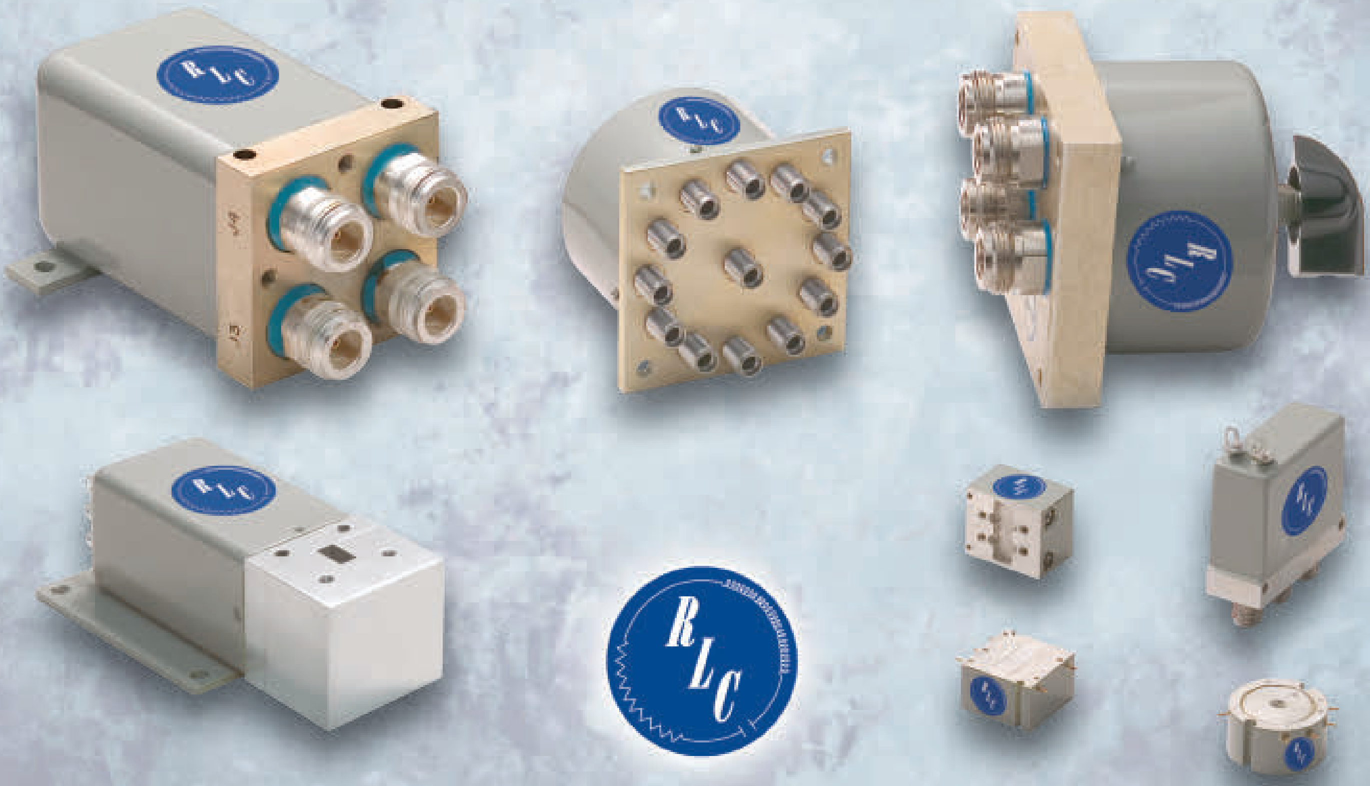

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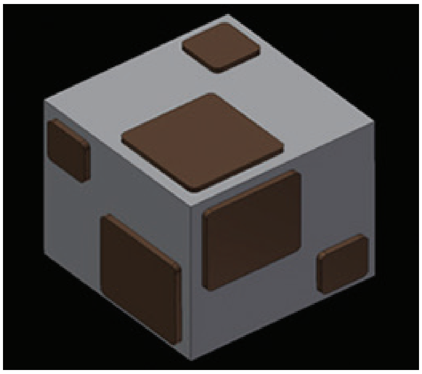
solutions, where size and weight are not the limiting factors; and miniaturizing them to fit the new compact satellites and achieving a commercial-off-the-shelf (COTS) price point. Equally important, however, remains performance. Achieving a balance between these competing goals is a challenge. Performance in particular has several considerations. The designer needs to consider not only the antenna itself and the degradation to performance through miniaturization, but the nature of the structure the antenna is mounted on. This is always an important consideration for Telemetry, Tracking and Control (TT&C) antennas, which are typically low gain operating in L- or S-Band. Also, many low Earth orbit satellites utilize GPS receive antennas. The performance of all of these antennas can be strongly affected by the size and shape of the ground-plane and the presence of other nearby objects. The ground-plane in this case is the satellite which, given its reduced size, is often less than ideal. Using computer modeling and calculating the pattern with the antenna mounted on an electromagnetic solid model of the satellite is a key design step discussed later.

One of the major benefits of small satellites is the reduced cost for entry into space. Educational institutions, as well as small businesses with great ideas but limited resources have not been afforded the opportunity to participate in this market until now. The cost to build and launch the satellite along with high insurance expense has left this market unattainable to all but a few in the past. With a more affordable price point and easier access, this market is poised to show significant growth over the next five to seven years. According to a MarketsandMarkets report (March 2014), the nano and micro-satellite market is estimated to grow from \$702.4 million in 2014 to \$1887.1 million in 2019 with the commercial sector being the largest contributor by 2019. The payloads may encompass such things as general weather observations, text-messaging backhaul, science experiments or still-photo reconnaissance, and may be tailored for specific applications from basic to complex. The cost associated with each type of payload will vary. The more complicated the payload requirements the more expensive the satellite and its component parts, including the antenna.



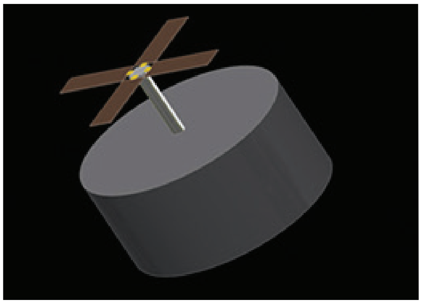
▲ *Fig. 1 Conformal antennas on a CubeSat (1U).*

THE SHAPE OF THINGS TO COME

Given launch container limitations, such as those imposed by an NLAS, there are two basic antenna designs for small satellites that may be utilized: conformal and deployable. There is a significant need for rugged conformal antenna designs that are shaped to naturally mate with the flat, cylindrical or conical surfaces of the satellite with little or no protrusion. ***Figure 1*** is a representation of mounted conformal GPS and S-Band antennas. Each type of antenna individually provides hemispherical coverage and when installed in pairs, connected through a power divider/combiner, will yield spherical coverage. The two can also be connected through a switchable divider/combiner to initially provide spherical coverage during insertion, and then hemispherical coverage when operational and aligned properly. Using only hemispherical coverage will provide increased gain, which is always desirable.

There are also requirements for deployable antennas. In this application, the antenna lies flat on the satellite so it will not interfere with the required launch dimensions. When it is released into orbit the antenna's radiators are deployed and locked in place. While there are several configurations for deployable antennas, a basic version is shown deployed in ***Figure 2***.

Each of these approaches requires advanced design and manufacturing capabilities, while staying within a COTS target price point. Some may believe that standardization of antenna requirements is the solution,



▲ *Fig. 2 Deployed antenna elements on a cylindrical satellite.*

which would result in lower costs, but it would also be extremely challenging since each satellite will present with varying electrical and environmental requirements to meet the demands of the particular mission. In addition, this would require collaboration between many organizations in a competitive environment, which is unlikely, so the concept of true standardization is challenging. The world of micro and mini-satellites require designs that are specific or highly tailored to optimize antenna performance given the size, limited placement options and other objects that need to be placed close to the antenna, so standardization will be even tougher on these platforms.

LAUNCH VEHICLE ANTENNA DESIGNS

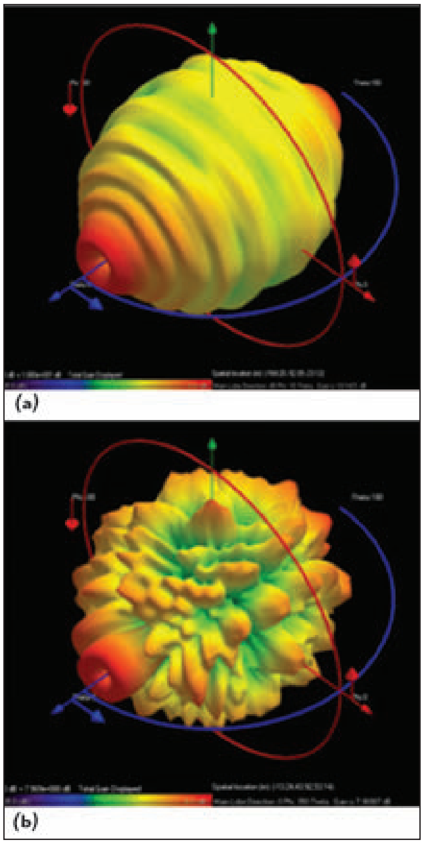
Hand-in-hand with the discussion of smaller satellites is consideration of the method to put them into orbit. These new small satellites can be deployed in both traditional ground rocket launch vehicles (i.e., Atlas, Delta, Falcon-9) and non-traditional small, dedicated launch vehicles (both ground and sub-orbital air launch). Currently, there are a number of NASA and DARPA awards to companies that are bringing this new launch technology to market. These new, dedicated nano-launch vehicles require antenna performance schemes similar to the traditional large launch vehicles, including UHF Flight Termination, C-Band Transponder, GPS Metric Tracking and S-Band Telemetry. The ultimate challenge is meeting size and weight restrictions while providing higher gain. Higher gain helps when using a lower-power configuration, which in turn, helps reduce vehicle battery draw and thus, can help reduce battery weight and size.

A traditional launch vehicle is right now a one-time-use method of launching a main payload, and in some cases will also carry along several smaller satellite packages, "piggybacked," for the ride. As a result, the insertion of the smaller satellites might be less than desirable since they are not the primary payload. Since these new, smaller launch vehicles are dedicated to the smaller satellite market, they ensure the satellite will be put into the preferred orbit. These smaller satellites may prove to be considerably more productive and relied upon since the mission profile will be known with certainty.

SYSTEM PERFORMANCE

One of the tasks facing both the satellite and antenna companies is optimizing performance of these systems once they are in space. Simulation or modeling of the antenna mounted on the satellite is an integral part of initial antenna design activities. This is especially important with smaller satellites, where, as previously mentioned, the reduced size of the satellite imposes considerable limitations on antenna performance (reduced ground plane), placement and size. Haigh-Farr combines its expertise in antenna design with unique software tools and techniques to simulate the performance of antennas in real-world environments. When antennas are placed in a working environment, such as on the body of a satellite, the proximity of metallic and dielectric structures will affect its radiation pattern. The resulting change in the coverage may adversely affect the performance of the communication link. In order to avoid costly and time-consuming trial-and-error methods to fix these problems, computer modeling is used to optimize the performance of the antenna in its actual environment. Early in the design cycle, simulation may be used to change the shape and spacing of structures to further optimize antenna performance.

To further highlight the impact of vehicle geometry, the radiation patterns of a Wraparound™ antenna were calculated when mounted, first on a smooth cylinder, then with strategically shaped and placed fins near the antenna. The patterns for both cases are shown in ***Figure 3***. While this is certainly a dramatic case, it is not out of the realm of possibility. It is our ex-



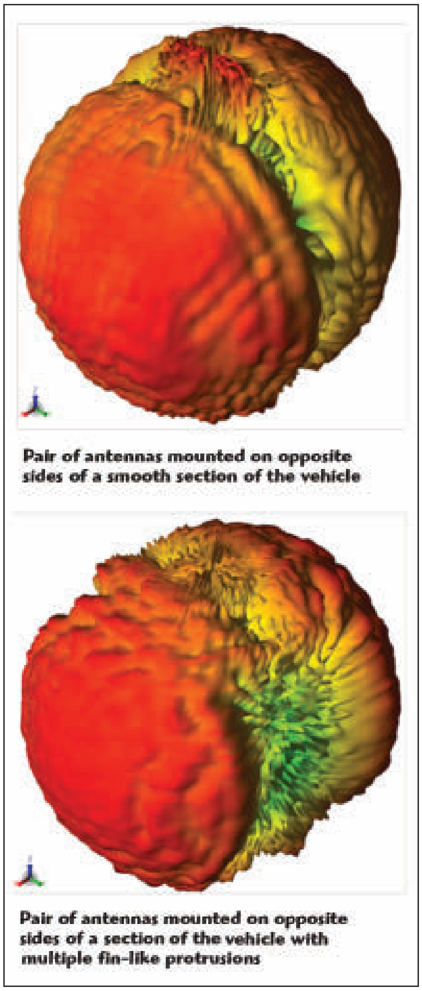
▲ *Fig. 3 Antenna pattern on a smooth cylinder no fins (a) and on a smooth cylinder with strategically placed fins (b).*

perience that these types of parasitic structures can have a dramatic effect on pattern characteristics.

Simulation tools are also used to optimize the performance of an antenna in the presence of other antennas. When multiple antennas are placed in close proximity to one another, the radiation pattern of each antenna is distorted from its ideal. In this scenario, modeling is used to alter electrical, mechanical and spacing parameters of the antennas to mitigate, or at least minimize, the effect of nearby antennas. The analytical techniques used provide far field gain performance of complex antenna configurations and/or complex vehicle geometry (including effects of solar panels, protruding sensors, other antennas, etc.). ***Figure 4*** is another example of computer modeling.

MAKING CONNECTIONS

The growth of the small satellite market, while very exciting and far reaching, must conform to the laws of physics – as the physical size gets smaller, a conformal antenna that might work with one application may need to migrate over to a deployable antenna for another. As a case in point, the nano-satellite is particularly challenging when the mission needs UHF capabilities. A conformal antenna may not work for this satellite class because the satellite can be substantially smaller than the wavelength at UHF, thus, unable to support the necessary physical size of the antenna. Switching to a small UHF deployable antenna that folds for launch and opens up once inserted into orbit is the best current solution.



▲ *Fig. 4 Simulated performance of a pair of antennas on a launch vehicle.*

It is common to use circularly polarized antennas, since it eliminates the need to align the polarization of the transmit and receive antennas. This is not the case with linearly polarized antennas, which must be perfectly aligned in order to avoid loss of signal due to polarization mismatch. Circular Polarization (CP) however, often presents imple-

mentation challenges, especially at low frequencies, since the antenna is typically larger than its linear counterpart.

Finally, the use of the antenna must be considered when determining coverage (i.e., directional or omnidirectional). As previously discussed, TT&C antennas are typically low gain antennas with broad antenna patterns. For data link antennas, which tend to be directional but not necessarily, the choice of antenna architecture is driven by a complex interplay among many system level considerations including performance, cost (both recurring and non-recurring) and regulatory issues. Key factors determining the performance needs of the satellite antenna are propagation loss, required data rates and spectral efficiency, along with the nature of the ground antenna.

Consider two extreme examples: a UHF antenna in a low Earth orbit and a Ka-Band satellite in geostationary orbit. When both free space loss and weather related attenuation are considered, the total difference in propagation loss between the two scenarios can be 80 dB or more. For the Ka-Band Satcom application, high gain, directional antennas are always necessary. However, the low propagation loss at UHF implies that for some applications low-gain (omni-directional or hemispherical coverage) antennas can be employed for both the space and ground antennas. The omni-directional antenna has obvious advantages with regard to equipment costs, especially for applications with a mobile earth terminal. However, greater antenna gain enables higher data rates and better spectral efficiency (more bits/sec of data per Hz of bandwidth), which translates to lower operating costs.

These kinds of performance and cost tradeoffs are important factors to consider for all Satcom applications. In the realm of conventional large satellites, these tradeoffs have led in part to the fact that currently most high data rate satellite applications utilize high gain antennas on geostationary satellites, while low Earth orbit communication satellites have been utilized more for lower data rate (and greater cost per bit) applications. It is fair to say that the trade space for small satellites has only begun to be explored and the implications for large scale deployment of small satellite based communication systems is not fully understood.

Another important aspect of this will be employing new methods to share the spectrum with the current satellite infrastructure. Optimizing the performance of the current satellite antennas to the needs of future small satellite-based systems will be one key to their success. It should be noted that in the past, deployment of new types of satellite-based communication systems (e.g. those employing VSATs or mobile ground terminals) have often required working around the existing infrastructure that was optimized for different applications. The low cost and rapid deployment that is possible with small satellites should facilitate avoiding some of the associated pitfalls.

CONCLUSION

A viable commercial market is enabling innovative companies to carry multiple payloads with clusters of small/nano satellites that are affordable and yield quick access to space for everything from intelligence, surveillance and reconnaissance, to planetary science and internet backhaul. Large clusters are possible, however, as these small satellites are less expensive and can be replaced frequently with technological advances and shorter life cycles (some between 90 to 180 days). Data from both individual and clustered satellites can be sent to multiple ground stations and processed very quickly, enabling, for example, updated images during natural disasters or battle ground assessments for combat situations. This capability will open new commercial, scientific and military monitoring that will benefit the industry in a multitude of ways, making it possible to design and produce a working satellite at lower costs.

As the market continues to explore and expand the small satellite trend, the antenna technology will continue to cater to the broader availability of these smaller satellites. Specific mission requirements will vary. The complexity of the payloads will also change depending on the specific application. The common theme will be transmitting video, pictures, voice and data to large, fixed ground stations or mobile receivers. Even though these are desired to be at COTS prices, they still need to be built with well-proven materials and methods of fabrication to withstand the extremely harsh thermal, shock and vibration environments from launch to orbit. It would be catastrophic if the antennas did not perform after launch, since in most cases this would render the mission a total failure. While balancing these competing interests is the challenge, in the end the integrity of the mission must be the forefront consideration. ■

David Farr *received his degree in electrical engineering with honors from Northeastern University. He joined Haigh-Farr in 1984 and has been responsible for the design and development of several circularly and linearly polarized antennas, arrays, and directional antennas for high performance missile use utilizing both traditional methods, as well as innovative software providing advanced design capabilities. He has worked his way through the ranks of the company serving as program manager on numerous high-level programs and now serves as Haigh-Farr's CEO. He has developed and implemented electromagnetic microwave measurement techniques, conducted radiation pattern measurements utilizing scaled model measurement techniques as well as simulation software packages, and has been responsible for environmental qualification of several designs.*

Bill Henderson *received his PhD in Condensed Matter Physics from Rutgers University in 1996 and his bachelor's degree in physics and math from the State University of New York in 1988. He has a wealth of antenna design, analysis and test experience from positions as lead RF engineer with both ThinKom Solutions and Raytheon. In addition to his engineering design and analysis experience he has served in the role of program lead engineer overseeing and managing staff engineers to bring designs from conception to execution.*

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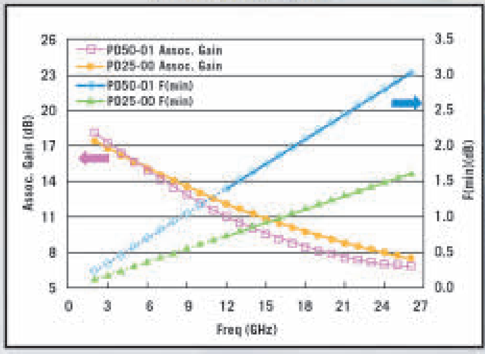
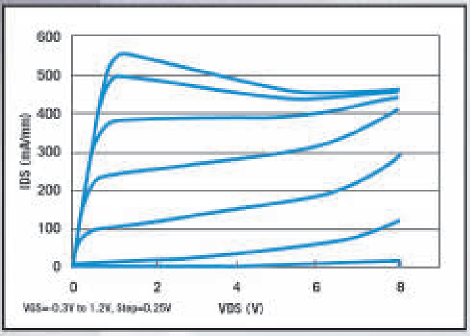
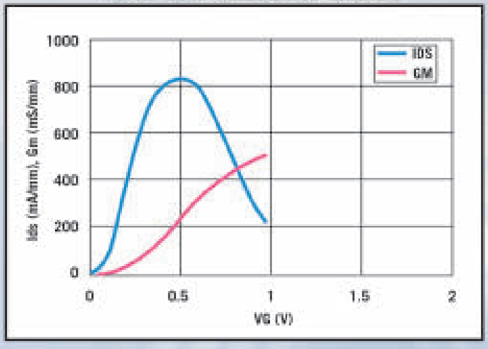


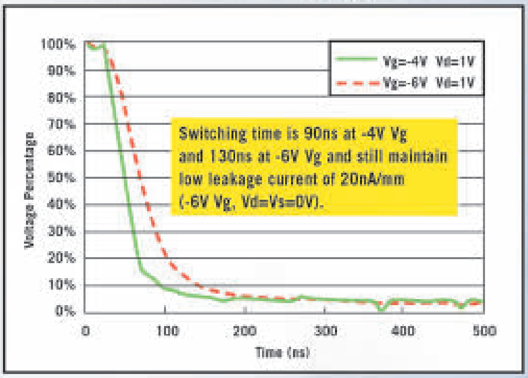
E-mode I-V Characteristics



E-mode Transfer Curve



D-mode Switching Speed



D-mode Device Performance

	PD50-01		PD25-00	
	Single	Triple	Single	Triple
Ron (ohm.mm)	1.9	3.7	1.3	2.2
Coff (fF/mm)	168	83	163	92
RonxCoff(ohm.fF)	316	310	209	198

DUT: NOF x UGW= 5 x 12μm

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U.S. Army Places Blimp-Borne Radar in Strategic Readiness

VIEW VIDEO

Should the U.S. or its allies need enhanced protection against cruise missiles, hostile airplanes, sea-borne threats or unmanned aircraft, military commanders will have a new system at their disposal. Previously used for testing, Raytheon Co. has finished preparing a blimp-borne radar system that will be used as a rapidly deployable strategic asset.

JLENS is a powerful airborne radar system that floats at altitudes as high as 10,000 feet, suspended from two 80-yard long, helium-filled blimp-like aerostats that are tethered to ground stations via a rugged cable. It helps defend critical assets, population centers and infrastructures against a variety of threats, such as manned and unmanned aircraft and missiles.

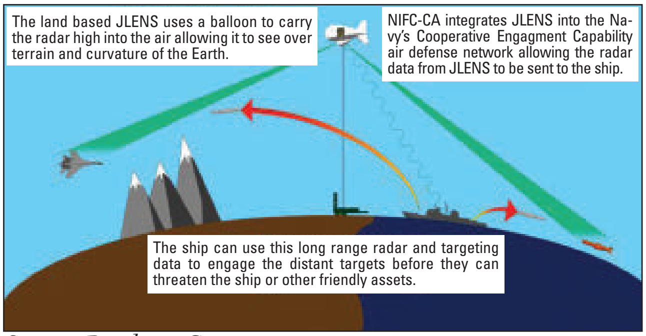
"By putting JLENS in strategic reserve, the Army is giving combatant commanders around the globe the ability to pick up the phone and, in short order, receive this incredible air defense capability in their area of responsibility," said Raytheon's Dave Gulla, vice president of Integrated Defense Systems' Global Integrated Sensors business area.

The U.S. Army has procured two JLENS systems to date. In addition to keeping one system in strategic reserve, a second system is scheduled to participate in an operational evaluation at Aberdeen Proving Ground, Md., in fall of 2014. JLENS completed early user testing in the third quarter of 2013, and concluded system design and development in the fourth quarter of 2013.

"By putting JLENS in strategic reserve, the Army is giving combatant commanders around the globe the ability to pick up the phone and, in short order, receive this incredible air defense capability in their area of responsibility..."

"JLENS has proven its ability to extend the air-defense umbrella by integrating with our nation's land, sea, and air-based air defenses to detect and intercept threats, such as airplanes, drones and cruise missiles," said Doug Burgess, Raytheon's JLENS program director. "The success of this operational evaluation is another significant step forward because it will demonstrate that JLENS has unmatched defensive capabilities. Raytheon is doing its part to get both the soldiers and the system ready."

Since JLENS began development in 2005, it has completed a rigorous testing program that included tracking and targeting airplanes and drones, and helping destroy cruise missile targets by integrating with the Patriot Air and Missile Defense System, Standard Missile 6 and AMRAAM defensive systems. JLENS has also tracked threats such as swarming boats, unmanned aircraft, and detected tactical ballistic missiles in their boost-phase.



Source: Raytheon Corp.

Boeing-Led Missile Defense Team Achieves 1st Intercept Using an Enhanced Version Exoatmospheric Kill Vehicle (EKV)

VIEW VIDEO

In a complex test over the Pacific Ocean on June 22, the U.S. Missile Defense Agency and an industry team led by Boeing intercepted and destroyed a target in flight using the ground-based midcourse defense (GMD) system. This was a successful test using an enhanced version of the exoatmospheric kill vehicle (EKV), a device attached to the intercept booster that flew on its own, hit and destroyed the target.

"Today's test demonstrated the system's performance under an expanded set of conditions that reflect real-world operational requirements," said Jim Chilton, vice president and general manager, Boeing Strategic Missile & Defense Systems. "Working together with our government, military and industry partners, we have delivered a capability that continues to demonstrate its readiness and reliability to protect the United States."

"Today's test demonstrated the system's performance under an expanded set of conditions that reflect real-world operational requirements..."

The test began at 2:49 p.m. Eastern time when a threat-representative target was launched into the Pacific Range from the Marshall Islands. With tracking data from the Boeing-developed Sea-based X-Band Radar and the Aegis SPY-1 radar, ship-based military operators launched the ground-based interceptor from Vandenberg Air Force Base, Calif.

The EKV was released while the interceptor was in space. The EKV received updates from the GMD system, detected and tracked the target and destroyed it through a high-speed impact. This test met several key objectives,

For More Information Visit mwjournal.com for more defense news including achieving a long flight time and high-velocity closing speeds.

"The operational complexity of the GMD system is a major engineering challenge, but we have drawn upon our unmatched expertise to work toward today's successful intercept," said Norm Tew, Boeing vice president and GMD program director. "This test enables us to continually modernize and improve the system, providing even greater capabilities to protect this country."

With interceptors at Vandenberg and Fort Greely, Alaska, GMD is an integral element of the United States' layered ballistic missile defense architecture. The program consists of command-and-control facilities, communications terminal, and a 20,000-mile fiber-optic communications network that interface with ballistic missile defense radars and other sensors. Boeing has been prime contractor since 2001 and works with partners Northrop Grumman, Orbital ATK and Raytheon.

NGC, U.S. Navy Increase MQ-8B Fire Scout's Visual Reach with a Modernized Radar

Northrop Grumman Corp. and the U.S. Navy recently demonstrated a new multimode maritime surveillance radar on the MQ-8B Fire Scout unmanned helicopter that will drastically enhance long-range imaging and search capabilities for Navy commanders.

Source: U.S. Navy photo

Warfighters will now have the latest in radar technology to pair with their current electro-optical infrared payload. Integrating this new radar system will provide the MQ-8B Fire Scout with essential operational capabilities in all tactical environments and will improve how it addresses threats in real-world scenarios.

"Fire Scout is pushing the limits of unmanned helicopters by continuing to add enhanced capabilities to its already advanced payload," said George Vardoulakis, vice president, medium range tactical systems, Northrop Grumman Aerospace Systems. "This modernized radar complements Fire Scout's other sensors and systems to provide the Navy with increased visibility far beyond the horizon, while collecting vital imaging for maritime operations."

Northrop Grumman modified a Telephonics Corp. AN/ZPY-4 multi-mode maritime surveillance radar system used for manned aircraft, so it could be used on the unmanned MQ-8B Fire Scout.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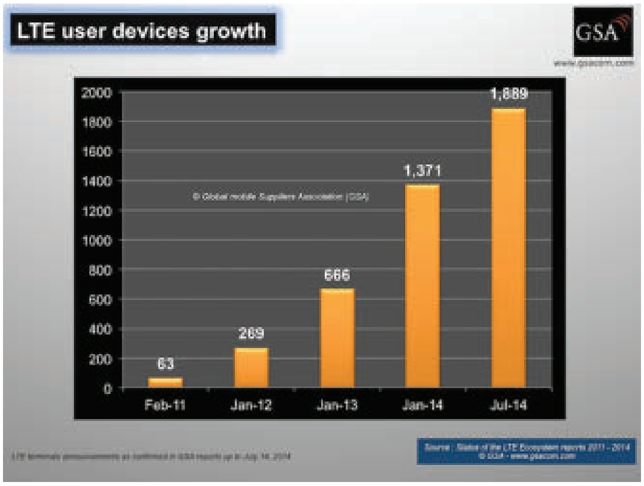
GSA Confirms 100 Percent Surge in LTE User Devices

The *Status of the LTE Ecosystem* report (July 14, 2014) published by the Global mobile Suppliers Association (GSA) confirms that 168 manufacturers have announced 1,889 LTE-enabled user devices, including operator and frequency variants. At least 941 new LTE user devices were launched in the past year, representing virtually 100 percent annual growth. The number of manufacturers increased by 68 percent in the same period.

Worldwide, 1800 MHz (3GPP Band 3) continues to be the most used band for LTE network deployments. Forty three percent of LTE operators use 1800 MHz in their networks, either as a single band, or as part of a multi-band deployment. The 1800 MHz band also has the largest LTE user devices ecosystem. At least 769 LTE1800 user devices have been announced, achieving 170 percent year on year growth. Over 40 percent of all LTE devices can operate in the 1800 MHz (Band 3).

The report covers LTE FDD and TDD devices. While the majority of terminals operate in the FDD mode, support for the TDD mode (TD-LTE) has significantly strengthened. At least 530 devices, which is 330 more than a year ago, can operate in the LTE TDD (TD-LTE) mode. The ecosystems for TDD Bands 38 (2.6 GHz) and 40 (2.3 GHz) dominate and are almost identical, each being supported in 68 percent of TDD devices in the market. Deployments in China appear to be the main catalyst for growth with several new product launches being confirmed recently by a growing number of manufacturers and across different price points.

Another key trend is the growing availability of category 4 and category 6 terminals for the rapidly growing number of LTE-Advanced network deployments. There are now 373 category 4 terminals (capable of supporting up to a theoretical downlink speed of 150 Mbps), plus a further 7 category 6 devices (300 Mbps).



Airbus Defence and Space and Inmarsat Deliver Global Xpress Terminals

Airbus Defence and Space and Inmarsat have signed an agreement covering high-throughput airborne Global Xpress (GX) terminals. Global Xpress is set to be the world's first globally available commercial high-speed broadband service delivered via a Ka-Band satellite network.

This latest agreement unleashes high throughput satcom options for comms-on-the-move Intelligence, Surveillance and Reconnaissance (ISR) operations for aircraft – specifically helicopters – as well as for the Unmanned Aerial Vehicle (UAV) domain. Military and other government customers will now have access to Inmarsat's Global Xpress Ka-Band service through Airbus Defence and Space's airborne portfolio.

> "...a new era of operational flexibility."

Andy Start, president, Inmarsat Global Government said, "Combining the unique Global Xpress service with Airbus Defence and Space's proven heritage in airborne satcom heralds a new era of operational flexibility. The ability to deploy anywhere, without notice, with high speed internet quality links will drive massive improvements in capability and cost effectiveness."

Graphene Research Centre Opens at University of Surrey

The University of Surrey is establishing a graphene centre within its Advanced Technology Institute (ATI), expanding and consolidating the UK University's graphene research and manufacturing capabilities.

Through the Centre, the ATI will further its research into the uses and manufacture of graphene across industries such as high frequency electronics, flexible and transparent electronics, smart coatings such as emissivity and barrier layers, energy generation and storage, electrical interconnect technology and antennas all within calibration standards.

At the heart of the centre will be the ATI's photo thermal deposition technology which produces large scale electronic-grade graphene on wafer-scale substrates. The new tool performs both steps in creating electronic-grade graphene, catalyst deposition and graphene growth, saving the need to transfer the sample between machines. Since the sample is kept in a vacuum, the grown material results in higher quality. Additionally, the process allows high volume production in an industrial environment.

"The opening of our new centre will help ensure that our graphene research is focused on the practical benefits and applications of this material across industries," said Professor Ravi Silva, University of Surrey and director of the ATI.

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> ...high volume production in an industrial environment.

"This tool is an exciting addition to our existing capabilities. Together with industrial and academic partners, we can combine our expertise in nanomaterials and graphene to advance technologies such as electronic devices, supercapacitors, solar cells, OLEDs and printed transistors."

Thales Alenia Space Acquires SEA's Space Business

Thales Alenia Space has completed the acquisition of the space activities of Systems Engineering & Assessment Ltd. (SEA), part of Cohort plc. This acquisition will reinforce the strength of its new subsidiary Thales Alenia Space UK and will boost its growth in systems engineering and research & technology (R&T). The acquisition will also provide Thales Alenia Space UK with expertise in electronics and space mission subsystems and a customer base that already includes the European Space Agency (ESA).

Thales Alenia Space UK has recently opened new offices in Harwell, Oxfordshire, which, in addition to space propulsion activities in Belfast, and the new acquisition of SEA's space business, establishes Thales Alenia Space as a national contributor to the UK space industry.

> "...a kickstart to our ambitions in the UK..."

Martin Gee, CEO of Thales Alenia Space UK, said "Our decision to come to the UK was motivated by the UK Government's work and has been supported by concrete actions to bolster the development of our activities in the short term. Our acquisition of the space business of SEA gives a kickstart to our ambitions in the UK and aligns well with the global business of Thales Alenia Space, particularly regarding a number of technologies that have been developed by SEA engineers and their use in future space missions, as well as to a number of exciting ongoing international programs."

Thales Alenia Space President and CEO Jean Loïc Galle emphasized that, "Through this acquisition, Thales Alenia Space UK is in working order to support the UK Space Agency and aspires to reinforce its development in the advanced space technologies. This approach is a natural fit with the company's 'Ambition 10' growth plan for the coming years."

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Model	Frequency (MHz)	Gain (dB)	Pout @ Comp. 1 dB (W)	Pout @ Comp. 3 dB (W)	$ Price (Qty. 1-9)
ZVE-3W-83+	2000-8000	36	2	3	1295
ZVE-3W-183+	5900-18000	35	2	3	1295
ZHL-5W-2G+	800-2000	45	5	6	995
ZHL-5W-1	5-500	44	8	11	1020
ZHL-10W-2G	800-2000	43	10	13	1295
• ZHL-16W-43+	1800-4000	45	13	16	1595
• ZHL-20W-13+	20-1000	50	13	20	1395
• ZHL-20W-13SW+	20-1000	50	13	20	1445
LZY-22+	0.1-200	43	16	32	1495
ZHL-30W-262+	2300-2550	50	20	32	1995
ZHL-30W-252+	700-2500	50	25	40	2995
LZY-2+	500-1000	47	32	38	2195
LZY-1+	20-512	43	37	50	1995
• ZHL-50W-52+	50-500	50	40	63	1395
• ZHL-100W-52+	50-500	50	63	79	1995
• ZHL-100W-GAN+	20-500	42	79	100	2395
ZHL-100W-13+	800-1000	50	79	100	2195
NEW ZHL-100W-352+	3000-3500	50	100	100	3595
NEW ZHL-100W-43+	3500-4000	50	100	100	3595
NEW LZY-5+	0.4-5	52.5	100	100	1995

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

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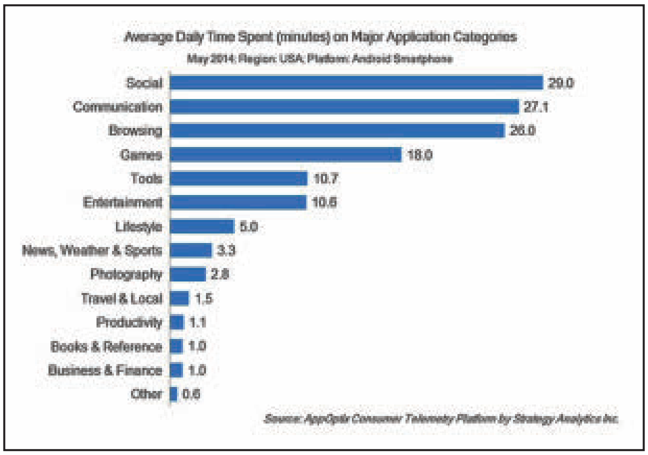
CommercialMarket
Cliff Drubin, Associate Technical Editor

U.S. Android Users on Average Engage 138 Minutes Daily with Their Smartphones

According to Strategy Analytics, U.S. Android users have been spending more time on their devices. Android smartphone users on average spent 138 minutes on their devices in May 2014, an increase of 20 percent from the usage in December 2013.

The analysis is based on over 1 million individual application sessions on more than 1,500 Android smartphone users in the U.S. during that period. The results are powered by Strategy Analytics' state-of-the-art Consumer Telemetry Platform.

While Facebook, YouTube and messaging apps demonstrate category leading performance with over 50 percent share in total time spent in their respective categories, niche segments such as lifestyle, productivity, and news, weather & sports are characterized by a broad range of smaller apps – no single publisher dominates the category and thereby presents opportunities for new and inspiring app concepts.



Home and Away: Chinese Handset Vendors Advancing in Mobile Content and Services

Leading Chinese handset vendors are making progress in mobile content and services, in addition to winning increasing market share in the devices markets. According to Strategy Analytics' latest smartphone market data, five out of the top 10 smartphone vendors by shipment in Q1 2014 are Chinese. However, the leading Chinese vendors are not satisfied with just being on the shipment leaderboard. In its latest report, Handset Vendors' Content and Service Strategy: Team China, Strategy Analytics' looks into the leading Chinese vendors' commendable progress in the mobile content and service as a means to attain more ecosystem orchestrating power.

"One of the things that have impressed us the most is the speed at which the Chinese vendors, especially the four featured in this analysis, Lenovo, Huawei, ZTE and Xiaomi, have expanded their footprints in the mobile content and service domains," said David MacQueen, executive director, Apps and Media at Strategy Analytics. "For example, Huawei has already built a catalog of 1 million apps in its app store. This is all very impressive considering that companies like Huawei started from a much lower starting point in apps and have not been as vocal as a global heavyweight in promoting its own developer program; something the company may want to do more of in the future."

> "One of the things that have impressed us the most is the speed at which the Chinese vendors, have expanded their footprints in the mobile content and service domains..."

"With the ambition level raised higher in the overseas markets, the Chinese vendors may find the content and service markets much harder to crack than the devices markets. Particularly as the partnerships they have in place with content providers in China, where the Internet market is rather insulated due to social, cultural and regulatory reasons, are not easily expanded overseas," said Wei Shi, Wireless Media Strategies analyst at Strategy Analytics. "The unchartered waters may prove challenging, but it will be a challenge worth taking if the Chinese vendors are seriously aiming at going beyond hardware shipping and manufacturing."

Mandates, Consortiums, and Autonomous Vehicles to Drive Cooperative V2X Technology Deployments by 2020

Global penetration of V2X modules in new vehicles will reach 62 percent by 2027. The total installed base of OEM and aftermarket DSRC V2X modules in vehicles will grow to 423 million by 2027.

"V2X technology has been a long time coming, but its hour of glory might just be around the corner, at least in terms of automotive time frames. The U.S. Department of Transportation's (DoT) decision on a V2V mandate and Europe's voluntary approach via the C2C-CC consortium with an MoU signed by 11 vehicle OEMs committing to deployments by 2015 will drive the V2V market forward. Additionally, the accelerating developments in autonomous driving will further fuel interest in V2X technology as a critical component for adding redundancy and reliability," comments VP and practice director Dominique Bonte.

While the V2X ecosystem is still small, a host of Automotive Tier 1 suppliers, and semiconductor and module vendors are lining up with tested and proven solutions: Autotalks, Cohda Wireless (NXP), Qualcomm, Savari, Continental, Bosch, Hitachi, Denso, Visteon, Kapsch TrafficCom, Arada Systems, Delphi and DGE.

However, it is not just about providing in-vehicle tech-

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> "V2X technology has been a long time coming, but its hour of glory might just be around the corner, at least in terms of automotive time frames..."

nology (on board units or OBUs). The full potential of cooperative systems will only be realized through the deployment of road side units (RSU) attached to traffic lights, light poles, digital signage, tolling gates and buildings allowing vehicle-to-infrastructure (V2I) communication and services. ABI Research expects the rollout of V2I to kick start in the wake of the first wide-scale V2V deployments by the end of this decade and forecasts 1.92 million RSUs to be installed globally by 2030.

Aircraft Providing In-Flight Connectivity to Double in Next Decade

According to Euroconsult's newly released report, Prospects for In-Flight Entertainment and Connectivity, the global in-flight connectivity market is expected to grow over the next 10 years, with over 12,900 commercial and 24,000 business aircraft providing in-flight connectivity to passengers by 2023. Along with the growth in installation, both the take-up rate and ARPU are expected to improve. As a consequence, total revenue from passenger connectivity services is expected to grow from $440 million in 2013 to $2.1 billion by 2023.

"At present, 59 airlines provide passenger in-flight connectivity services via satellite or ATG networks. Over 80 percent of connected aircraft are still from North America; however, Europe, the Middle East and Asia are gaining importance in the market, and are expected to be the major growth engines in the next decade," said Wei Li, senior consultant at Euroconsult and editor-in-chief of the report. "Despite the highly competitive nature of the existing market, new entrants including incumbent telecom operators such as AT&T and China Mobile continue to enter the segment. Moreover, it is expected that in the next 12 to 36 months, additional inflight connectivity projects will be announced."

Gogo is currently ahead of its competitors in terms of market share, due to the dominant presence of Gogos' ATG service in the U.S. While long-haul flights over oceans and in regions outside of North America have helped other connectivity providers rapidly catch up in market share, Gogo has also unveiled plans for international expansion.

There is a clear trend that inflight connectivity is becoming increasingly integrated with the inflight entertainment (IFE) business.

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Around the **Circuit**

Barbara Walsh, Multimedia Staff Editor

MERGERS & ACQUISITIONS

Altair has completed its acquisition of 100 percent of **EM Software & Systems – S.A. (Pty) Ltd.** and its international distributor offices in the United States, Germany and China. This development adds the FEKO® solver to the HyperWorks® suite and strengthens the Altair simulation offering in the aerospace, automotive and shipbuilding industries. In addition, in-house electromagnetic expertise crossing multiple industries will enable the company's consulting arm, Altair ProductDesign, to take on more responsibility in customer engagements where this specialized applied engineering knowledge is required.

Avago Technologies Ltd. and **PLX Technology Inc.** announced that they have entered into a definitive agreement under which Avago will acquire PLX, a leader in PCI Express silicon and software connectivity solutions, in an all-cash transaction valued at approximately $309 million, or $293 million net of cash and debt acquired. Under the terms of the agreement, which was approved by the boards of directors of both companies, a subsidiary of Avago will commence a tender offer for all of the outstanding shares of PLX common stock for $6.50 per share in cash.

Exelis completed the acquisition of **Celestech**, a privately held technology development and engineering firm, with locations in Chantilly, Va. and Phoenix, Ariz. Celestech's acquisition does not materially impact Exelis financial results for the second quarter of 2014. Celestech develops tailored technical solutions for government and commercial customers, with specific expertise in advanced signal processing and communications systems. The company provides engineering services and product development for next generation satellite and terrestrial wireless solutions. Celestech's expertise in the realm of data analytics also supports the Exelis intelligence, surveillance, reconnaissance and analytics strategic growth platform.

COLLABORATIONS

AWR Corp. and **ANSYS Inc.** announced that they have integrated ANSYS® HFSS™ into AWR's Microwave Office® high frequency circuit design software. This integration unites the industry standard for full-wave electromagnetic (EM) field simulation and NI AWR Design Environment™/Microwave Office to quickly and accurately simulate microwave circuits. With this design flow, Microwave Office users can readily access HFSS for analysis of EM fields and coupling of 3D structures like passive components, bumps, bond wires and pins which are essential to successfully designing and realizing microwave circuits like monolithic microwave integrated circuits (MMIC), densely-populated RF circuit boards and multifunction modules.

Agilent Technologies Inc. announced an agreement to collaborate with **China Mobile Communications Co. Ltd. Research Institute (CMRI)** on the next–generation 5G wireless communication systems. China Mobile is the world's largest mobile network operator and a market leader in 3G, 4G and next-generation wireless network development. The two companies signed a memorandum of understanding in Beijing. Agilent will actively support the research and development programs on 5G, led by CMRI, and provide test and measurement solutions for next-generation 5G wireless communication systems.

Intercept Technology Inc. announced its newest authorized reseller, **Tecnode Solutions Ltd.** Tecnode's primary goal is to expand its RF and microwave solutions portfolio by selling Intercept's PCB, RF and hybrid design software applications throughout India. Tecnode has been providing software and hardware systems solutions in India for over 20 years, with a major focus on the Defense, Space and Aerospace sector. The addition of Intercept's software to Tecnode's product list expands Tecnode's software solutions into the more traditional EDA market, thus providing a well-rounded set of options for current and future customers.

Granite River Labs (GRL) announced its agreement with **Royal Philips N.V.** to host Philips' High-Definition Multimedia Interface™ (HDMI™) Authorized Testing Center (ATC) compliance testing services in Taiwan and India. GRL will provide HDMI ATC services from two conveniently located facilities in Taiwan - Taipei and Hsinchu. Additionally, GRL will provide HDMI ATC services from its Bangalore, India lab, with day-to-day responsibilities of the existing Philips HDMI ATC transferring to GRL. The Philips HDMI ATCs hosted by GRL in Taiwan and India provide HDMI version 1.x and 2.0 pre-compliance and compliance testing and debugging support for sinks, sources, repeaters and cables.

The WhiteSpace Alliance (WSA)®, a global industry organization enabling sharing of underutilized spectrum, announced that **NuRAN Wireless™** has joined the organization. NuRAN Wireless has been involved in TV white space (TVWS) trials, using the technology as a broadband Internet access technology for schools in developing countries, and as a Non Line-of-Site wireless backhaul solution for connecting small cell base stations in remote areas. Additionally, it has been collaborating with academic institutions, such as the Institut National de la Recherche Scientifique in Montreal, Canada, which seeks to enhance spectrum sensing methods and radio access schemes targeting available white space spectrum.

ACHIEVEMENTS

For the fifth consecutive year, **Raytheon** has presented **Mini-Circuits** with the 4-Star Supplier Excellence Award at its annual supplier conference. The award recognizes top supplier performance based on overall quality and on-time delivery throughout the year. Mini-Circuits proudly

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accepts this honor as a significant achievement in their commitment to meeting customer needs with the highest standards of quality.

For two years in a row, **Raytheon** has awarded **SV Microwave** the Supplier Excellence Award, recognizing the company's outstanding business performance. Raytheon's business instituted the annual Supplier Excellence Awards program to recognize suppliers who have provided outstanding service and partnership in exceeding customer requirements. SV Microwave was one of only 60 suppliers out of 5,000 global partners recognized by Raytheon for 4-Star honors.

KOA Speer Electronics Inc. was presented the **Arrow Electronics Inc.** Perfect Order Index (POI) award for 2013. KOA Speer received the platinum award for the highest level of performance in the passive electromechanical components category. Arrow's POI awards honor suppliers that achieve best-in-class performance by delivering "perfect orders" as measured by Arrow's eight-point measurement system. Among other criteria, suppliers are measured on orders that are free of defects and delivered at the right time.

Pascall Electronics Ltd. has successfully gained accreditation to the internationally recognized aerospace quality requirements of EN 9100:2009. Building on the company's previous accreditation to ISO9001:2008, this latest achievement demonstrates its continued commitment to customer satisfaction, high quality products and processes and a thorough understanding of aerospace requirements. This certification ensures customers that Pascall is an approved, recognized and experienced partner in the aviation and aerospace industry.

ACHIEVEMENTS

Drone Aviation Corp. (DAC), a wholly owned subsidiary of Drone Aviation Holding Corp., and developer of specialized lighter-than-air aerostats and tethered drones, has announced that aerostat systems provided to the U.S. Army Space and Missile Defense Command (SMDC)/Army Forces Strategic Command have successfully completed operations in the U.S. Army's Network Integration Experiment (NIE) 14.2 at Fort Bliss, Texas and White Sands Missile Range, N.M. The Army requested that the two Winch Aerostat Small Platforms (WASP) return to NIE 14.2 as a carryover system following their successful evaluation at NIE 14.1 as a system under evaluation

Coaxial Components Corp. has recently completed their AS9100 audit and is being recommended for certification/registration by NSF. They will receive the certificate in a few short weeks. AS9100 certification is a prestigious certification requiring companies to meet the demanding, complex and unique requirements of the defense and commercial aerospace industry.

CONTRACTS

Vista Research, a subsidiary of Raven Aerostar, has been awarded an operations and maintenance contract for the upgrade and replacement of currently-fielded radar systems in support of the U.S. Army's Persistent Ground Surveillance Systems (PGSS) program. The firm-fixed-price, cost-plus-fixed-fee contract has been awarded for $8,381,917 and details an expected completion timeline of December 2014. Vista Research has been providing radar systems and support to the PGSS Program since 2011. The Vista Smart Sensor Radar Systems (SSRS) are designed and optimized for tracking targets against difficult radar clutter conditions.

Comtech Telecommunications Corp. announced its Santa Clara, Calif.-based subsidiary, **Comtech Xicom Technology Inc.**, received an order from an existing customer valued at $5.3 million for state-of-the-art 500 W Ka-Band high power amplifiers to be used in the High Throughput Satellite (HTS) market. These 500 W amplifiers will be located at multiple gateways to enable high capacity consumer broadband applications. HTS satellites provide significantly more total throughput compared to a classical spacecraft, thus significantly reducing cost-per-bit. This is accomplished by re-using spectrum across geographical areas with spot beams and operating at Ka-Band where greater amounts of spectrum are available.

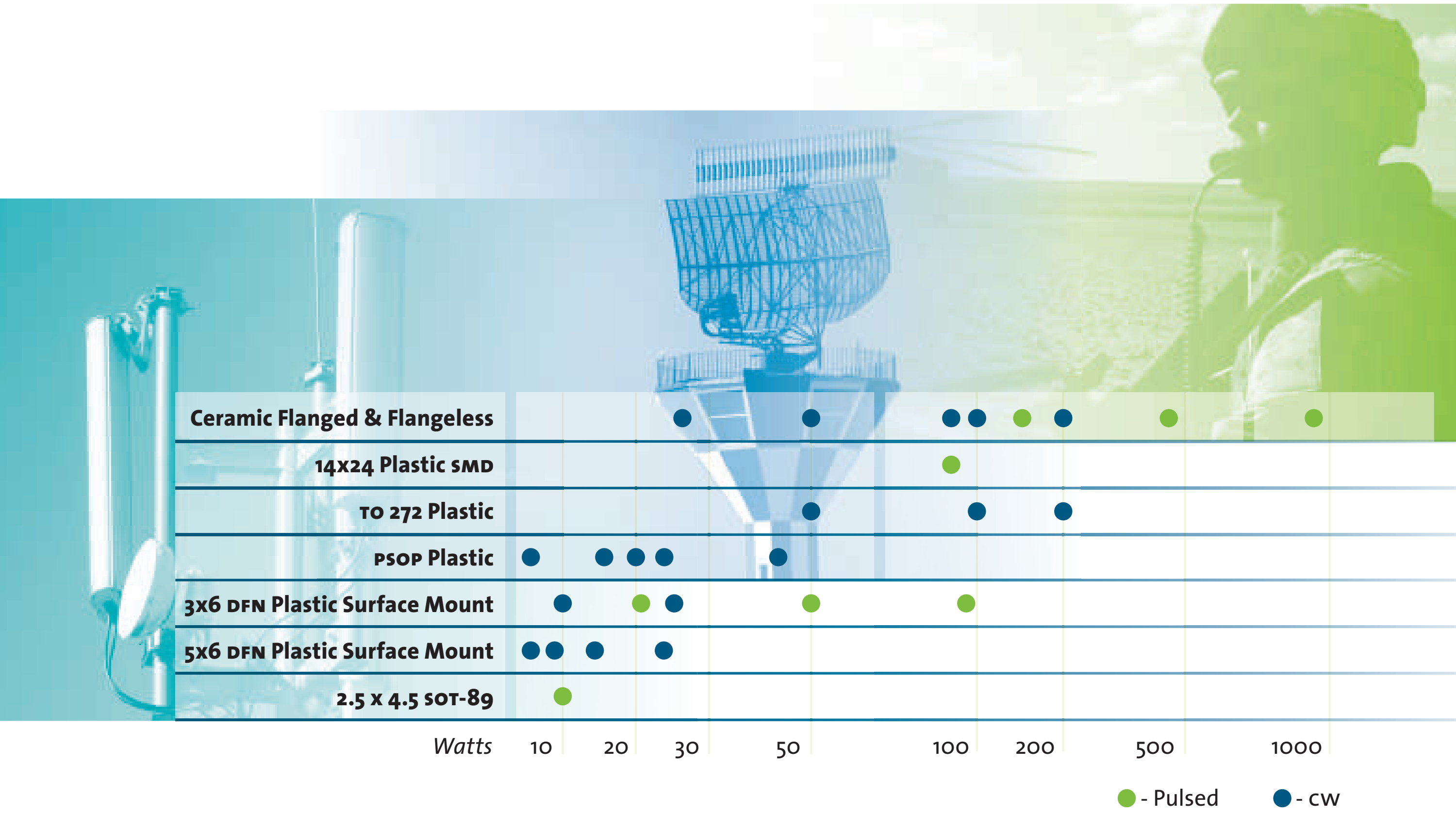
PEOPLE

Crane Aerospace & Electronics, a segment of Crane Co., has announced the appointment of **Steve Barr** as vice president of operations of the Electronics Group of Crane Aerospace & Electronics. In his role, Barr is responsible for operations and supply chain for all of Electronics Group locations, including Beverly, Mass., Chandler, Ariz., Ft. Walton Beach, Fla., Redmond, Wash., West Caldwell, N.J. and Kaohsiung, Taiwan. He will be located in Redmond, WA. Barr comes to Crane with a diverse background in electrical distribution equipment, power generation and defense contracting. This includes roles with companies such as Danaher, Cummins Engine Company and Hunter Defense Technologies.

Wireless Telecom Group Inc.'s board of directors appointed **Don C. Bell** to serve as a member of their board. Bell will also serve as a member of the board's compensation committee. Don Bell is a technology entrepreneur and investor. Since 2011, Bell has been a private investor. From 2007 until 2011, Bell served as the owner and president of Tidal Research, an Internet advertising company he founded. Bell recently served as a director of NTS Communications from December 2012 through the June 2014 acquisition of the company by Tower Three Partners.


▲ Graham Peel

Graham Peel has been appointed CEO at **Ranplan**, which has developed a powerful, all-in-one solution to plan, design and optimize outdoor/indoor small cell wireless networks. Previously CEO of Cambridge Broadband Networks, Peel grew the company to become market leader in point-to-multipoint wireless backhaul and access solutions.



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Around the **Circuit**

Ranplan is currently based in the UK with offices in China. In addition to growing business in these regions, the company is also expanding into EMEA and the U.S.

REP APPOINTMENTS

Barry Industries, an ISO9001:2008 certified, ITAR registered manufacturer of high quality thick film attenuators, resistors, terminations and high temperature co-fired ceramic (HTCC) packaging, welcomes **APC-Novacom** as their new representative to the United Kingdom and Ireland. APC-Novacom was established in 1991 and continues to serve the defense, communication, medical and instrumentation companies of the United Kingdom and Ireland. ISO9001:2008 certified APC-Novacom is headquartered in Lincoln, at the center of the United Kingdom's RF and microwave community.

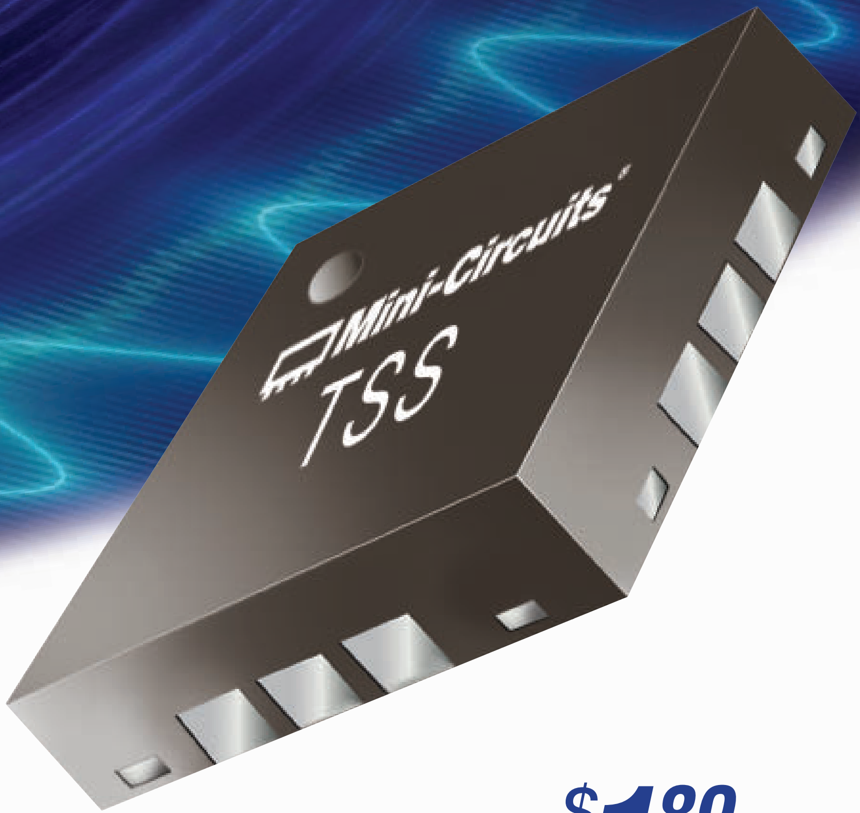
San-tron Inc., a leading manufacturer of RF and microwave coaxial connectors and cable assemblies, has announced the hiring of a new sales representative, **Cornerstone Technical Sales** (CTS) to handle customer relationships in Fla. CTS has been representing the best manufacturers in the industry for over 43 years. With their combined market knowledge and experience, CTS has increased sales through focused, targeted, synergistic sales and marketing.

PLACES

ARC Technologies held a ribbon-cutting ceremony for its new advanced manufacturing facility in Amesbury, Mass. Government officials and business partners joined the opening celebration and toured the manufacturing operations. ARC Technologies has a long history of success in the local community and the microwave industry. ARC has experienced steady growth over the past 10 years, expanding from its 50,000 sq. ft. Chestnut St. facility into two adjacent buildings, to nearly 150,000 sq. feet of space. With the recent addition to the Hunt Road facility, ARC will have nearly 200,000 sq. ft. of space in three facilities. ARC employs over 120 people.

Rigol Technologies held a grand opening ceremony in Suzhou, China to commemorate the opening of its new 440,000 square foot manufacturing facility. The event was attended by over 100 of Rigol's international distribution partners, local and state government dignitaries and many industry leaders. The new manufacturing campus will house all of Rigol's instrument manufacturing operations as well as logistics, dormitories, conference facilities and expansion of its R&D team. The manufacturing facility includes two state-of-the-art SMT lines for board build as well as injection molding and metal fabrication capabilities.

LOW NOISE BYPASS AMPLIFIERS



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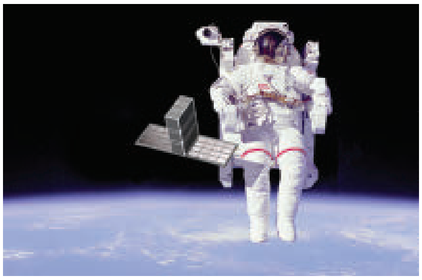
Next Generation Communications for Next Generation Satellites

Nathan Kundtz
Kymeta Corp., Redmond, Wash.

The past decade has witnessed a massive growth in interest in satellites that are smaller, cheaper and quicker to deploy than larger space-borne assets. One of the major challenges associated with these platforms, however, has been the limited communications bandwidth available to and from them. While the communications industry has done a stellar job in improving available radios and amplifier equipment, antenna systems for satellite platforms continue to be challenged with meeting size, weight and power requirements while still providing the flexibility demanded by the mission set. In this article a new antenna design platform will be introduced, and its effects on space-communications will be discussed.

Small satellites, so-called 'smallsats,' have captured the imaginations of hobbyists, entrepreneurs and the wider aerospace industry (see ***Figure 1***). The interest in these platforms is being driven by both cost and technical considerations. Smallsats can be deployed quickly and cost-effectively, allowing new technologies to be adopted rapidly in an industry that is famous for risk aversion. While the cost of launching a satellite is being driven down by entrepreneurial companies such as SpaceX, the availability of powerful sensors and communications equipment is being driven lower by volume applications on Earth. The average cell phone is now capable of doing much of what a powerful satellite was once required to do.



▲ *Fig. 1 Rendition of a smallsat showing a deployable panel antenna concept.*

There is no cellular network available for satellites, though. Information collected by a satellite must be broadcast from the satellite to an earth-terminal in order to be accessed; and this is one of the most significant challenges facing the smallsat industry. A typical cube-sat will be outfitted with a UHF communications payload, which, when paired with a large tracking earth terminal, is capable of a few kbps. This shortage on connectivity has resulted in a misperception within the industry that smallsats are interesting, but only to amateurs interested in hearing a satellite go 'ping' from orbit. This is unfortunate because a spacecraft travelling in LEO and operating in the Ka-Band would be capable of gigabit connections, significantly higher than the connectivity available to even very large communications satellites operating from the GEO arch.

The bottleneck to providing gigabit levels of throughput to LEO smallsats is the antenna. The use of communications at X-Band and above generally requires some directivity from the antenna (typically 30 dB+ of gain).

TABLE I

EXAMPLE CLEAR-SKY LINK BUDGETS FOR GEO KA-BAND, LEO S-BAND AND LEO KA-BAND SPACE-TO-GROUND COMMUNICATIONS

	GEO	LEO S-Band	LEO Ka-Band
Satellite Transmit Frequency (Hz)	2.650E+10	2.200E+09	2.650E+10
Antenna Gain (dBi)	33	6	33
Power level (dBW)	7	7	7
Satellite EIRP (dBW)	40	13	40
Path Length (Km)	35,786	1000	1000
Free Space Loss (dB)	212.681	159.298	180.915
Terminal G/T (dB/K)	10.000	-14.500	10.000
Rx Filter Width (Hz)	1.00E+06	1.00E+06	1.00E+09
C/N	5.579	7.462	7.345
MODCOD	QPSK 5/6	8PSK 2/3	8PSK 2/3
Bits per Hz	1.655	1.981	1.981
Required C/N	5.1	6.6	6.6
Data Throughput (Mbps)	**1.7**	**2.0**	**1980.6**
Link Margin	0.449	0.822	0.705

This gain is necessary to achieve the desired throughput and avoid interference with others in the same band. Gain levels of 30 dBi+ are easy to achieve using a reflector based antenna, but in a LEO orbit the antenna must also be capable of tracking. On a smallsat platform this currently must be accomplished either using mechanically gimbaled systems or by repointing of the satellite itself with its inertial stabilization system. The former (gimbaled) approach requires a set of motors that are relatively heavy and power consumptive. In fact, the motion of the antenna itself will impart momentum to the satellite and move the satellite itself.

The alternative is to use the momentum wheel of the satellite itself to point the satellite and dish simultaneously. The challenge with this approach is that the orientation of the satellite is now intimately connected to the communications direction. In earth observation applications this leads to large latencies in data-backhaul because the satellite sensors must be pointed on a first-pass, and then backhaul must be done on a second pass over a region. Given that a typical LEO orbit is in the range of a few hours, this approach makes real-time or near real-time sensing impossible from these platforms. In communications architecture the situation is worse. The relative positions of the Earth-station and the backhaul source (either teleport or inter-satellite link) of a moving satellite will move with respect to one another, and cannot be managed through the orientation of the satellite alone.

To address these communications challenges, a reconfigurable high-gain antenna with no moving parts and a small size, weight and power footprint is required. Through the dual use of metamaterial and liquid-crystal technologies, companies like Kymeta are spearheading the effort to create such antennas.

TECHNOLOGY

The antenna designs described here operate on the principle of reconfigurable holography. In such an architecture there is a feed which remains fixed throughout the operation of a device. The design challenge is to create a medium for scattering this feed-wave in a controllable way such that a requisite phase distribution can be developed over the surface of the antenna. In the design described here, this scattering is mediated through the use of a multitude of reconfigurable scattering sites aggregated together on a highly sub-wavelength scale. The use of such aggregations of scattering sites results in a device governed by the design paradigm known commonly as metamaterials.

Unlike phased-array antennas, devices constructed in this manner require no active components in the RF chain. The reconfigurableability of the antenna is built in to the metamaterial elements, and in this case liquid crystal is used. Nonetheless, the theory of operations is accessible through the well-known array-factor equations which govern the beam performance of a phased-array antenna.

$$AF(\theta,\varphi) = \sum_m A_m e^{-jko\left(x_m \sin(\theta)\cos(\varphi)+y_m \sin(\theta)\sin(\varphi)\right)} e^{j\Upsilon_m} \quad (1)$$

$$AF(\theta,\varphi) = \sum_m A_m(\omega) e^{-jko\left(x_m \sin(\theta)\cos(\varphi)+y_m \sin(\theta)\sin(\varphi)\right)} e^{j\beta x_m} \quad (2)$$

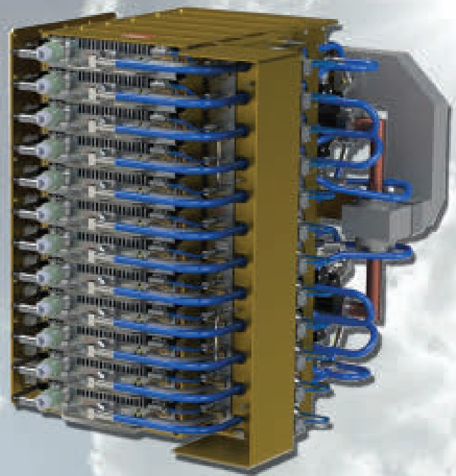
In equation 1, the controlled element is the phase, γ_m, with which each antenna element is fed. In equation 2, the phase is not dynamically controlled, but a travelling wave feed is used such that every element is fed with a variable phase (which is not time-dependent). In equation 2, the wave is assumed to be traveling along the x-axis. The phase of each element is determined by the position along that axis. The control mechanism is the amplitude with which each element scatters energy from the feed wave and into the far-field. This process will work to form antenna beams that can be scanned to any angle, subject only to the physical limitations of the subtended angle of the aperture with the direction of scan.

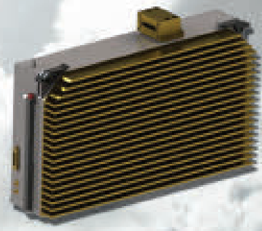
The fact that the antenna feed is integrated into the radiating aperture reduces the size, weight and complexity of the feed manifold. In practice the entire antenna can be built within a thickness of less than 1 cm; with associated weight savings.

The amplitude control can be implemented in many ways, but in our case we use a tunable dielectric – liquid crystal – to dynamically adjust the frequency with which each of our metamaterial elements resonates. When the frequency of operation is close to the resonance frequency of an element it scatters strongly; conversely, when the resonance frequency is tuned away from the frequency of operation the element scatters very weakly. This is shown explicitly with resonant curves in ***Figure 2***. Interestingly, in between the two resonant points a phase hologram is

Solid State Power Amplifiers

S-Band





X-Band

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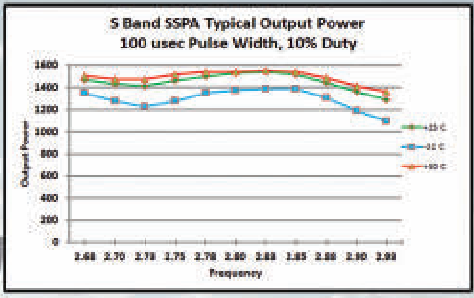

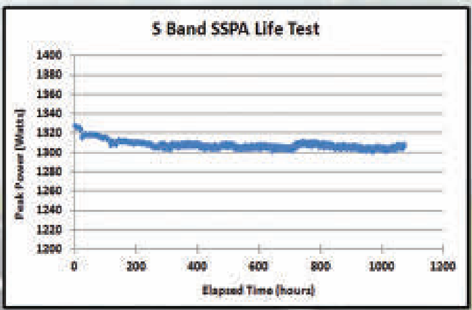

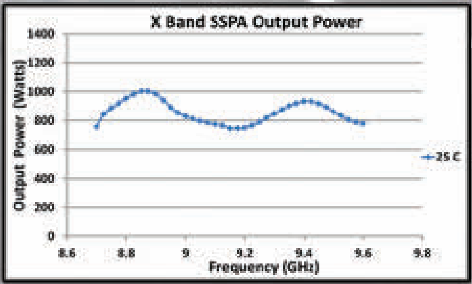

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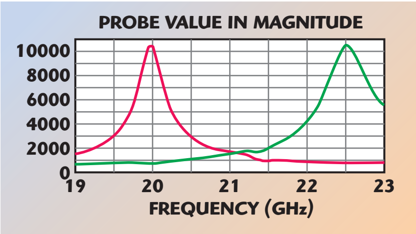
formed due to the 180 degree phase offset of the emitted signal associated with traversing the resonance.

The resonant elements work together through constructive interference to form an antenna pattern. One example antenna pattern from a prototype operating at 30 GHz is shown in ***Figure 3***. Without a bias voltage applied the resonance is at a higher frequency (green line in Figure 2). When a bias voltage is applied the effective permittivity of the liquid crystal which loads the capacitive region of the resonator is increased and the resonant frequency is lowered.

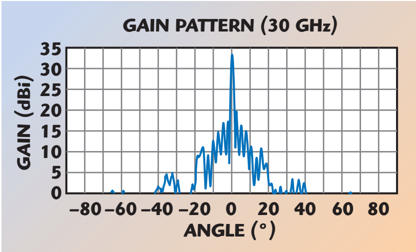
ELEMENT TUNING AND LIQUID CRYSTAL

The resonance frequency of the individual elements can be modulated by changing the effective capacitance in the resonator. The case of an in-plane capacitance in a resonator is shown in ***Figure 4***. This particular design is a complementary-ELC, or CELC, resonator.[1] In this case, the resonator is excited through an iris and has a well-defined resonant frequency determined by the inductance through the cell and the capacitance between the central region and the ground plane. In the center of the resonator, shown in Figure 3, there is an inductive region. Along the edges of the resonator there is a capacitive region between the resonator itself and the ground plane. Liquid crystal is added to this region as a tunable dielectric loading material. A bias line is threaded through the null region of the resonator so that a voltage difference between the CELC resonator and the ground plane may be applied.

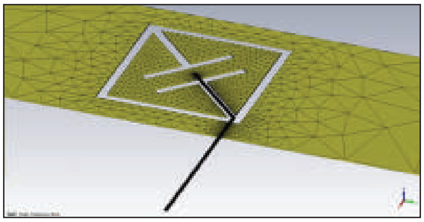
Liquid crystal can be introduced to the capacitive region by simple means as it is naturally exposed. The liquid crystal used is in this case is a nematic phase material in which the dielectric constant is anisotropic and best described as a tensor. Liquid crystal molecules are long and thin. The long axis of the LC molecules has a naturally higher polarizability than the two shorter axes. The effective dielectric constant along these axes are $\varepsilon_{\parallel}$ and $\varepsilon_{\perp}$ respectively.



▲ *Fig. 2 The simulated electric field magnitude above a resonant cell is shown in two states.*



▲ *Fig. 3 Beam performance for a small aperture prototype antenna operating at 30 GHz.*



▲ *Fig. 4 An example CELC resonator.*

The local orientation of the LC molecules, called the director, is a free-variable which can be manipulated by the application of an electric field. For the purposes of calculation, the orientation of the LC molecules can be found from FEM analysis based on well-known free-energy contributions in equation 3. Once the director axis is calculated the permittivity tensor can be found in the volume using the orientation of the director axis denoted by θ and φ in equation 4. The capacitance of the unit cell can then be found by calculating the stored energy in the gap region (equations 5 and 6).

$$F = \frac{1}{2}K_{11}(\nabla \cdot \hat{n})^2 + \frac{1}{2}K_{22}(\hat{n} \cdot \nabla \times \hat{n})^2 + \frac{1}{2}K_{33}|\hat{n} \times \nabla \times \hat{n}|^2 - \frac{\Delta\varepsilon}{8\pi}(\bar{E} \cdot \hat{n})^2 \quad (3)$$

$$\bar{\bar{\varepsilon}} = R(\theta,\varphi)\begin{pmatrix} \varepsilon_\perp & 0 & 0 \\ 0 & \varepsilon_\perp & 0 \\ 0 & 0 & \varepsilon_\parallel \end{pmatrix} R^T(\theta,\varphi) \quad (4)$$

$$U = \frac{1}{2}\int \bar{E} \cdot \bar{\bar{\varepsilon}}\bar{E}\, d^3r \quad (5)$$

$$U = \frac{1}{2}CV^2 \quad (6)$$

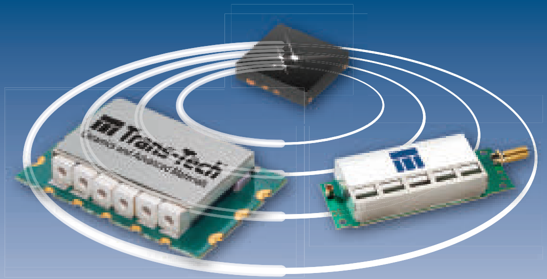
In the case of metamaterial unit cells based on the complimentary ELC resonator structure, the orientation of the liquid crystal itself can be modulated through the application of a bias voltage to the central island of a unit cell. This bias is entirely capacitive, resulting in no continuous current draw and minimal total power requirements. In practice, less than 2 W of power are required for even large antenna panels. In principal, it is possible the power draw could be limited to several milliwatts.

One of the particularly intriguing aspects of liquid crystal for space applications is that LC is naturally radiation hardened. Studies have shown no observable systematic effects from even very high levels of radiation from Cobalt 60 and neutron sources.[1] Regardless of architecture, this makes the use of LC attractive for these applications.

The use of liquid crystal in space applications is not without its challenges. One example is the thermal operating range. Decades of research into materials for the display industry have yielded materials which can operate over very large temperature variations. A typical material used in the display industry will have a temperature range in which it remains in the nematic phase from -25° to 160°C. If the desired operational temperature is colder than the nematic range, some heat will need to be provided to ensure that the LC remains in its nematic phase.

SYSTEM ANALYSIS

While it is beyond the scope of this article to provide a full satellite systems analysis, it is worthwhile to briefly emphasize the improved link performance over similarly equipped GEO spacecraft and LEO spacecraft utilizing semi-isotropic radiators. ***Table 1*** emphasizes



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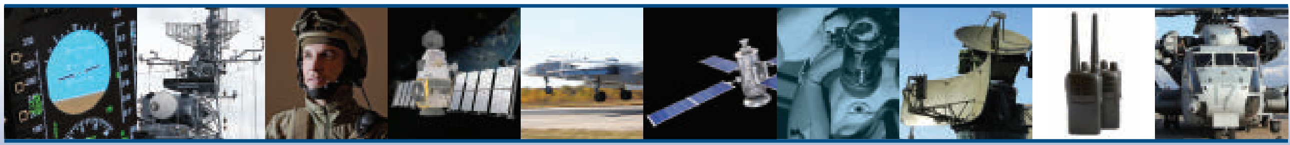

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the impact of bringing satellites from 35,000 km away into a LEO orbit. The decrease in distance provides a significant improvement in signal strength when compared to satellites in geosynchronous orbit. If the same assumptions are made for antenna size and power level, a satellite in LEO orbit can provide 1,000× the data rate. If scanning is not available, omni or near-omni directional antennas are needed to operate effectively from a LEO orbit. This is commonly done, for instance, at S-Band. In this case the link supports a similar data-rate to GEO.

A large, high-gain antenna on the earth station can alleviate some of the challenges at S-Band and improve the link performance (note: a quasi-omnidirectional S-Band earth station antenna was also assumed in the analysis). However, even with this infrastructure in place, there is a limited amount of bandwidth available at S-Band and it is broken into several bands. Even if the link performance were identical, the 1.5 GHz of bandwidth available for space-to-earth applications between 25.5 and 27 GHz gives the higher frequency solution a clear advantage.

For use cases such as data backhaul from Earth-observation satellites, the impact is clear. Real-time tracking over a large scan range allows for coverage without the latency of a second-pass; while multi-gigabit connectivity is possible because of the favorable link margin and large bandwidth available at Ka-Band.

The use case for a typical satellite communication architecture is more subtle. While the link margin is strong, the coverage area will be small due to the high gain aperture onboard the satellite and the distance of the orbit. At 1,000 km, for instance, a 2° beam will cover approximately a 30 km diameter region. This small coverage region potentially makes wide area coverage models cost-prohibitive to deploy using currently available launch methods. However, in circumstances in which high data-rates are needed in concentrated areas such a constellation could be enabling. As deployment costs to LEO orbit drop, additional capacity can be added or a multi spot-size architecture could be considered. As more capacity is added to the system, the deficiency of a small spot size becomes a significant advantage due to the frequency reuse it affords.

CONCLUSION

The smallsat industry has a bright future that is being driven by reduced cost of access to space, powerful sensors and increasing global demand for information and communication. However, connectivity to these platforms remains a significant challenge. The platform antenna technology described in this article shows promise for overcoming these challenges by providing flexible high-frequency connectivity with an appropriate size, weight and power footprint. ■

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A Compact Wideband Quadrature Hybrid Coupler

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Xidian University, Xi'an, China

A compact wideband quadrature hybrid coupler (QHC) with an arbitrary power division ratio is based on an artificial lumped-element simplified composite right-/left-handed transmission line (SCRLH TL) structure. The SCRLH TL can be easily tailored to satisfy the high or low impedance condition necessary to produce a QHC with a high power splitting ratio. An odd-even mode admittance resonant frequency ratio (n) is introduced to analytically formulate all the SCRLH TL elements, developing a relationship between the n value and the SCRLH TL phase and impedance bandwidths. This establishes a simple criteria to expand the QHC bandwidth. A prototype proof-of-principle 900 MHz QHC with a 10 dB power division ratio is only 4.5 × 4.5 mm² in size with greater than 32 percent bandwidth.

Quadrature hybrid couplers (QHC) are widely used in modern microwave integrated circuits and antenna feed systems, providing equal or unequal power division with 90° phase difference between the main and coupled ports. In this paper, a wideband QHC with a greatly reduced footprint and high power division ratio is introduced. It features a simplified composite right-/left-handed (SCRLH) transmission line (TL) structure, a version of the CRLH TL that omits either the series capacitance or the shunt inductance in the unit cell, exhibiting a right-handed passband with nonlinear dispersion properties and a smooth Bloch impedance distribution.[1] It has been employed in the design of dualband QHCs,[2,3] where each QHC branch contains two unit cells. Each branch of the QHC described in this article consists of only one unit cell composed of lumped elements, resulting in a significant size reduction.

Nonresonant and resonant type CRLH TL structures have been used to design QHCs with wide bandwidth and improved phase balance,[4,5] but their matching bandwidths improve little and can be even worse than those of their conventional counterparts. This is because the nonresonant type CRLH TL must satisfy the balanced state condition, i.e., seamless impedance transition from the left-handed passband to the right-handed passband; while for the resonant type CRLH TL, the impedance slope at the nominal frequency should be kept as small as possible. These are conditions not easily implemented in practice.

The SCRLH TL not only has controllable dispersion properties, but also has an intrinsic impedance distribution close to that of the balanced CRLH TL,[6] ensuring that the QHC's phase and impedance bandwidths are improved to the same degree. Chi[7] demonstrated a rat-race coupler with 6 dB power splitting ratio

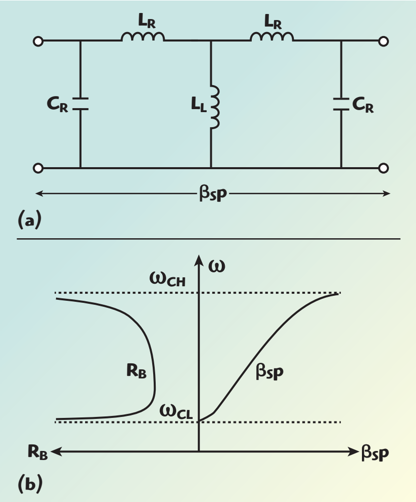

Fig. 1 Circuit model of SCRLH TL unit cell (a) phase shift per unit cell to the right of the vertical axis and the real part of the Bloch impedance to the left of the axis (b).

using an unbalanced CRLH TL; but it is only a narrowband device, and if a higher power division ratio is required, it may no longer be feasible. In fact, a high power division ratio demands extremely high and low branch impedances simultaneously. This is a stringent constraint for the unbalanced CRLH TL as well as for a conventional TL, but can be easily satisfied by the SCRLH TL with a wide-ranging Bloch impedance.

There is an additional degree of freedom in the SCRLH TL after realizing the required phase and impedance conditions. The odd-even mode admittance resonant frequency ratio n is a key parameter by which all the SCRLH TL unit cell parameters can be defined. By selecting a rational n, the branch phase balance bandwidth can be widened to its best value with obtainable discrete lumped elements, while the branch impedance bandwidth is naturally guaranteed due to the smoothly distributed Bloch impedance.

SCRLH TL ANALYSIS

The lumped circuit model of a single SCRLH TL unit cell is shown in ***Figure 1a***, where L_R is the series inductor, L_L the shunt inductor, C_R the shunt capacitor, β_S the propagation constant and p the physical length. By virtue of the Bloch-Floquet theory, the phase shift $\beta_S p$ and the Bloch impedance Z_B can be expressed as[8]

$$\beta_S p = \cos^{-1}(A) \tag{1}$$

$$Z_B = B / \sqrt{A^2 - 1} \tag{2}$$

where A and B are the first and second elements of the unit cell transfer function matrix.[6]

$$A = \begin{pmatrix} L_R + L_L - 2\omega^2 L_R L_L C_R - \\ \omega^2 L_R^2 C_R \end{pmatrix} / L_L \tag{3}$$

$$B = j\omega L_R (L_R + 2L_L) / L_L \tag{4}$$

Typical frequency dispersion and Bloch impedance are shown in ***Figure 1b***. The passband of the SCRLH TL is delimited by the zeroth-order resonant frequency ω_{cL} and the Bragg frequency ω_{cH}, over which the phase shift is nonlinear; while the Bloch impedance follows a continuous and smooth distribution with a large rise near both band edges. The odd-even mode method is used to determine the symmetrical SCRLH TL unit cell's parameters. Corresponding odd-even mode equivalent circuits are shown in ***Figure 2***, in which the odd-even mode input admittances are

$$y_o = j(\omega C_R - 1/\omega L_R) \tag{5}$$

$$y_e = j(\omega C_R - 1/\omega(L_R + 2L_L)) \tag{6}$$

respectively, and their resonant frequency ratio is defined by

$$n = \omega_o / \omega_e = \sqrt{1 + 2L_L / L_R} \tag{7}$$

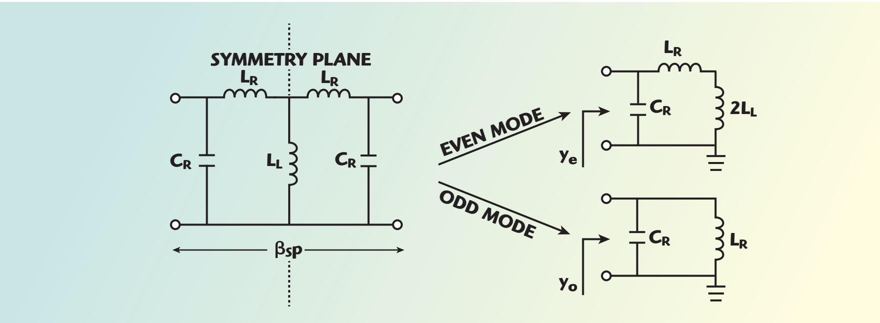

Fig. 2 Odd-even mode equivalent circuits for the SCRLH TL unit cell.

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If the SCRLH TL unit cell is to be equivalent to a 90° uniform TL with characteristic impedance Z, the following equations should be satisfied at the working frequency ω_0[9]

$$0 = (y_e + y_o)/2 \tag{8}$$

$$j/Z = (y_e - y_o)/2 \tag{9}$$

Substituting equations 5-7 into equations 8 and 9, we obtain

$$L_R = \frac{n^2-1}{2n^2}\frac{Z}{\omega_0} \tag{10}$$

$$L_L = \frac{(n^2-1)^2}{4n^2}\frac{Z}{\omega_0} \tag{11}$$

$$C_R = \frac{n^2+1}{n^2-1}\frac{1}{Z\omega_0} \tag{12}$$

All lumped elements in the SCRLH TL unit cell are uniquely determined by n, once ω_0 and Z are fixed. To study the effects of n on coupler bandwidth, equations 10-12 are substituted into equations 3 and 4, yielding

$$A = \frac{n^2+1}{n^2-1}\left(1-\frac{\omega^2}{\omega_0^2}\right) \tag{13}$$

$$B = j\frac{\omega}{\omega_0}Z \tag{14}$$

Equations 1 and 13 show that the dispersion frequency response of the SCRLH TL depends only on n; therefore, if an identical n value is chosen to design the QHC main-line and branch-line stubs, they will have fully consistent dispersive curves, which is beneficial in enlarging the coupler phase balance bandwidth.[4] With equations 1, 2, 13 and 14, the SCRLH TL phase shift and impedance slopes at ω_0 can be determined as

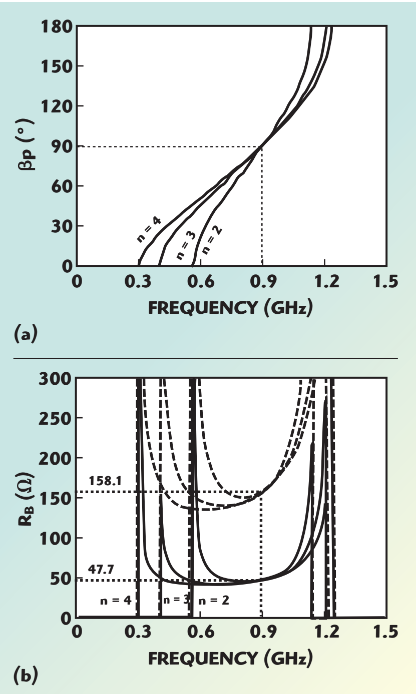
$$\left.\frac{\partial(\beta_s p)}{\partial\omega}\right|_{\omega=\omega_0} = \left(1+\frac{2}{n^2-1}\right)\frac{2}{\omega_0} \tag{15}$$

$$\left.\frac{\partial Z_B}{\partial\omega}\right|_{\omega=\omega_0} = \frac{Z}{\omega_0} \tag{16}$$

Equation 15 indicates that the dispersion curve slope at ω_0 will decrease as n goes up, and it has a minimum value of $2/\omega_0$. Equation 16 shows that the Bloch impedance slope at ω_0 is independent of n but is proportional to Z. In fact, a broadband QHC can only be realized by simultaneously extending the phase shift and impedance bandwidths for all its branches.[4] To increase the phase shift bandwidth, n should be as large as possible, however, since the dispersive curve slope has a minimal value and practically obtainable lumped elements are in discrete values, the same n should be applied to design both the main-line and branch-line stubs using equations 10 to 12 and 15. Additionally, the high impedance condition required to attain a high power division ratio will limit to a certain degree the QHC matching bandwidth according to equation 16.

LUMPED-ELEMENT SCRLH TL BASED QHC

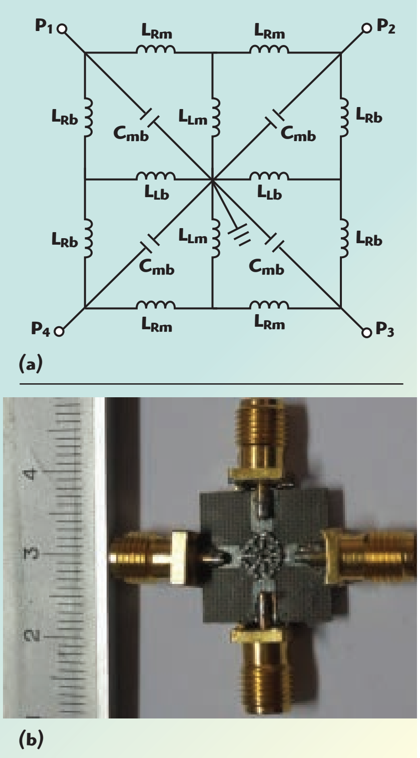
Let $\Delta = |S_{21}|^2 / |S_{31}|^2$ be the power division ratio of the designed QHC. If Δ = dB, the characteristic impedances of the main-line and branch-line stubs are Z_m = 47.7 Ω and Z_b = 158.1 Ω, respectively.[9] ***Table 1*** lists the SCRLH TL element values with different n when f_0 = 0.9 GHz, and the corresponding dispersion and impedance frequency responses are depicted in ***Figure 3***. According to equation 7, n can be any value larger than one, but herein only n = 2, 3, 4 are considered for illustration. ***Figure 3a*** shows that although $Z_m \neq Z_b$, the Z_m and Z_b branches, with identical n, exhibit the same dispersive curves. The phase slopes at f_0 flatten as n increases, hence generating wider phase shift bandwidth. ***Figure 3b***



▲ *Fig. 3 Frequency responses of dispersion (a) and Bloch impedance (b) for the SCRLH TL with different n (Z_m branch: solid line, Z_b branch: dash line).*

TABLE I
LUMPED ELEMENT VALUES OF SCRLH TLs

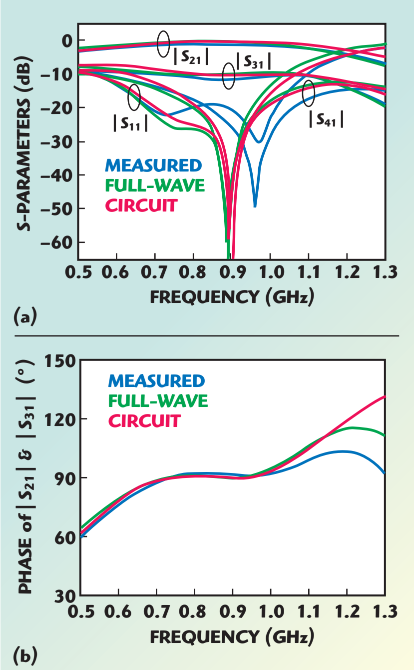
		n=2	n=3	n=4
L_R	Z_m	3.2	3.7	4.0
(nH)	Z_b	10.5	12.4	13.1
C_R	Z_m	6.2	4.6	4.2
(pF)	Z_b	1.9	1.4	1.3
L_L	Z_m	4.7	15.0	29.6
(nH)	Z_b	15.7	49.7	98.3



▲ *Fig. 4 Lumped SCRLH TL based QHC; Circuit topology (a), fabricated prototype (b).*

shows that for the same Z_m or Z_b, but with different n, the stub impedance slopes are equal, while the impedance slope of the Z_b branch is larger than that of the Z_m branch since $Z_b > Z_m$. Table 1 shows that $L_L = 98.3$ nH in the Z_b branch for n = 4, almost twice that for n = 3, while the dispersive curve slopes are very close. Therefore, n = 3 is finally chosen.

The circuit topology and the fabricated prototype of the QHC are shown in ***Figure 4***. The substrate has relative permittivity of 2.65, loss tangent of 0.002 and thickness of 1.0 mm. The strips connecting the ports are 2.575 mm in width, for a 50 Ω port impedance. All main-line and branch-line stubs share only one via, centered at the QHC, and the shunt capacitors



▲ *Fig. 5 Measured and simulated S-parameters for the lumped SCRLH QHC with 10 dB power division ratio; magnitude of S_{11}, S_{21}, S_{31} and S_{41} (a), phase difference between S_{21} and S_{31} (b).*

of adjacent stubs are included in C_{mb}. All lumped elements are in 0402 type packages, producing an overall area of 4.5 × 4.5 mm² (only about 0.6 percent the footprint of a conventional microstrip QHC with the same power split ratio). Due to microstrip discontinuities, the finalized chip values optimized using Ansoft HFSS (L_{Rm} = 3.6 nH, L_{Lm} = 15.0 nH, L_{Rb} = 15.0 nH, L_{Lb} = 47.0 nH, C_{mb} = 5.0 pF) are slightly different from the theoretical values listed in Table 1.

Measured and simulated S-parameters (see ***Figure 5***) are in good agreement. Bandwidth closely corresponds, while an upward frequency shift of 58 MHz in the measured result is attributed to element tolerances. The measurement shows that $|S_{11}|$ = -20.7 dB, $|S_{21}|$ = -1.14 dB, $|S_{31}|$ = -11.34 dB, $|S_{41}|$ = -25.8 dB at f_0 = 0.9 GHz, demonstrating Δ = 10.20 dB as well as good matching and isolation; with the relative phase difference $\angle S_{21} - \angle S_{31} - 90°$ = 1.8°. Bandwidths defined by $|S_{11}| < -15$ dB, $|S_{41}| < -15$ dB, $|S_{21}| / |S_{31}| - \Delta = \pm 1.0$ dB and $\angle S_{21} - \angle S_{31} - 90° = \pm 5°$ are 46.7 percent, 47.4 percent, 34.3 percent and 41.7 percent, respectively, with the overlapping band ranging from 0.74 to 1.03 GHz, for a total relative bandwidth of 32.2 percent. Compared to a conventional

microstrip QHC,[8] this QHC features a broader bandwidth, significantly reduced footprint and a relatively high power splitting ratio; although, an additional 1 dB insertion loss is introduced along both the transmission and coupling paths due to inherent losses of the chip elements.

CONCLUSION

A wideband QHC with a small footprint and an arbitrary power splitting ratio is demonstrated using a purely lumped SCRLH TL, by virtue of its nonlinear dispersion characteristics and smoothly distributed Bloch impedance. Its bandwidth is optimized with obtainable lumped chip elements. A prototype QHC with 10 dB power split ratio occupies only 0.6 percent the footprint of a conventional microstrip QHC, while achieving an overall bandwidth in excess of 32 percent. ■

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Tri-Band Bandpass Filter Using Quad-Mode Stub-Loaded Resonator

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A miniaturized tri-band bandpass filter (BPF) design uses a quad-mode stub-loaded resonator (SLR). Its characteristics are investigated by using even- and odd-mode analysis. Without occupying additional area, tapped side-coupled open-loop resonators are used to induce the third passband. The three passbands are designed at 1.57, 3.5 and 5.2 GHz for GPS, WiMAX and WLAN applications. The center frequencies of the three passbands are independently controlled and their bandwidths tuned by the filter dimensions. In addition, four transmission zeros improve selectivity.

The multi-band planar bandpass filter is a key component in a modern wireless communication system because of its compact size, high selectivity and low integration cost. As a result, the multi-band bandpass filter is extensively investigated and various design approaches have been reported.[1-10]

Tri-band filters are commonly achieved with cascaded stepped-impedance resonators (SIR),[1,2] but are relatively large. Composite configurations consisting of three split-ring resonators have also been used.[3] To reduce size, a combination of one set of half-wavelength resonators and one set of SLRs has been proposed.[4] One set of tri-section SIRs has also been utilized;[5,6] however, the dependence of the resonant frequencies of the SIRs complicates the filter design. Recently, tri-band BPFs have been constructed using a SLR with a defected ground structure (DGS) resonator[7] and a square ring loaded resonator.[8,9]

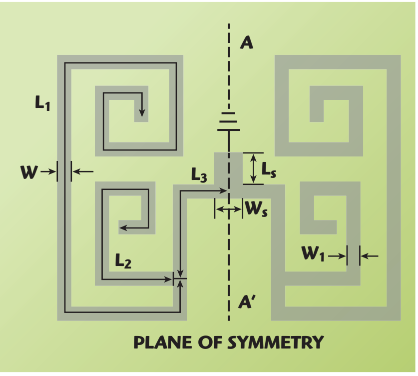

Fig. 1 Quad-mode SLR configuration.

In this article, a compact tri-band BPF using a quad-mode SLR and a pair of side-coupled resonators is described. The former generates the first and second passbands and the latter generates the third passband without increasing circuit size. The three passbands are conveniently tuned by properly controlling the dimensions of the filter. Four transmission zeros improve selectivity and stopband suppression.

ANALYSIS

As shown in ***Figure 1***, the quad-mode SLR consists of one pair of spiral open-circuited stubs, with length (L_2) and width (W) connected by a uniform impedance resonator (UIR) with length ($2L_1 + 2L_3$) and width (W). One short-circuited stub (L_S, W_S) located along the symmetrical plane is added to provide dual-mode characteristics. Since it is symmetrical to the A-A' plane, even- and odd-mode theory is adopted to analyze the resonator structure. The corresponding odd-mode and even-mode equivalent circuits are shown in ***Figures 2a*** and ***b***, respectively. In Figure 2a, the odd-mode equivalent circuit contains two resonant circuits and the resonant frequencies are determined by:

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$$f_{odd1} \approx \frac{c}{4(L_1 + L_3)\sqrt{\varepsilon_e}} \quad (1)$$

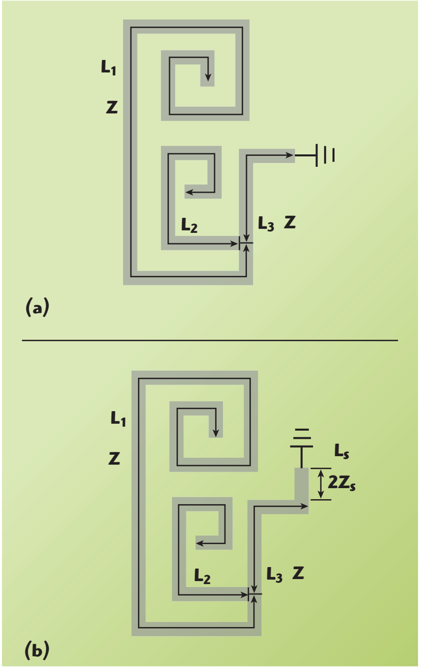
$$f_{odd2} \approx \frac{c}{4(L_2 + L_3)\sqrt{\varepsilon_e}} \quad (2)$$

where c is speed of the light in free space and ε_e denotes the effective dielectric constant of the substrate. For the even-mode excitation, the required resonant frequencies are determined by:

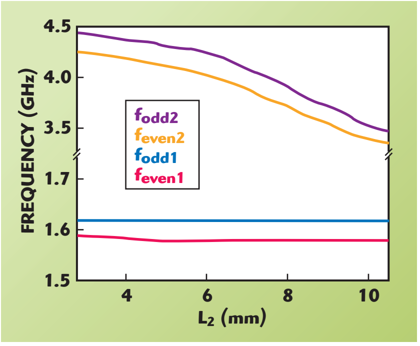
$$f_{even1} \approx \frac{c}{4(L_1 + L_3 + L_S)\sqrt{\varepsilon_e}} \quad (3)$$

$$f_{even2} \approx \frac{c}{4(L_2 + L_3 + L_S)\sqrt{\varepsilon_e}} \quad (4)$$

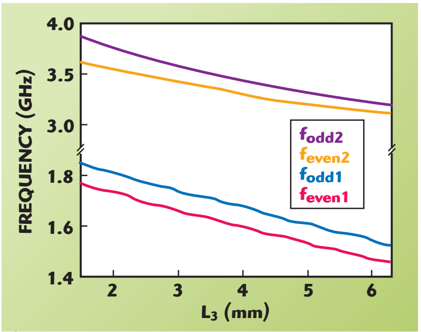
Equations 3 and 4 are based on the special case where $2Z_S = Z$. From equations 1-4, it is apparent that adjusting the spiral open-circuited stub length, L_2, has no influence on the resonant frequencies f_{even1} and f_{odd1}, whereas it leads to a variation of the resonant frequencies f_{even2} and f_{odd2}. As shown in ***Figure 3***, the high resonant frequencies f_{even2} and f_{odd2} move towards the lower frequency, whereas the resonant frequencies f_{even1} and f_{odd1} remain relatively stationary, as the open-circuited stub length (L_2) increases. ***Figure 4*** shows that the quad-mode resonant fre-



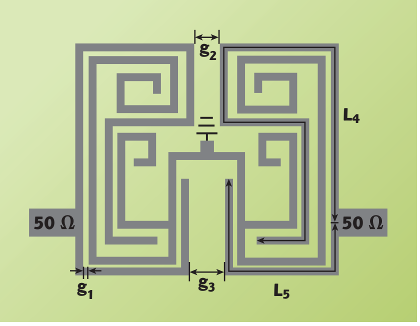
▲ *Fig. 2 Equivalent circuit; odd-mode (a), even-mode (b).*



▲ *Fig. 3 Even-/odd-mode frequencies with varied L_2.*



▲ *Fig. 4 Even-/odd-mode mode frequencies with varied L_3.*



▲ *Fig. 5 Tri-band BPF configuration.*

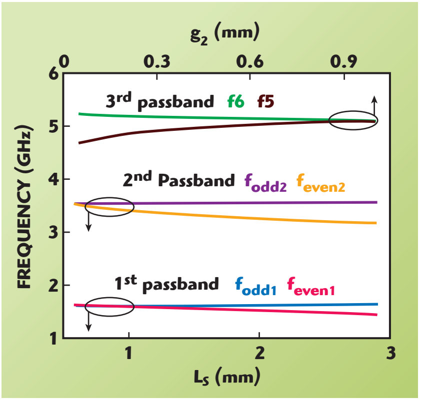
quencies decrease with larger L_3. Also, from the equations, the short-circuited stub length, L_S, changes only the even-mode frequencies.

RESULTS

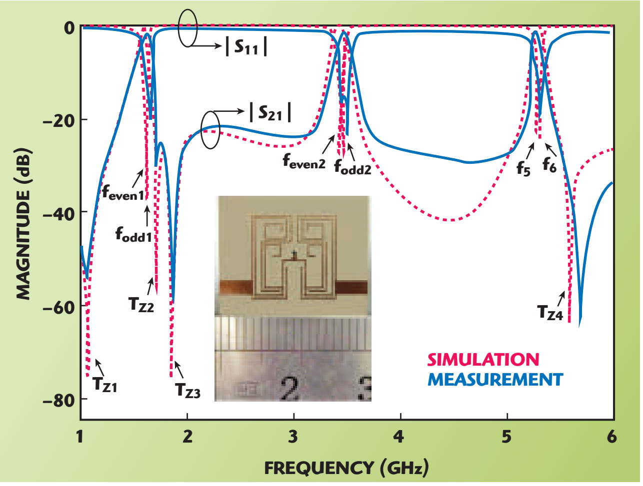
A compact tri-band BPF is shown in ***Figure 5***. It consists of the quad-mode SLR and a pair of side-coupled resonators with length (L_4+L_5) and width (W). As previously mentioned, the former is used to generate the first and second passbands and the latter generates the third passband for the tri-band BPF design. Based on the above analysis, it can be seen that the first passband (formed by f_{even1} and f_{odd1}) is determined by L_1+L_3, and its bandwidth is tuned by L_S. Similarly, the second passband (formed by f_{even2} and f_{odd2}) is controlled by tuning L_2+L_3, and its bandwidth is also changed by L_S. The distance between the center frequencies of two passbands is controlled by the difference between L_1 and L_2. As shown in ***Figure 6***, as L_S increases, the even mode frequencies (f_{even1} and f_{even2}) shift lower in frequency, while the odd mode frequencies (f_{odd1} and f_{odd2}) are fixed. Thus, the bandwidths of the first and second passbands can be tuned by the length of L_S. The bandwidth of the third passband can be tuned by the gap (g_2), as shown in Figure 6. Also, the pair of side-coupled resonators encircles the SLR and serves as a part of the feed-line structure for compactness.

The demonstration tri-band BPF is fabricated on a substrate with a relative dielectric constant of 3.5 and a thickness of 0.76 mm. The parameters are L_1=24.6 mm, L_2=10 mm, L_3=4.2 mm, L_4=26.3 mm, L_5=9 mm, L_S=1.15 mm, W=0.2 mm, W_S=0.6 mm, g_1=0.2 mm, g_2=0.58 mm, g_3=1.7 mm.

Figure 7 shows good agreement between simulated and measured results. Fractional bandwidths are about 6.3 percent at 1.57 GHz, 3.7 percent at 3.5 GHz, and 4.3 percent at 5.2 GHz, respectively. Measured minimum insertion losses within the three passbands are 1.4, 1.25 and 1.28 dB, respectively. Four transmission zeros located at 1.04, 1.69, 1.84 and 5.65 GHz improve filter selectivity. Also shown in Figure 7 is a photograph of the fabricated BPF.



▲ *Fig. 6 Even-/odd-mode mode frequencies with varied L_S (colored lines) and resonant frequencies with varied g_2 (black lines).*



▲ *Fig. 7 Simulated and measured frequency responses; photograph of fabricated filter (inset).*

Its overall size is about $0.092\lambda_g$ by $0.091\lambda_g$, where λ_g is the guided wavelength at the center frequency of the first passband.

CONCLUSION

A miniaturized tri-band BPF for GPS, WiMAX and WLAN applications using a quad-mode SLR is introduced and analyzed. Center frequencies and bandwidths of the three passbands are adjusted by controlling the filter dimensions. This compact tri-band filter with simple topology is particularly suitable for multi-band and multi-service applications in wireless communication systems. ■

ACKNOWLEDGMENTS

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MIPI's RFFE: A Standard for Unifying Mobile Device Communications Designs

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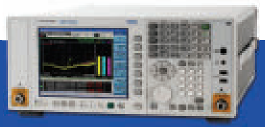
Vic Wilkerson and Peter Lefkin
MIPI® Alliance

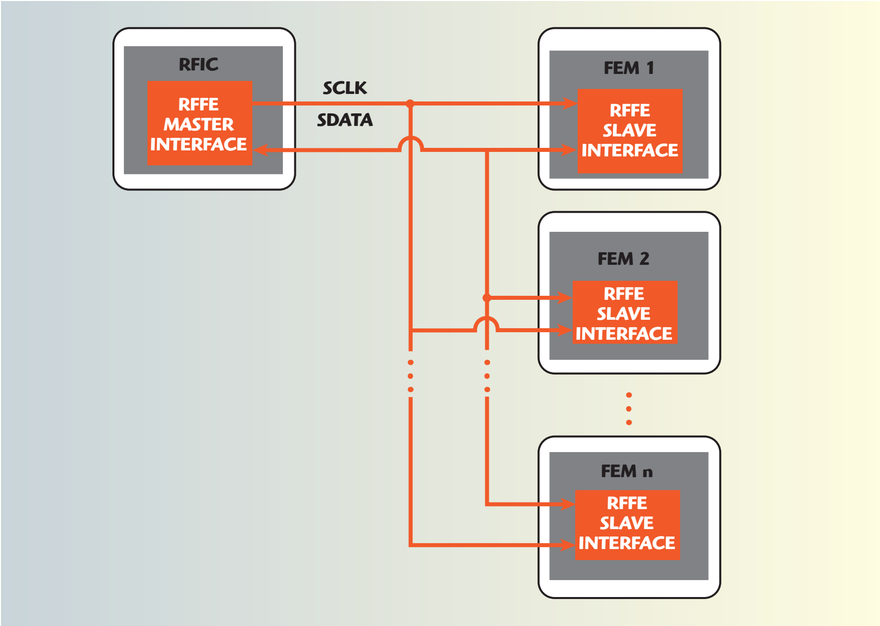
Long-term evolution (LTE) advanced carrier aggregation trends are changing the design game for smartphones. The insatiable consumer demand for more capable smartphones and the rush to get them to market quicker is creating a nightmare of design headaches for mobile phone manufacturers. They must accommodate skyrocketing consumer market demands for the latest generation phones, while handling rapidly expanding and changing wireless communications protocols, fewer dropped calls, wider bandwidths, and better voice and data quality levels.

Recognizing this, the MIPI® Alliance (MIPI) was formed over a decade ago to benefit the mobile smartphone industry by establishing standard hardware and software interfaces and encourage their adoption throughout the mobile telecommunications ecosystem. It seeks to reduce fragmentation caused by too many proprietary industry interfaces that are incompatible, yet are not typically differentiated from each other.

There's no question that consumer demand for smartphones is insatiable. Many market estimates are that smartphone users change their devices an average of once every two years to acquire more advanced units with greater capabilities. According to a recent study by ABI Research, some 800 million Android smartphones and 300 million Apple iPhones were in active use at the end of last year, while IDC Research forecasts that total smartphone sales will reach 1.7 billion units by 2017, up from 2013's 1 billion units.

The evolution of wireless communications from 2G, 2.5G, 3G, and 3.5G to 4G technologies is putting a strain on the smartphone's RF design, particularly the RF front end (RFFE). The continuing emphasis on smaller form factors with higher efficiencies, lower power consumption, faster data rates and higher bandwidths is giving rise to more complex RF designs. Actual voice conversations supported by smartphones are but a small fraction of their vast capabilities. These include the integration





▲ *Fig. 1 Simplified RF front end interface model of the MIPI RFFE standard. Source: National Instruments.*

of high-quality video cameras, music and video playback, texting, gaming and a multitude of different touch-screen applications.

Incompatibility leads to redundant engineering investment and higher design costs (but not higher margins/value). The MIPI goal is to reduce fragmentation with a simplified RF front end model (see ***Figure 1***). This provides attractive convergence targets that have technical and intellectual property (IP) rights benefits over proprietary alternatives. The first version (version 1.0) of the MIPI RFFE standard was adopted back in 2010. While not providing a one-size-fits-all solution, it has attracted wide industry interest because it broadly accommodates the many existing standard bus interfaces, such as the serial-peripheral interface (SPI) and the I^2C bus standards. The former cannot handle much more than 10 MHz data rates and lacks protocol-level standardization, while the latter is limited to about 1 MHz which is unsuitable for meeting RFFE standard requirements.

A NEED FOR UNIFICATION

The RFFE standard addresses the need for unifying multi-band and multi-radio support. It aims to unify the RF front end by providing a bus interface between a mobile device's transceiver, having a myriad of front end functions, to an internal device. This challenges both wireless communications carriers and mobile terminal makers. Carriers demand support for their increasing number of selected frequency and roaming bands, while mobile terminal makers prefer a minimum number of different designs to maximize their sales and profit margins.[1] It is exacerbated by the fact that radio access technologies (RAT) are not supported globally in a standardized manner. Historically, frequency spectrum allocations have been specific to each country and are typically controlled by local governments. Waiting in the wings and ready for deployment is the advanced LTE (LTE-Advanced) standard put forth by the Third Generation Partnership Project (3GPP). It offers a significant upgrade to the LTE standard, and features up to 40 frequency bands,[2,3] while analysts are predicting up to 50 frequency bands within the next couple of years. This will make mobile device front end design even more complex. "We used to have four RAT bands with 4G LTE. Now we have 40 and it is rapidly exploding," says Rick Wietfeldt of Qualcomm. Wietfeldt is chairman of the Technical Steering Group of the MIPI Alliance.

Seeing that front ends were becoming more complex in handling multi-band and multi-mode radio transmissions with no standard control mechanism in existence, the International Wireless Industry Consortium (IWPC) challenged MIPI to develop a standard. The MIPI RFFE standard has

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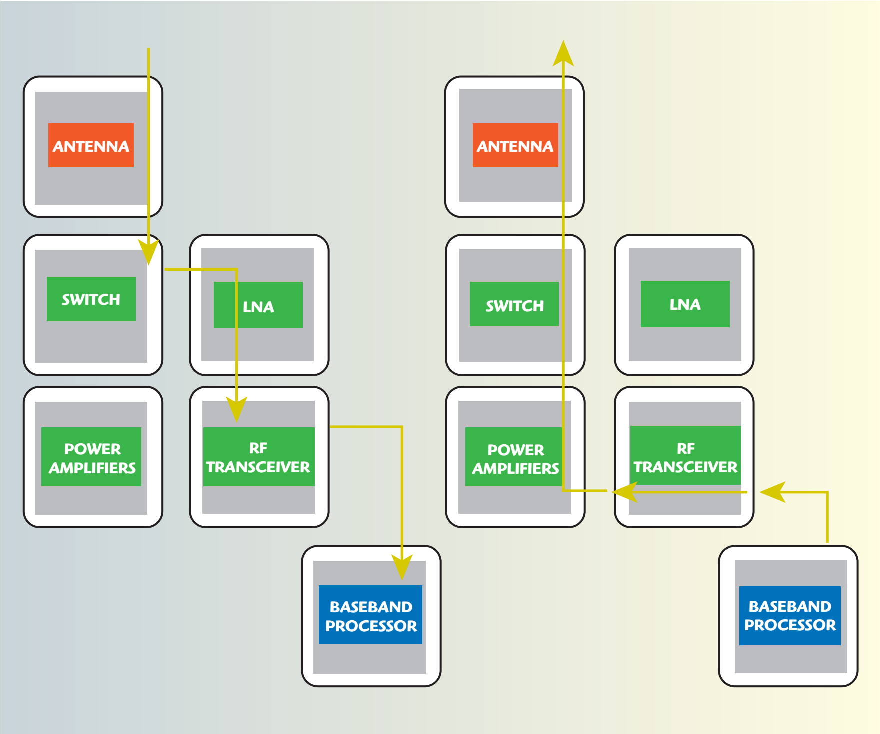

▲ *Fig. 2 The MIPI RFFE interface. Source: The MIPI Alliance.*

been widely adopted by the industry and has become the pre-eminent standard for RF front end control.

A ROBUST RFFE BUS

The RFFE interface control bus can be used for (but is not limited to) controlling RF front end devices like antennas, power amplifiers, switches and filters. It is a two-wire system defining one line for system clock and another for the bidirectional system data. It uses a third common line for voltage referencing and interface power. RFFE is a single-master system that avoids timing uncertainties inherent with bus arbitration (see ***Figure 2***). The 26 MHz bus operates from either 1.8 or 1.2 V and can be implemented in standard CMOS. The signaling levels employ hysteresis for even greater noise immunity and is slew-rate controlled for improved electromagnetic interference (EMI) mitigation.

An objective of the RFFE standard is to keep silicon implementation as simple as possible and as small as practical; hence, the MIPI standard specifies just a three-pin device that is multi-drop capable and scalable using one master and 15 slaves per master. Each master circuit may be designed using about 5,000 gates and slaves may take as few as 500 gates. Other specifications include a low latency of less than 1 μs, broadcast message capability to multiple slaves and user-defined IDs for write commands. The RFFE standard is based on the system power management interface (SPMI) specification but is simplified for front end devices by removing the multi-master capability and certain other SPMI features.[4]

A number of integrated all-silicon approaches have been demonstrated, as well as individual-function IC solutions. The challenge is to provide enough flexibility for the smartphone manufacturer to distinguish itself in the market from other mobile phone competitors' products. The research analyst Heavy Reading predicts that LTE RF issues will create large opportunities for IC RF front end chip makers to address the needs of active antennas, tuning circuits and other RF components for future LTE devices. It cites Qualcomm's RF360 front end IC solution that supports up to 40 bands as an example of what's to come.

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panies have demonstrated discrete implementations of completely integrated RF front end system-in-package (SiP) using CMOS, gallium-arsenide (GaAs), silicon-germanium (SiGe), silicon-on-insulator (SOI), and BiCMOS processes.

Major IC vendors offer various RFFE interface chips for power, RF communications, control and transceiver functions in standard, custom, FPGA, IP and other package forms. These devices include: front end tuning circuits, buck-boost DC-DC converters for 3G and 4G LTE RF power amplifiers, general-purpose output expanders with an RFFE host interface, power amplifiers, antenna switches, and front end configurable matching networks. Other companies have introduced RFFE compatible custom IP cores using field-programmable gate arrays (FPGA). RFFE hardware and software development tools are also on the market. At the academic level, several universities worldwide have shown that RFFE compliant ICs are possible for any number of interface functions. These include camera, cognitive radio, display, power amplifier and ultra-wideband, front end interfaces.

CONCLUSION

The MIPI RFFE bus standard addresses the need for a simplified front end network interface design, driven by the soaring complexity of mobile communications LTE smartphone technologies. MIPI is also working on developing other interface standards with working groups such as the BIF battery interface, the CSI camera interface, the DigRF interface, the Debug standard for tracing and debugging, the DSI display signal interface, the LLI low-latency interface, the PHY physical layer interface, the SLIMbus serial low power interchip Media bus, the SPMI system power management interface, and the Uni-Pro Unified Protocol standard.

Membership in MIPI has rapidly grown to more than 260 member companies. It is not surprising that major semiconductor IC manufacturers form MIPI's board of directors. The membership includes a large number of IC chip makers, hardware and software product manufacturers, telecommunications computer companies, test equipment houses, and academic institutions. The objective of MIPI is to enlist the membership of companies, organizations and academic institutions; all with an interest in simplifying mobile communications device designs. However, solutions must be robust enough to allow those interested members the freedom of choice in their design approaches, as dictated by market and consumer demands.[6-10] ■

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Mergers and Collaborations Dominate Landscape at IMS 2014

Pat Hindle
Microwave Journal *Technical Editor*

The "Powering the Waves" theme was cleverly executed at IEEE MTT-S International Microwave Symposium with an opening reception that featured a water skiing show starring IMS general chair Larry Dunleavy. The IMS 2014 team did an excellent job of running the event and the Tampa Convention Center was laid out well with the session rooms and exhibition in close proximity. IMS 2014 reported total attendance of about 7,500 in Tampa (including WAMICON which is typically held separately). These numbers are consistent with the last two years when the event was held in Seattle and Montreal. The total number of exhibiting companies reported was 587, with 74 of them first time exhibitors.

The Microwave Week Monday evening reception was preceded by the plenary session featuring Vida Ilderem, vice president and Intel Labs director, Integrated Computing Research, Intel Corp. Her lecture, "How Data, Devices and Personalization are Fueling Demand for Innovation" was a highlight of the night. She discussed how the Internet of Things (IoT) connects everything from appliances to cars and medical devices, stressing that industry and academia need to innovate faster to keep up with increasing expectations of users. With her company leading the effort, Ilderem also covered the required technology innovations for a digitized world where everything can be made intelligent and connected.

On Thursday afternoon the IMS closing ceremony featured "This Stuff is Fun!", a fun and interactive talk by Quenton Bonds, research electronics engineer, NASA GSFC, and "No Excuses!" an inspiring personal journey by Kyle Maynard, athlete and N.Y. Times best-selling author. Bonds shared some of the challenges he faced as a youth and what motivated him to overcome these challenges while having fun along the way. Maynard's keynote explained why there are no worthy excuses in life. Maynard was born with a condition known as congenital amputation that has left him with arms that end at the elbows and legs that end near his knees. He showed how everyone has the capacity to achieve their goals and why they should never give up.

Reviewing the IMS 2014 technical sessions, workshops and panels, much attention was paid to mmwave technologies, 5G, IoT, tunable filters/antennas, high efficiency amplifiers (envelope tracking, DPD, switched mode PAs, etc.) and biomedical devices/sensors. Envelope tracking has become so popular, nearly all the major test and measurement companies featured demonstrations on how to characterize and measure this technique.

The biggest news of the event was the significant company mergers and collaborations. The mergers of RFMD/TriQuint and Cobham/Aeroflex were announced just prior to IMS and Analog Devices (ADI) acquired Hittite, shortly afterward. These consolidations are making big waves in the industry. Collaborations included AWR/ANSYS with their interoperable design software; Agilent and Cascade's plans to deliver probing test systems and Copper Mountain systems integration into several test systems such as Maury and Focus loadpull test sets. National Instruments' RF presence is now a combination of companies such as AWR, Phase Matrix and NMDG, as well as their original test/measurement products and LABVIEW software.

The MicroApps sessions offered many company executives the opportunity to discuss their new technologies and capabilities right on the exhibition floor. *Microwave Journal* coordinated a featured panel session for the MicroApps on the Challenges of 5G Technologies that included experts from both the test/measurement and semiconductor industries. Close to 110 people attended our session to learn more about this

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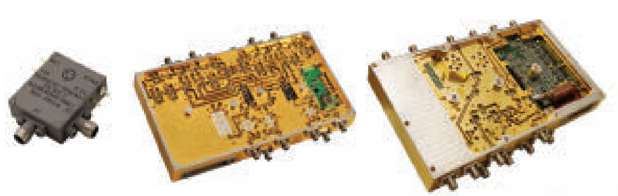

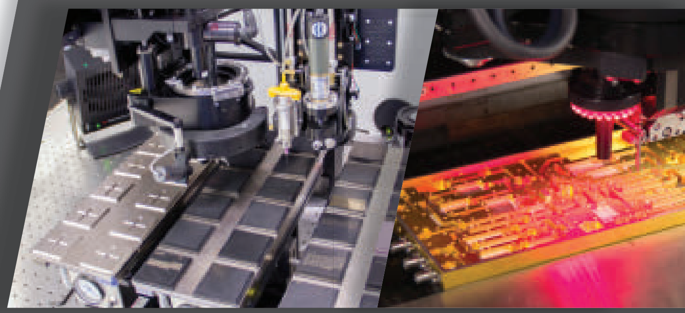

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trending hot topic. EDI CON 2015 will dedicate an entire day of sessions on this topic in Beijing next April.

The IMS 2014 exhibition is approaching 600 participating companies, making it quite large and diverse. All types of RF/microwave companies ranging from material and device manufacturers to component and subsystem providers were represented. *Microwave Journal* highlighted close to 100 different products and services featured on the exhibition floor. A complete show review including videos and photos can be found at www.microwavejournal.com/IMS2014Exhibition.

The IEEE MTT-S Microwave Week was comprised of several conferences that were co-located at the Tampa Convention Center and other local venues. In addition to the IMS Conference, Microwave Week also hosted the IEEE RFIC and ARFTG conferences, and this year also hosted the WAMICON conference, an event that is typically held separately.

RFIC SYMPOSIUM

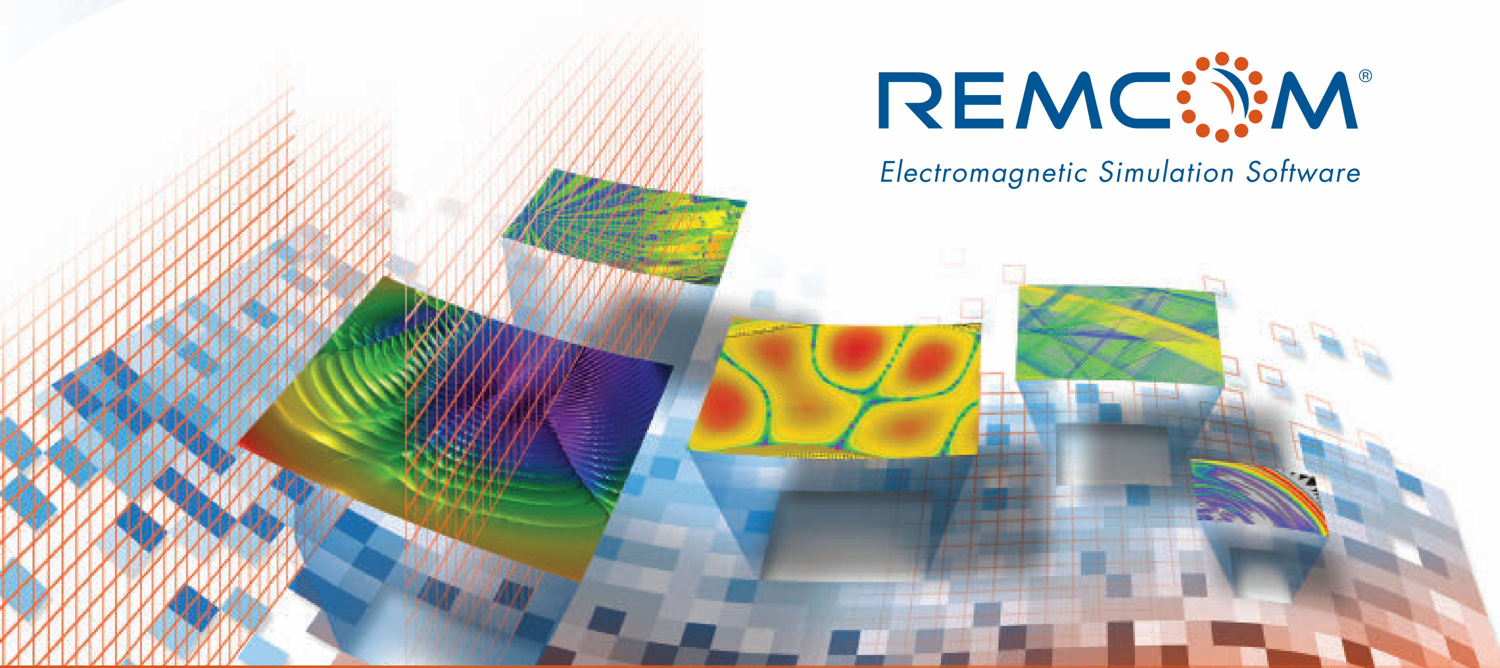
The RFIC Symposium technical program showcased the latest innovations in RF integrated circuit design with sessions that covered a broad spectrum of topics. The conference included papers on RFIC design, system engineering, system simulation, design methodology, RF integrated circuits, fabrication, testing and packaging to support a wide range of RF applications.

RFIC added a number of new initiatives this year. Only the most innovative and highly-rated industrial papers were invited to present a poster (and optional demo) at a special Industry Showcase Session that was held concurrently with the evening RFIC reception on Sunday, June 1. Another new initiative for 2014 was aimed at increasing academic submissions through programs supporting students. The lead authors of the top three student papers received $500 honorariums along with special recognition at the RFIC Plenary Session award ceremony.

The RFIC workshops covered a wide array of topics. PA design workshops in particular, included: silicon and GaN PAs for RF and mm-wave applications, highly-efficient power amplifiers and smart transmitters, power amplifiers for software defined radios, and critical supporting circuit designs such as GaN-based power supply modulators.

In the frequency synthesis area, the "Frequency Synthesis for 60 GHz and Beyond: Architectures and Building Blocks" workshop focused on design techniques for low phase noise frequency synthesizers at mm-wave frequencies. Workshops on some of the emerging technologies in RF transceivers include techniques for handling interference and self-interference, RF and wideband data-converters for transmitters and receivers, and EMC/EMI-aware design practices for reducing coupling and interference in integrated circuits.

The RFIC Plenary Session held Sunday, June 1 began with some overall conference highlights, followed by the student paper awards. The first plenary speaker was Pieter Hooijman, vice president, R&D and strategy at NXP Semiconductors, with a paper entitled "How to Differentiate with RF Silicon Technologies in High Volume Applications?" The second speaker was Professor Lawrence Larson, dean of the School of Engineering at Brown University, who talked about "The Next Era of Wireless Communications – Enabling Revolutions in Health Care, Transportation,



Energy and the Environment."

Immediately following the Plenary Session, the new Industry Showcase Session and the RFIC reception were held in separate ballrooms. The inaugural RFIC Plenary Round Table Discussion was held next with leaders from the RFIC community engaging in a lively discussion on "Beyond 4G Wireless Communications: An RFIC Perspective." During lunchtime on Monday, June 2 and Tuesday, June 3 the conference featured panel sessions on "Fabless Design: Got Any Problem with That?" and "Is Spectrum Explosion Muffled without Tunable RF?," respectively.

83RD ARFTG MICROWAVE MEASUREMENTS CONFERENCE

Jon Martens, Conference Co-Chair

Capping off an exciting IMS 2014, the 83rd ARFTG Microwave Measurements Conference was held Friday, June 6 at the Tampa Marriott Waterside Hotel and Marina. This year the conference was co-located with WAMICON 2014 to allow attendees to sample papers on a wide variety of topics and visit a greater assortment of vendor exhibits.

The theme of the ARFTG conference this year was "Microwave Measurements for Emerging Technologies'. Two invited papers helped motivate related discussions: "Instrumentation in Mixed-Signal and Mixed-Domain Emerging Technologies," Nuno Borges Carvalho (University of Aveiro, Portugal) and "Microwave Measurements for Biological Materials Analysis," Katia Grenier (LAAS-CNRS, France). Fourteen additional oral presentations on a variety of topics included AM/PM estimation, improved calibration approaches for loadpull, mm-wave S-parameter verification, calibrations for extreme impedances, active harmonic load-pull and source-pull measurements at X-Band, power amplifier output harmonic modeling and IQ mixer measurements. The interactive forum session consisted of 18 papers on a wide variety of measurement topics with ample time for discussions between authors and attendees. The conference attendees voted on the best oral and interactive forum papers with the winners to be announced at the next ARFTG Microwave Measurement Symposium to be held in Boulder, Colo., December 2-5, 2014.

Eighteen exhibitors presented their latest equipment, tools and components with considerable time for discussions with both ARFTG and WAMICON attendees throughout the day. Two ARFTG co-sponsored workshops entitled "Efficient RF Design using Practical Behavioral Models – Bridging the Gap between Measurement and Simulation" and "Challenges and Advances in Wafer-Level Calibration and Characterization at Millimeter and Sub-Millimeter-wave Frequencies," were held earlier in the week. Co-sponsored IMS sessions re-

lating to measurements and a nonlinear vector network analyzer (NVNA) users' forum meeting were held on Thursday. In total, more than 100 attendees had the opportunity to absorb information on a plethora of measurement topics.

WAMICON JOINS IMS 2014

Ray Pengelly, General Chair and Jing Wang, General Co-Chair

The 2014 IEEE Wireless and Microwave Technology Conference (WAMICON) was held in conjunction with IMS 2014, in a joint conference with the Automated RF Techniques Group (ARFTG). This special arrangement was chosen because WAMICON is a Florida-based regional conference, and most of its regular steering committee members were busy working on IMS.

The WAMICON portion of the week's activities began Thursday afternoon during a session honoring the career and contributions of Dr. Rudy Henning, a long time professor at the University of South Florida. His aca-

demic career followed his professional career at Sperry, where he was chief engineer of the Sperry Microwave Electronics Division. At the conclusion of the session, the WAMICON-sponsored Rudolf E. Henning Award for Distinguished Mentoring was presented to Professor John Cressler of Georgia Tech. In his acceptance comments, Cressler described his personal views on mentorship and the methods he employs to support his graduate students as they progress through their studies and into their careers. Further comments were offered in a panel session, where Cressler was joined by the two most recent Henning Award recipients, John Volakis and Linda Katehi.

Later Thursday evening, a joint reception was held, celebrating the end of IMS and the beginning of the WAMICON and ARFTG conferences. During the reception, a group of graduate students participated in a special poster session, presenting updates on their research in various areas of microwave technology.

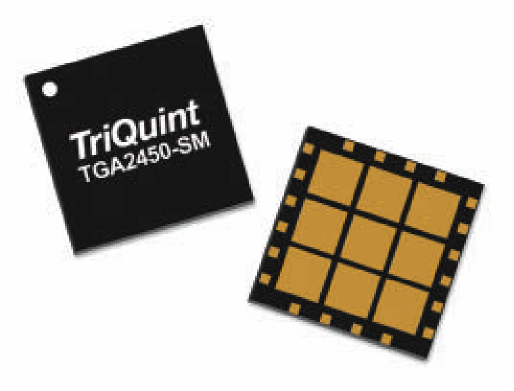
The plenary session on Friday morning, hosted by WAMICON General Chair Ray Pengelly, was a highlight of the event. The keynote speaker was Linda Katehi, Chancellor of the University of California, Davis. Her thought-provoking talk, “The Challenge to Diversify,” explained why gender equality in engineering made good business sense. The issue of gender bias has been discussed for decades, but the engineering profession remains more than 85 percent male. Katehi encouraged more women to seek careers in science and technology. Her common sense reason to hire female engineers – companies would create better products if more women were on the design teams.

The second plenary speaker, Upkar Dhaliwal of Future Wireless Technologies, offered many facts, figures and perspectives on the size and complexity of the wireless marketplace. Among the most important points made in his talk, “Future Wireless Communication Technologies 2020-30,” was the need to support rapid growth in wireless network traffic with higher density coverage through smaller cell size and flexible reconfigurability that responds to changes in demand. The “Internet of Things” continues to develop, with automated appliances, medical devices and environmental controls adding to the flow of data. As they reach large-scale implementation, support for these devices will require all types of communication technologies – short range wireless, ad hoc networks, commercial wireless, power line communications and cable or fiber wired networks.

The WAMICON program included eight sessions with oral presentations covering such topics as high efficiency power amplifiers, nano-electronics, medical and biological wireless systems, fabrication technologies, component design and antennas. Several invited papers offered unique insight into advanced research efforts in key areas of wireless and microwave technology. A large interactive poster session was held in the exhibits room and the adjacent foyer.

WAMICON had 140 participants, which is considered very good for a one-day conference that is part of a larger event. Thirty oral papers were scheduled, along with a sizable group of 51 poster papers. The poster session was expanded this year to accommodate quality papers that could not be included in the smaller number of oral paper sessions.

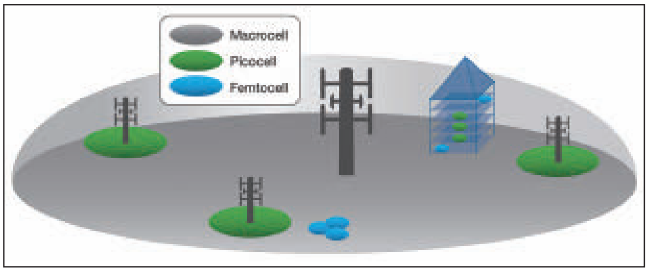
In 2015, WAMICON will once again be a stand-alone event, April 12-15 at the Hilton Oceanfront Hotel in Cocoa Beach, Fla. IMS 2015 will be held May 17-22 in Phoenix, Ariz. As the centerpiece of Microwave Week, IMS 2015 will continue to include RFIC and ARFTG conferences. *Microwave Journal* hopes to see everyone there next year. ■



High Efficiency Amplifier for Picocells

TriQuint Semiconductor
Hillsboro, Ore.

According to Cisco®, global mobile data traffic reached 1.5 exabytes (10^{18} bytes) per month by the end of 2013, nearly doubling the 820 petabytes (10^{15} bytes) per month from 2012. [Source: The Cisco® Visual Networking Index (VNI) Global Mobile Data Traffic Forecast Update.] This data explosion is driven by video streaming, picture uploading and cloud-based services on smart phones and other handheld devices. With mobile broadband data traffic growing exponentially, the traditional homogeneous network has had to extend bandwidths, increase modulation and increase cell sectors to meet demand. [Source: Jeanette Wannstrom, masterltefaster.com and Keith Mallinson, WiseHarbor, "HetNet/Small Cells" *3GPP.*] There is a limit to subdividing sectors, though, as it is becoming very difficult to procure new cell sites for the large towers often employed for macro base stations. In addition, the classical macro cell site cannot maintain high data rates for users at the outer edge of the site.



▲ *Fig. 1 Heterogeneous network employing femtocell and picocell BTS within a macrocell BTS footprint.*

To meet this data growth challenge, the industry is making the change from homogeneous networks to heterogeneous networks (HetNet). A HetNet is simply a network which uses multiple types of access points rather than a single type. It gives the network the opportunity to offload users from the primary macro site to a local micro, pico or femtocell site that offers the user higher data rates and higher quality of service (QoS).

An example of a heterogeneous network is shown in ***Figure 1***. Small cell base stations (BTS) in the form of femto and picocell BTS are embedded within the larger macro BTS network. Femtocells can be clustered in neighborhoods or within floors of buildings. Picocells can be placed in high capacity areas of the macro cell site and for whole floor coverage in buildings. Key parameters for the various small cell BTS are given in ***Table 1***.

While the HetNet has the advantage of improving the user experience and adding data capacity, the available small cell base stations have been met with challenges from a business case perspective due to cost, size and backhaul. Looking at these challenges, a number of semiconductor companies have introduced highly integrated

TABLE I
SMALL CELL BTS KEY PARAMETERS

	Residential Femtocell	Enterprise Femtocell	Picocell	Pico/Active Antenna
Antenna Power (avg)	20 mW	100 to 250 mW	1 W	2 to 5 W
Cell Size	~ 50 m	~ 200 m	~ 500 m	>1 km
Users	4	8 to 16	>16	>32
Location	Indoor	Indoor	Indoor Outdoor	Outdoor

single chip transceiver solutions for the small cell BTS market, particularly the femtocell class. However, the internal power amplifiers remain discrete in form and suffer from poor efficiency. Little has been offered for the picocell class of BTS—until now. TriQuint has taken the challenge to develop and produce a family of miniaturized, multistage power amplifier modules intended to be a plug-and-play component for picocell base stations requiring extremely small form factor.

TRIQUINT TGA2450-SM PERFORMANCE

The first product of the picocell power amplifier module family is TriQuint's TGA2450-SM, a fully integrated surface mount three-stage power amplifier module. The final stage is a Doherty configuration in order to significantly increase power added efficiency over current integrated solutions. The block diagram is shown in ***Figure 2***. The module has 50 ohm RF input and output impedances and requires minimal external components. The TriQuint TGA2450-SM is extremely compact at a 20 × 20 × 1.5 mm size, offering a much smaller footprint compared to traditional discrete component solutions and much higher power and efficiency than existing integrated solutions. Other features include on-chip temperature compensated bias circuits, two positive supply voltages (5 and 18 V) and a single pin for power down functionality.

The TriQuint TGA2450-SM module has 35 dB of power gain and 35 percent power added efficiency when delivering 2.5 W of average power at 8 dB back off. Saturated power is approximately 16 W. The module PAE drive-up curve using a 20 MHz LTE signal with 8 dB PAR is shown in ***Figure 3***. The gain drive-up curve under CW signal is shown in ***Figure 4***. When stimulated with a

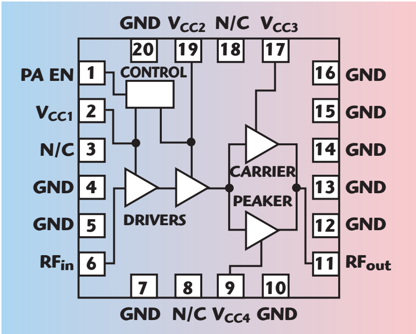


Fig. 2 TriQuint TGA2450-SM block diagram.

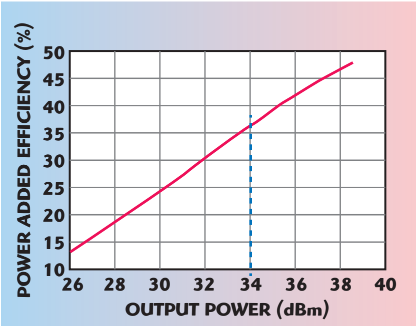


Fig. 3 Power added efficiency versus output power for an 8 dB PAR, 20 MHz LTE signal.

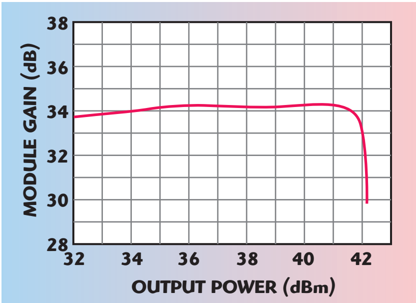


Fig. 4 CW drive-up of the TGA2450-SM showing Psat > 42 dBm.

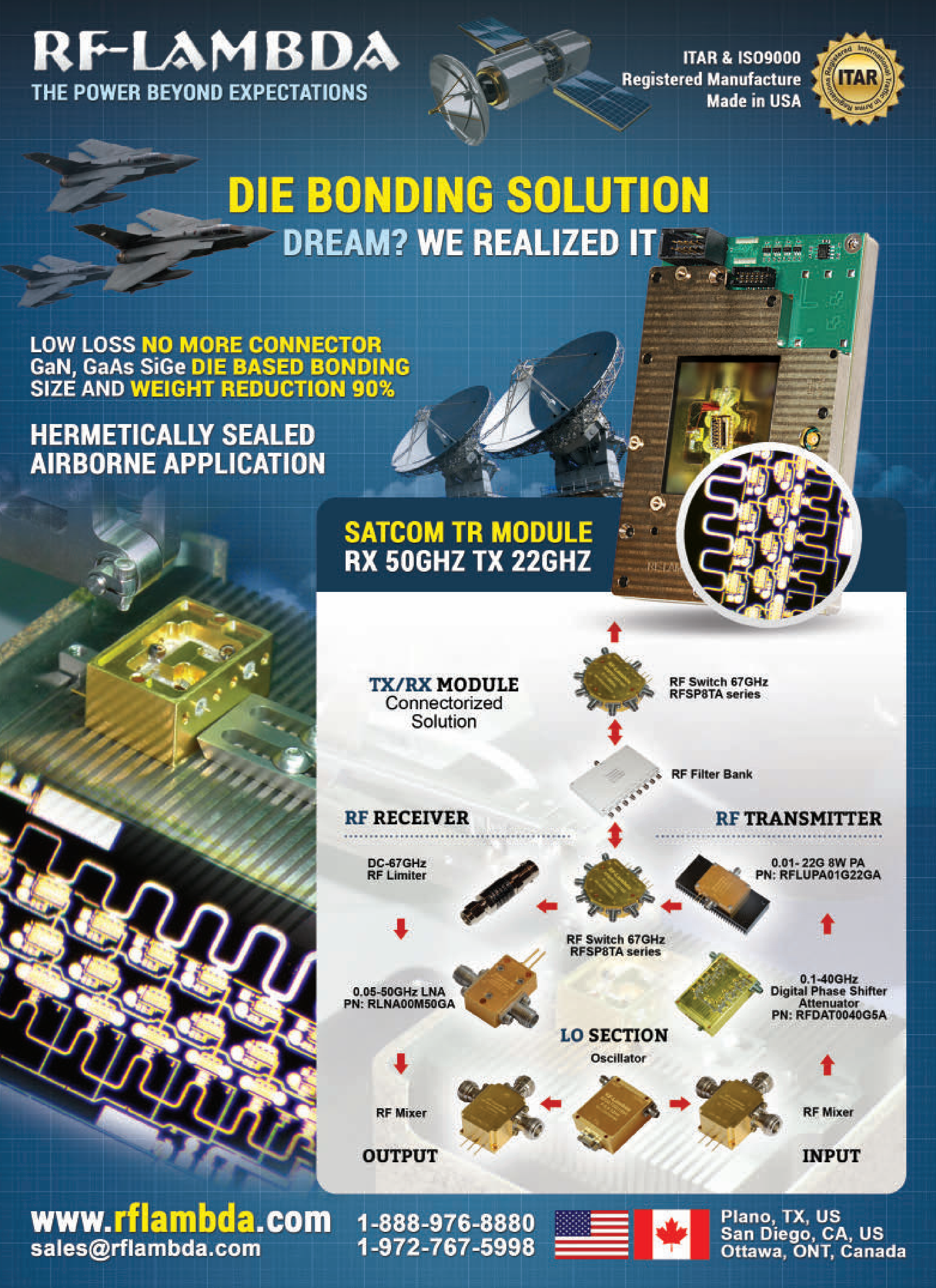

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TABLE II

KEY PERFORMANCE PARAMETERS

Average Power (8 dB back off)	2.5 W
P3dB	42.5 dBm
PAE (@34 dBm)	35%
ACPR (5 MHz), corrected	-50 dBc
Video Bandwidth	> 70 MHz
Package	20 × 20 mm LGA

20 MHz LTE signal having a PAR of 8 dB, the TGA2450-SM can be corrected to better than -50 dBc, using a low order digital pre-distortion algorithm (DPD). Uncorrected, adjacent channel power is -33 dBc. ***Table 2*** summarizes the key performance parameters.

Other devices in the TriQuint picocell module family include the TQP2451 (1.9 GHz) and TQP2453 (1.8 GHz). All modules are designed to have similar gain and efficiency at 34 dBm average output power. The modules also have a common footprint and I/O configuration as the TGA2450-SM to maintain compatibility in manufacturing. TriQuint expects to release the complete family of products in 2014.

Small cell base stations hold the promise to improve data throughput of the heterogeneous network and provide a better user experience as data demand dramatically increases. Although the power consumption of the small cell is significantly less than a macrocell BTS, when numerous picocell class base stations are added into the macro BTS footprint, the total power consumption will increase significantly. Thus, there is a need for significant improvement in efficiency for the small cell BTS. The TriQuint TGA2450-SM helps meet that power consumption need by improving typical multi-stage PA power added efficiency to 35 percent. The TriQuint family of picocell power amplifier modules is designed to be a true 50 ohm plug and play component for OEMs developing small cell base stations in multiple cellular bands.

TriQuint Semiconductor
Hillsboro, Ore.
www.triquint.com

High Performance, Off-the-Shelf Switch Matrix

SenarioTek
Santa Rosa, Calif.

ExecutiveInterview

Bob Alman, chief technology officer at SenarioTek.
Visit www.mwjournal.com to read his in-depth interview.

SenarioTek's FlexMatrix RF switch matrix family delivers off-the-shelf performance from DC up to 40 GHz. FlexMatrix offers test engineers a high performance RF switching capability over the broadest range of standard input and output configurations for applications such as radar, military communications, consumer wireless and signal integrity.

The FlexMatrix RF switch matrix family incorporates design and manufacturing knowledge acquired by delivering over 400 custom switch matrix design solutions. With guaranteed on-time delivery and a standard three-year warranty, SenarioTek expands its ability to deliver products to test engineers on time.

SWITCH MATRIX CONFIGURATIONS

RF switch matrix solutions are found in a wide variety of test solutions. The type of switch matrix configuration required depends on the key functions that are required for a particular test station. SenarioTek's FlexMatrix RF switch matrix family includes product series that are focused on the most widely used switch matrix solutions: common highway, full access blocking, full access non-blocking, differential and expandable. ***Figure 1*** highlights each of the configuration types.

Standard switching configurations range from a simple 2 × 4 switch matrix, all the way to 36 × 36. Switches can be either terminated or unterminated, with connections located on either the front or rear panels. The SenarioTek website offers a configuration tool that easily configures a switch matrix and quickly generates a quote.

RF PERFORMANCE

The FlexMatrix family is designed specifically for high performance applications – minimizing loss and VSWR, while maximizing isolation. Frequency ranges are available from DC to 6, 26.5 or 40 GHz on the standard products – higher frequencies are available via custom solutions.

FlexMatrix offers excellent cycle-to-cycle insertion loss magnitude and phase repeatability, lowering test system calibration uncertainty for longer periods of time. ***Figure 2*** shows a repeatability measurement of the insertion loss of 4 switches in series, with each switch cycled 1 million times. Each switch is guaranteed for

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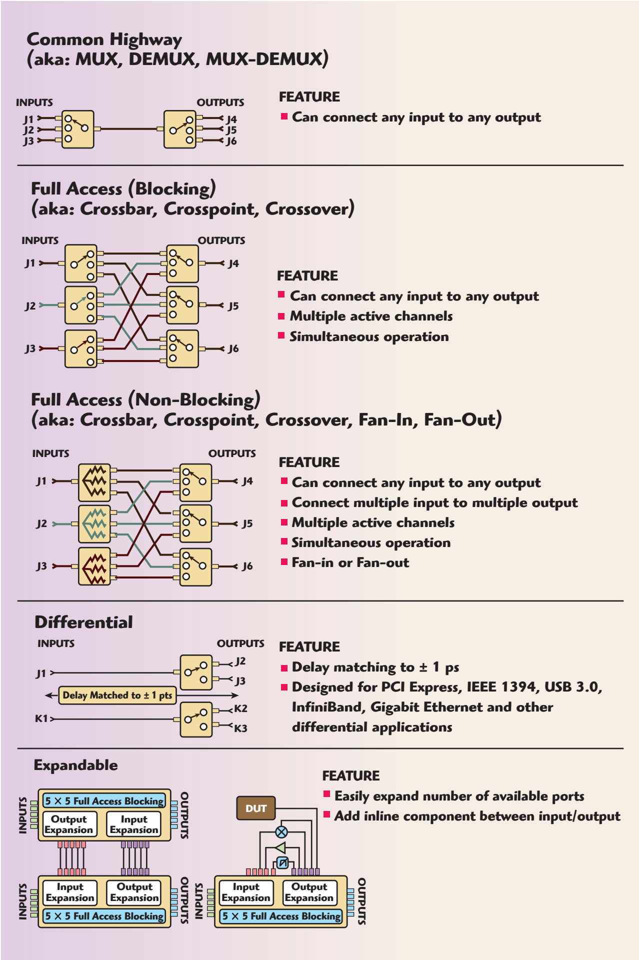
over 10 million switching cycles for either terminated or un-terminated products. In addition, each switch matrix contains on-board internal memory providing the ability to conveniently de-embed correction files.



▲ *Fig. 1 FlexMatrix RF switch matrix configurations.*

INTUITIVE AUTOMATION

The FlexMatrix controller allows for remote control via LAN, GPIB and USB. Basic SCPI compatible switch commands may be used or the controller may be configured to interpret existing commands in order to maintain compatibility with existing test software. The controller offers intuitive switch/path controls and allows for switch path queries as well as a switch lifecycle counter. For manual control, the FlexMatrix family has an option for an easy to use LCD interface mounted on the front panel or as a removable handheld display.

THREE-YEAR STANDARD WARRANTY

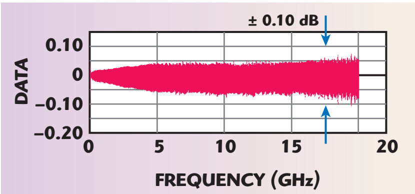
Having test station downtime is time consuming and expensive. SenarioTek switch matrix solutions are in use at manufacturing test sites around the world. They are so serious about quality that they offer a three-year standard warranty at no cost.

TARGETING SPECIALTY APPLICATIONS

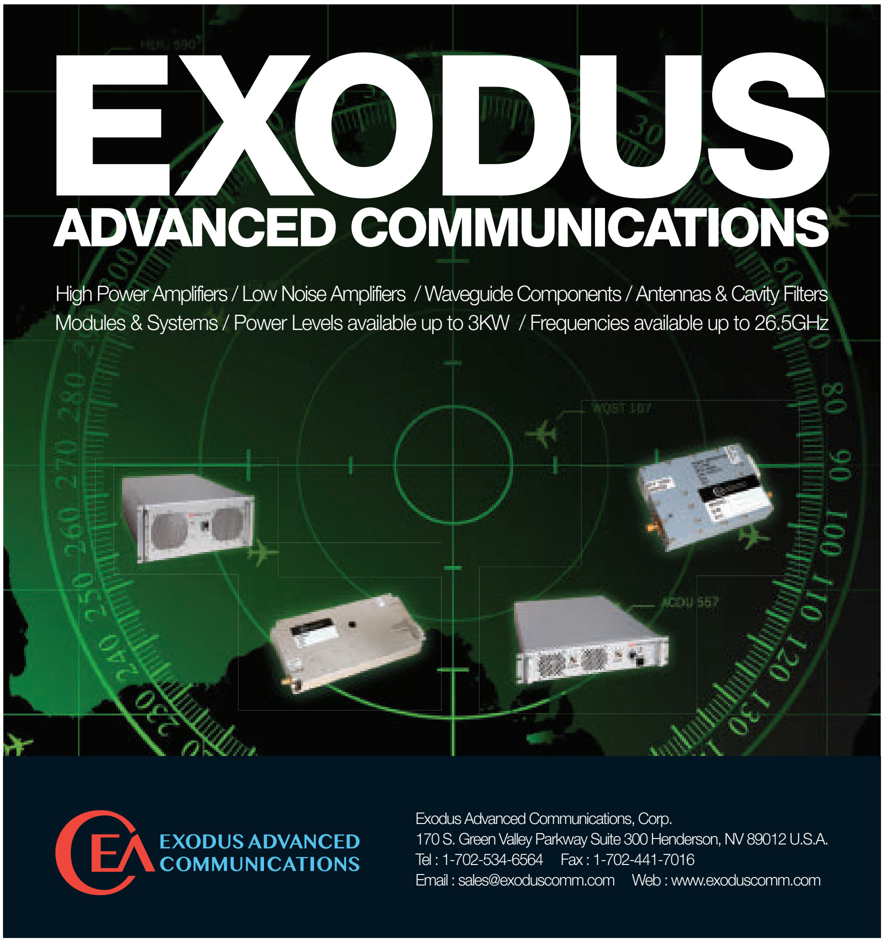
While FlexMatrix is being used for a wide variety of applications, there are several specialty applications where it is unique. The following highlights a few of these applications.

Signal Integrity: Multi-lane, Single Connection

The FlexMatrix Differential Series offers dual one by 4, 8, 16 or 32 port solutions to speed time-to-market for products using the latest standards such as PCI Express Gen 3, IEEE 1394, USB 3.0, SATA, SerDes, InfiniBand and Gigabit Ethernet (10 GbE and 100 GbE). The differential series minimizes



▲ *Fig. 2 FlexMatrix RF switch matrix repeatability demonstration showing insertion loss of four switches in series with each switch cycled 1 million times.*



path delay skew between differential pairs, including delay matching for transmitter measurements as low as two picoseconds at the DUT interface. Test engineers can perform multi-lane testing with a single connection. Complete test plans may be automated and suspected problems may be checked without changing any connections.

Expandable Platforms

The FlexMatrix Expandable Series enables adjustment, modification or expansion as needed. For example, the expansion ports provide test engineers with the capability to expand their 5×5 or 10×10 solutions to a greater number of ports. As needs change, the port count can be increased by adding an expansion matrix. The boxes may be daisy-chained together with one box used as the controller for the others. If an LCD display is present, it will represent the expanded switch matrix.

In addition, the expansion ports provide the flexibility to allow an in-line component to be added between the FlexMatrix input and output, without the need for external switching. For example, an external amplifier may be added with the amplified signal being routed to any or all of the FlexMatrix outputs.

THERMAL VACUUM (TVAC) SOLUTIONS

As satellite complexity increases, there is a growing need for qualified RF/microwave TVAC compatible subsystems. SenarioTek has been in a unique position to address this challenging problem. As a designer of custom RF/microwave test products for many years, the company has worked with a wide variety of component manufacturers. Over the years they have developed special solutions that are successfully being used in TVAC chambers for satellite and satellite component testing.

FlexMatrix solutions are available from DC to 32 GHz with operation from -30° to +70°C at < 10^{-6} Torr vacuum. Not only does it allow the use of the same test solution inside and outside the chamber, but it enables the satellite test system to be further optimized in this difficult environment.

VENDORVIEW

SenarioTek
Santa Rosa, Calif.
sales@senariotek.com
www.senariotek.com

Planar Monolithics Industries, Inc.

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- Switch Filter Banks
- Threshold Detectors
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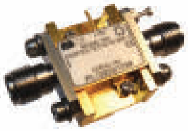
- +15VDC, 180mA
- Temperature Compensated from -54C to +95C
- 0.53" x 0.59" x 0.26"



50MHz to 40GHz USB Powered Amplifier

Model No. AMP-12-50M40G-USB

- 50MHz to 40.0GHz (Other frequency ranges available)
- Gain 12dB
- Gain Flatness +/-2.5dB
- Noise Figure 4.5dB
- OP1dB +10dBm
- DC Power via USB 2.0
- RF Connectors 2.92mm Female
- 2.25" x 1.0" x 0.36"

500MHz to 40GHz Low Noise Amplifier

Model No. PEC-42-500M40G-20-12-292MM

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- Gain 42dB
- Gain Flatness +/-2.5dB
- Noise Figure 5.5dB
- OP1dB 22dBm
- Input Power +17dBm CW max
- +12 to +15VDC, 450mA
- 1.37" x 1.0" x 0.6"

2-18GHz Limiting Amplifier

Model No. PEC2-2G18G-60-2DBM-LM-SFF

- 2.0 to 18.0GHz (Other frequency ranges available)
- Input Power Range -60 to +30dBm
- Limited Output Power +2dBm (Up to +26dBm Available)
- Output Power Flatness +/-2dB
- Harmonics -10dBc
- Spurious -60dBc
- +12 to +15VDC, 460mA
- 2.98" x 0.78" x 0.36"

6-18GHz Medium Power Amplifier

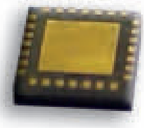
Model No. PEC-33-6G18G-7R0-31-SFF

- 6.0 to 18.0GHz
- Gain 32.5dB
- Noise Figure 7dB max
- OP1dB 30.5 +/-1.5dBm
- Harmonics -18dBc max
- Input Power +20dBm CW max
- +12VDC, 1.25A
- 2.62" x 1.28" x 0.42"

14.4-15.5GHz Limiter/LNA Integrated QFN

Model No. PSMT-0001

- 14.5 to 15.5GHz (Other frequency ranges available)
- Gain 16.5dB
- Noise Figure 2.5dB
- OP1dB +10dBm min
- Input Power +30dBm CW max
- AC Coupled / DC Blocked
- +3.5VDC, 100mA
- 5mm x 5mm QFN 32/L



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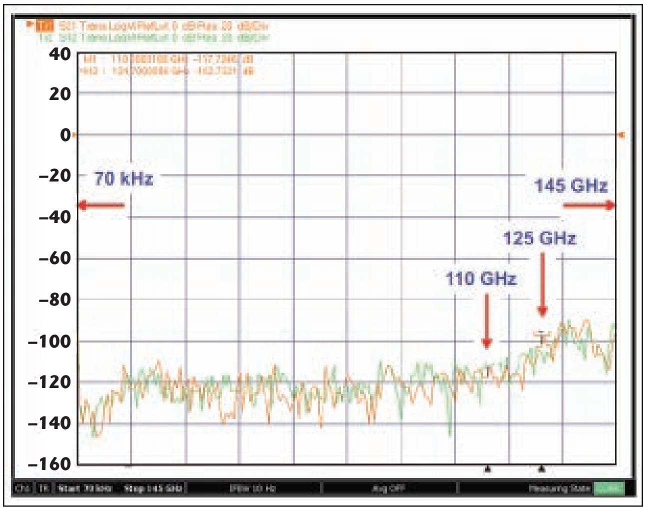
Anritsu Co.
Morgan Hill, Calif.

The VectorStar ME7838D 145 GHz Broadband system is the first VNA combining RF, microwave and two mm-wave bands in a single coaxial output. Through the use of the Anritsu-developed 0.8 mm coaxial connector, frequencies up to 145 GHz can be propagated within a coaxial transmission line without waveguide flange connections. A broadband frequency sweep from 70 kHz to 145 GHz is now available without the need to concatenate multiple systems. The result is more accurate device characterization from near-DC through the W- and F-Band frequencies. W-Band devices can now be characterized beyond the operating frequency of the application for more accurate modeling and higher success rate from the first design turn.

The ME7838D fully supports the 3744A-Rx 30 to 125 GHz receiver for noise figure measurements up to 125 GHz. Integrating Anritsu's unique strength in nonlinear transmission line technology (NLTL), the ME7838D system offers many advances in broadband performance over traditional systems including:

- Broadband frequency coverage, from 70 kHz (instead of 10 MHz) and operational from 40 kHz to 145 GHz through a single coaxial connector
- Dynamic range of 120 dB at 10 MHz, 108 dB at 65 GHz, 108 dB at 110 GHz, and 94 dB at 145 GHz
- Measurement speed of 55 ms for 201 points at 10 kHz IFBW
- Compact, lightweight mm-wave modules for easy, precise and economical positioning



▲ *Fig. 1 Dynamic range of ME7838D system at the 0.8 mm coaxial test port.*

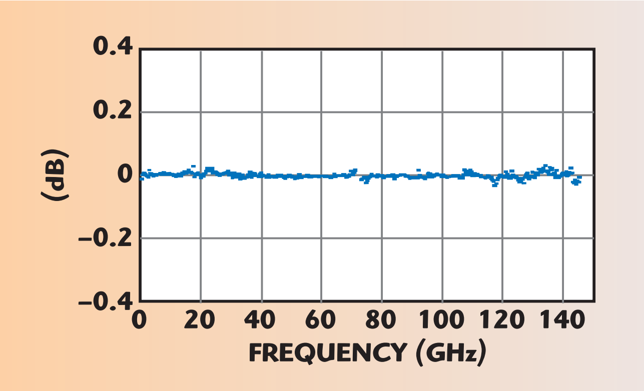
on a wafer probe station; 0.7 lb and 1/50 the volume of traditional mm-wave modules

- First millimeter-wave system with real-time leveling of power without the need for calibration software correction tables
- Excellent calibration and measurement stability, 0.1 dB over 24 hrs
- Fully supports tri-axial Kelvin bias tee connections for on-wafer device biasing up to 145 GHz
- Millimeter-wave waveguide coverage to 1.1 THz
- The ME7838A 110/125 GHz broadband system can be easily upgraded to 145 GHz by incorporating the new Anritsu MA25300A mm-wave module

BROADBAND VNA SYSTEM: 70 kHZ TO 145 GHz

The ME7838D broadband VNA system provides single sweep coverage from 70 kHz to 145 GHz and is operational from 40 kHz to 145 GHz. It consists of the following items:

- MS4647B VectorStar VNA, 70 kHz to 70 GHz with Option 007, Option 070, and Option 080/081
- 3739C broadband millimeter-wave test set and interface cables
- MA25300A millimeter-wave module, two each



▲ *Fig. 2 24-hour reflection magnitude stability.*

Figure 1 shows the dynamic range of the ME7838D system at the 0.8 mm coaxial test port from 70 kHz to 145 GHz. ***Figure 2*** shows 24-hour reflection magnitude stability from 70 kHz to 145 GHz in a typical lab environment when measured at 23°C ± 3°C.

MILLIMETER WAVEGUIDE VNA SYSTEM 50 GHz TO 1.1 THz

The ME7838D millimeter-wave configuration provides waveguide output from 50 GHz to 1.1 THz in waveguide bands. The frequency range of the broadband system can be extended using millimeter-wave modules or it can be configured to operate only as a waveguide system. It consists of the following items:

- MS4647B VectorStar VNA, 70 kHz to 70 GHz with Option 007, and Options 80/81
- 3739C broadband millimeter-wave test set and interface cables
- Millimeter-wave module, two each

Three configurations are available for waveguide band

Phase Adjusters

Part Number	Connectors	Frequency Range (GHz)	VSWR max.	Insertion Loss max. (dB)	Phase Shift min. (°)	No. of Turns	Phase Shift Deg/GHz/Turn	Time Delay min. (psec.)	Time Delay max. (psec.)	Temperature (°C)	Weight max. (g)
LS-0002-YYYY[1]	div.	DC - 2	1.2:1	0.3	85	37	1.15	393	516	-65 to +125	98-220[2]
LS-0103-6161	Nf	DC - 3	1.15:1	0.4	540	cont.		1826	2328		700
LS-0203-6161				0.9	1080			3693	4694		1200
LS-0012-YYYY[1]	div.	DC - 12	1.3:1	0.8	520	37		406	530		114-234[2]
LS-0112-XXXX[3]	SMA	DC-12.0	1.25:1	0.4	230	16.5	1.2	238	293	-65 to +125	70
LS-A112-XXXX[3]											47
LS-0212-1121											70
LS-A212-1121											47
LS-0118-XXXX[3]		DC-18.0		0.6	350						70
LS-A118-XXXX[3]											47
LS-0218-1121											70
LS-A218-1121											47
LS-0118-5161	N							300	355	-65/+70	105
LS-U118-5161										-65/+165	
LS-0018-YYYY[1]	div.	DC - 18	1.5:1	1.0	770	37	1.15	406	530		98-220[2]
LS-0121-XXXX[3]	SMA	DC-26.0	1.30:1	0.8	500	16.5	1.2	238	293	-65 to +125	70
LS-A121-XXXX[3]											47
LS-0221-1121											70
LS-A221-1121											47
LS-0321-1121			1.31:1		580	35	0.6	236.7	290.5		30
LS-0170-1121			1.26:1	0.26	127	13.5	0.36	109.2	122.8		9
LS-S008-1121			1.50:1	0.4	155	10	0.6	118.6	135.1		20
LS-P140-KFKM	2.92 mm	DC-40.0	1.2:1	0.6	590	12	1.2	168	208	-65 to +65	51
LS-0140-KFKM			1.4:1								49
LS-P150-HFHM	2.40 mm	DC-50.0	1.3:1	0.8	400	7		172	195		55
LS-0150-HFHM			1.5:1								53
LS-P165-VFVM	1.85 mm	DC-63.0	1.4:1	0.8	600	8		167	195		55
LS-0165-VFVM			1.5:1								53

[1] div.: Connector Configuration available: SMA, male and female; N, male and female; TNC male and female
[2] Weight depends on connector configuration
[3] SMA Connector Configuration available: male/female; male/male; female/female; female/male

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when Quality is needed

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Email: sales@spectrum-et.com

PhaseShiftersTable

operation when using the ME7838D system.

1. The Anritsu MA25300A broadband millimeter-wave module can be adapted to waveguide measurements using waveguide adapters. Waveguide adapters from Flann are available with 0.8 mm connectors and cover the WR08 and WR06 bands.
2. The Anritsu 3744A-EE or 3744A-EW millimeter-wave module can be used. These version modules operate in the extended E and W waveguide bands and are operational using the MS4644B, MS4645B or MS4647B VectorStar (with options 08× and 007) and the 3739C broadband/millimeter-wave test set.
3. The third configuration option is to use external millimeter-wave modules with any model VectorStar (with options 08× and 007) and the 3739C test set. For millimeter bands, either OML or VDI modules may be used.

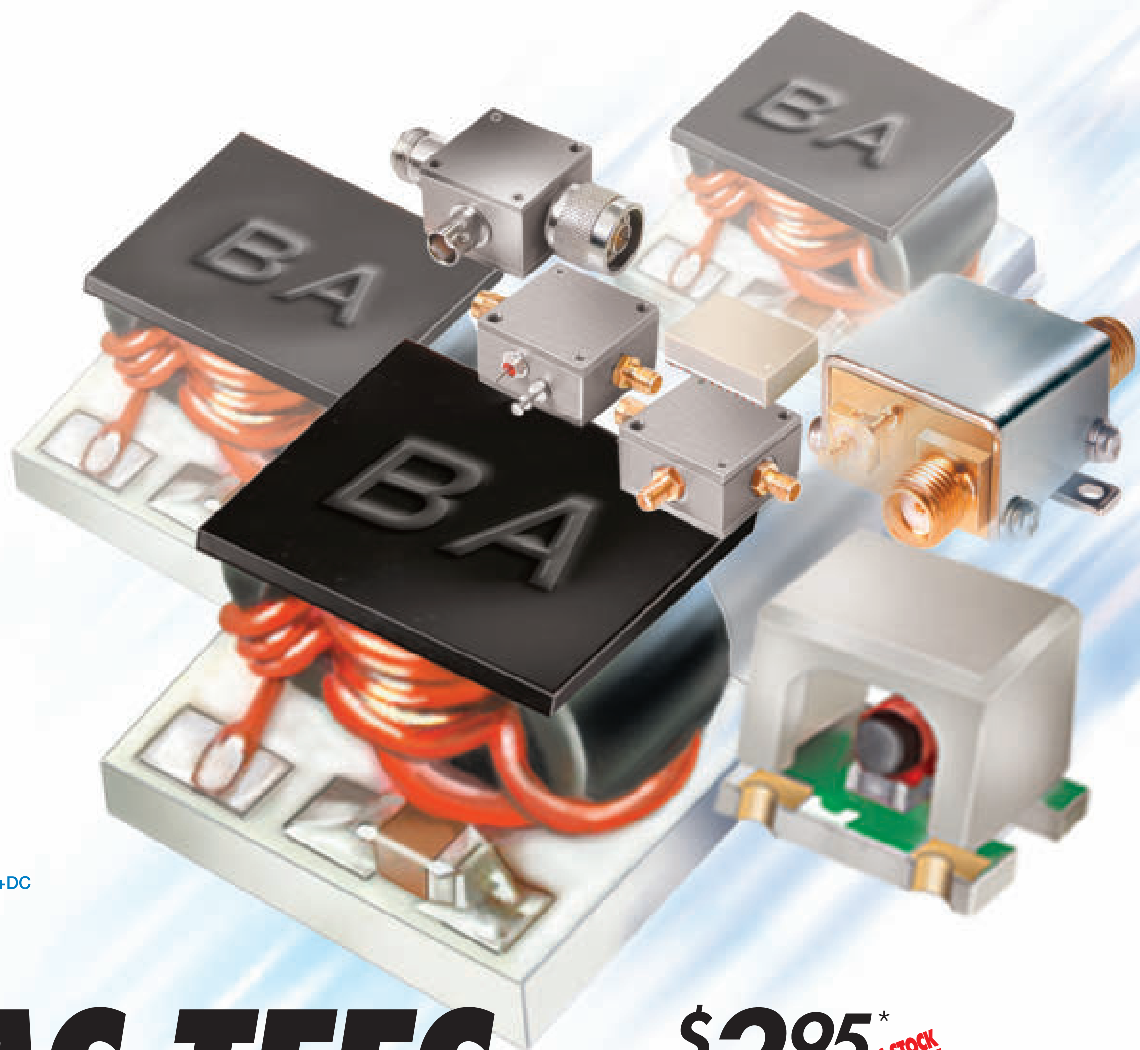
The MA25300A broadband mm-wave module can be adapted to a waveguide band output by adding an available waveguide band adapter. Using the MA25300A modules provides the opportunity to sweep frequencies for broadband applications and quickly convert to waveguide configurations for banded measurements. The advantages of small compact modules with excellent RF performance and power range control can be realized in both broadband and waveguide configurations when using the MA25300A mm-wave module.

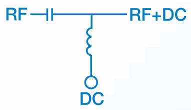
The 3744A-Rx receiver module can be used with Option 041, noise figure, and the ME7838D mm-wave or broadband system to perform mm-wave noise figure measurements from 30 to 125 GHz. The receiver bypasses the internal couplers, maximizing the noise figure of the receiver for optimum noise figure measurement accuracy. The receiver is derived from the 3743A mm-wave module utilizing the same nonlinear transmission line technology for optimum mm-wave performance. The advantages of the 3743A mm-wave module system architecture provide a unique solution to mm-wave noise figure measurements previously unavailable.

A broadband frequency sweep from 70 kHz to 145 GHz is now available with the VectorStar ME7838D 145 GHz Broadband system. W-Band devices can now be characterized beyond the operating frequency of the application for more accurate modeling and higher success rate from the first design turn.

VENDORVIEW

Anritsu Co.
Morgan Hill, Calif.
www.anritsu.com





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TYPICAL SPECIFICATIONS

Model	Freq (MHz)	Insertion Loss (dB)	Isolation (dB)	Max Current mA	Price $ea. Qty.10
TCBT-2R5G+	20-2500	0.35	44	200	6.95*
TCBT-6G+	50-6000	0.7	28	200	9.95
TCBT-14+	10-10,000	0.35	33	200	8.45
TCBT: LTCC, Actual Size .15" x .15", U.S. Patent 7,012,486.					**Qty.1-9**
JEBT-4R2G+	10-4200	0.6	40	500	39.95
JEBT-4R2GW+	0.1-4200	0.6	40	500	59.95
PBTC-1G+	10-1000	0.3	33	500	25.95
PBTC-3G+	10-3000	0.3	30	500	35.95
PBTC-1GW+	0.1-1000	0.3	33	500	35.95
PBTC-3GW+	0.1-3000	0.3	30	500	46.95
ZFBT-4R2G+	10-4200	0.6	40	500	59.95
ZFBT-6G+	10-6000	0.6	40	500	79.95
ZFBT-4R2GW+	0.1-4200	0.6	40	500	79.95
ZFBT-6GW+	0.1-6000	0.6	40	500	89.95
ZFBT-4R2G-FT+	10-4200	0.6	N/A	500	59.95
ZFBT-6G-FT+	10-6000	0.6	N/A	500	79.95
ZFBT-4R2GW-FT+	0.1-4200	0.6	N/A	500	79.95
ZFBT-6GW-FT+	0.1-6000	0.6	N/A	500	89.95
ZFBT-282-1.5A+	10-2800	0.6	45	1500	56.95
ZFBT-352-FT+	30-3500	0.4	23	4000	48.95
ZNBT-60-1W+	2.5-6000	0.6	45	500	82.95
ZX85-12G+	0.2-12000	0.6	N/A	400	99.95

ZX85: U.S. Patent 6,790,049.

Note: Isolation dB applies to DC to (RF) and DC to (RF+DC) ports.

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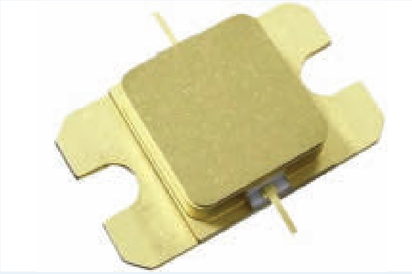

High Power C- to X-Band GaN Amplifiers

Sumitomo Electric Device Innovations (SEDI) is now sampling the industry's first family of 60 W GaN devices ideal for point-to-point radios and SATCOM applications for C- and X-Band. These GaN HEMTs are internally matched for 50 ohm systems. They are housed in an industry standard flange-mount package.

Key features:

- Frequency: 5.85 to 6.75 GHz, 6.4 to 7.2 GHz and 7.7 to 8.5 GHz
- 60 W output power
- 40 percent efficiency
- Industry's standard flange-mount package

SEDI is also sampling 20 W internally matched GaN devices for C- and X-Band. They are housed in a plastic surface mount package suitable for low cost assembly, and cover broader bandwidth than conventional GaAs IMFETs.

Key features:

- Broadband coverage: 5.85 to 7.2 GHz and 7.1 to 8.5 GHz
- 20 W output power
- Surface mount package

30 and 100 W GaN IMFETs are also available in production. These new samples expand SEDI's product portfolio of high frequency GaN devices. Samples are available direct or through distribution (www.cdiweb.com).

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San Jose, CA
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POWER DIVIDERS RoHS

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

• With matched operating conditions

HYBRIDS RoHS

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

◊ In excess of theoretical coupling loss of 3.0 dB

COUPLERS RoHS

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

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

Unless noted, products are RoHS compliant.

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- 6U / 17" Deep Rack Mountable
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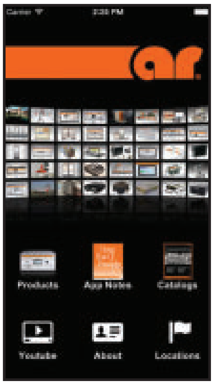

AR RF/Microwave's new mobile app is available as a free download from Apple iTunes and Google Play. This application is a quick and easy tool to access various content for AR's products. Home screen icons give you easy access to basic and full product descriptions, app notes, AR's literature library, YouTube videos, contact information and social media icons. For more details and to download the app, visit www.arww-rfmicro.com/html/ar-moblie-app.asp.

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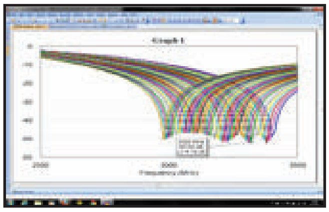
NI AWR Design Environment V11

VENDORVIEW



NI AWR Design Environment™ V11 includes new features, enhancements, and user interface changes to Microwave Office®/Analog Office® circuit design software, Visual System Simulator™ (VSS) system design software, AXIEM® 3D planar electromagnetic (EM) software, and Analyst™ 3D finite element method (FEM) EM software. These improvements enable users to spend more time focusing on their design challenges and less time on driving the software. Analyst's 3D parts library, for example, provides ready-built models for most needs and makes the process of custom model creations faster and more efficient.

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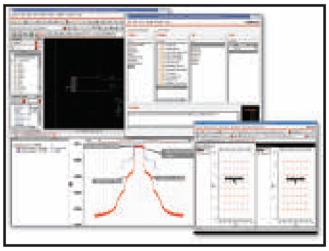

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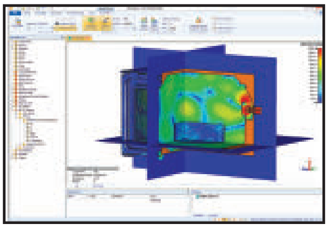

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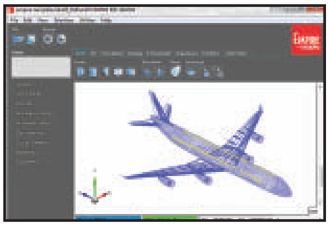
3D EM Solver EMPIRE XPU 7.0



EMPIRE XPU is a 3D EM solver for modeling antennas, microwave circuits, EM chip design and more. Due to its unique on-the-fly compilation, EMPIRE is highly efficient and extremely fast on plain conventional hardware using optimized algorithms. New features of EMPIRE XPU include a powerful and highly intuitive 3D graphical user interface, a complete new 3D modeling kernel enabling fast import, modeling and meshing of large and complex objects, a near field source and a circuit simulator.

IMST GmbH
www.imst.com

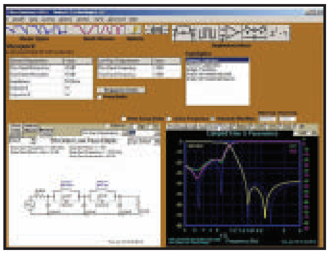
Smartphone App

Molex Inc. has expanded access to its free Molex app designed for Apple and Android devices. Providing mobile users with information on over 90 different Molex product families, the Molex app allows tablet and now smartphone users to view product information, search products, view literature and view videos without being online. Featuring enhanced screens with convenient layouts, tablet and smartphone users can explore product options, compare key features, save favorites plus email data, images and links. App users with Internet access can link to the Molex website for detailed product and order information.

Molex Inc.
www.molex.com

Software and Mobile Apps

Vendor and Custom Spice Models Available in FilterSolutions

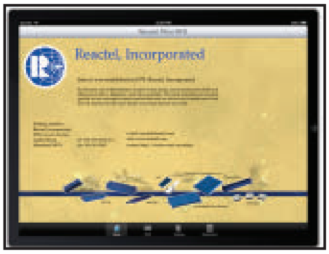


Nuhertz Technologies introduces a new capability in FilterSolutions®, Version 13.6.1. The leading filter circuit synthesis software can now import vendor and custom user spice models; using them as a basis for synthesis and simulation. Spice models can be automatically selected for each synthesized element. Synthesized filters are automatically updated and simulated with the "best fit" spice model at synthesis time for easy viewing. Spice models are included in FilterSolutions exports to circuit simulators such as AWR's Microwave Office® and CST's Design Studio®.

Nuhertz Technologies
www.nuhertz.com

Filter RFQ

VENDORVIEW



Submitting RFQ's for filters, multiplexers and multifunction assemblies has never been easier or more convenient with Reactel's mobile app for Apple and Android devices. Download Filter RFQ from the App Store or Google Play to get your requirements quickly to engineers. This full featured app also contains the company's complete catalog and a growing number of datasheets. Download today and leave your filter worries behind.

Reactel Inc.
www.reactel.com

Tech-X Releases VSim 7

VSim 7 is an electromagnetic time-domain three-dimensional solver with particle and plasma simulation capabilities. It uses a package model to customize the powerful physics engine to meet customers' needs for electromagnetic, microwave device and plasma simulation capabilities. This release includes VMesh™, a new mesh generator that makes gridding up complex geometry easier and blazingly fast. VSim 7 now supports STEP CAD files in addition to the STL and VTK formats. The VSim for Electromagnetics package has a greatly simplified problem setup and improved external circuit modeling, new analysis and plasma modeling capabilities.

Tech-X Corp.
www.txcorp.com/vsim7

The 2014 Defence, Security and Space Forum

At European Microwave Week

EuMA | Microwave Journal — Frequency Matters.

Wednesday 8 October • Room Flavia, Fiera di Roma Conference & Exhibition Centre, Rome

A one day Forum addressing the application of RF integrated systems to defence & security infrastructure

Programme

09:00 - 10:40 Microwave Journal Industry Panel Session

The session offers an industry perspective on the key issues facing the defence, security and space sector. In accordance with the theme for 2014, the Panel will address: *Defence and security infrastructure*.

11:20 - 13:00 EuRAD Opening Session

13:10 - 14:10 Strategy Analytics Lunch & Learn Session

This session will add a further dimension by offering a market analysis perspective, illustrating the status, development and potential of the market.

14:20 - 16:00 Integrated RF solutions and its enabling and disruptive technologies on critical infrastructures and civil protection

Speakers from industry and academia present RF solutions and systems that contribute to civil protection, the protection of our critical infrastructures and disaster relief. The topics will be:

- The domino effects in critical infrastructures
- Civil protection, protection of critical infrastructures, disaster relief: vertical applications over a common architecture with heterogeneous communications
- Threats and countermeasures in the homeland security scenario
- Security at European institutional level

The three most highly rated unsolicited papers will complete the analysis of the main session topic.

16:40 - 18:20 EuMW Defence, Security & Space Executive Forum

Two executives from space industry and governmental institutions present their view on defence and space systems for our security. The titles of these two VIP talks will be announced closer to the event on the EUMW2014 website.

These two presentations will be complemented by three pitch presentations:

- Joint Applications of Airborne and Spaceborne Radars
- Instrumented fuzes for aero-ballistics diagnostics of large-caliber projectiles
- New Technologies and Innovative Payload for Space Q/V-Band Telecommunications

The session will conclude with an open forum discussion with all speakers.

18:20 - 19:00 Cocktail Reception

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

Registration fees are €10 for those who have registered for a conference and €50 for those not registered for a conference.

Register online at www.eumweek.com

Sponsored by:

Peregrine Semiconductor | ROHDE&SCHWARZ

Components

Wi-Fi Filter Solution

This is a three section, cavity filter with a passband of 5725 to 5875 MHz, with <0.25 dB insertion loss. The Wi-Fi filter provides >10 dB attenuation at 5570 and 6030 MHz and >70 dB at DC to 2500 MHz and is capable of handling 50 W CW with a peak rating of 500 W. Size: 2.3" × 1.1" × 0.75" excluding sma connectors.

3H Communication Systems
www.3hcommunicationsystems.com

Switched Filter Banks

This new line of standard switched filter banks features customer-specified frequency bands from 2 to 7 channels. With lead times as fast as four weeks, the configurable solution significantly reduces development cycle time, resulting in cost savings and faster time to market. Offering customer-defined passband frequencies from 20 to 7500 MHz with ultimate rejection up to 20 GHz, these switched filter banks can be used in a wide variety of applications where cost-efficiency and high performance is required.

API Technologies Corp.
www.apitech.com

Broadband Power Dividers

Models 152-045-002 and 152-045-004 are two and four-way power dividers with an operating frequency range of 500 to 4500 MHz. Typical isolation is 20 dB and insertion loss above theoretical split is 1 to 2 dB nominal depending on configuration. The wide frequency range of these 5 W average power devices allows use with multiband antennas and leaky cable systems. Applications include LTE, UMTS/WCDMA, TD-SCDMA, AMPS, GSM, PCS, CDMA, Wi-Fi/WLAN. Delivery is from stock. Other configurations, connector types and frequency ranges are available.

BroadWave Technologies Inc.
www.broadwavetech.com

Tiny Shielded Power Inductor

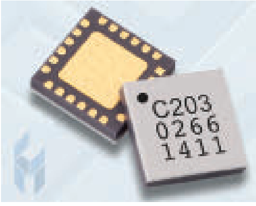
Coilcraft's XPL2010 Series of ultra-small, magnetically shielded power inductors combine excellent current handling, low DC resistance and inductance values up to 220 µH in a package that measures just 1.9 × 2.0 mm. The XPL2010 Series offers DCR as low as 0.027 ohms and current ratings up to 3.75 Amps. They are available with 22 inductance values ranging from 0.20 to 220 µH, and their soft saturation characteristics make them ideal for point-of-load (POL) DC to DC converter applications.

Coilcraft
www.coilcraft.com

SP4T Non-reflective Switch

VENDORVIEW

The CMD203C4 is a DC to 20 GHz single-pole, four-throw (SP4T), MMIC, switch housed in a leadless 4 × 4 mm ceramic package. It features a low insertion loss of 2.4 dB and high isolation of 40 dB at 10 GHz. The CMD203C4 is the latest control device added by Custom MMIC to its growing library of standard products.



Custom MMIC
www.custommmic.com

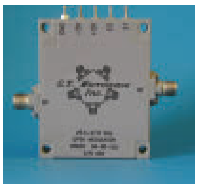
77 GHz Economic Sensor

Model SRF-77120910-01 is a low cost 77 GHz sensor designed for Doppler speed measurement. It is constructed with a high performance circular horn antenna, a linear to circular polarizer and T/R diplexer. It also incorporates a balanced mixer and a high performance Gunn oscillator. The sensor features a 12 degree 3 dB beamwidth, 10 dBm output power and 9 dB conversion loss. The sensor can readily be modified to offer different beamwidths, dual channel (I-Q) output or FMCW versions.

Ducommun Inc.
www.ducommun.com

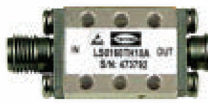
Digitally Controlled PIN Diode QPSK Modulator

Model SA-80-2JJ is a digitally controlled PIN diode QPSK modulator that operates from 25.5 to 27 GHz with a dynamic range of 0, 90, 180 and 270, ± 10°. This unit features an insertion loss of less than 10 dB with a 1.8:1 VSWR in 50 ohms. The supply voltage accommodates up to ± 5 VDC at ± 100 mA with a handling power of +15 dBm CW, 1 W max.



G.T. Microwave Inc.
www.gtmicrowave.com

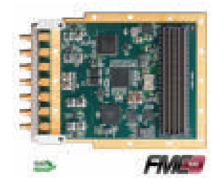
Broadband Limiter



Herotek offers a new series of high limiting threshold limiters with various threshold levels. Model LS0160TH10A operates from 0.1 to 6 GHz up to 2 W CW input. It has a hard limiting level (flat leakage) of typically only 2 to 3 dB above threshold level. The limiter has maximum insertion loss of 1 dB, maximum VSWR of 1.5:1, typical limiting threshold is +10 dBm, typical leakage power at 2 W CW input is +22 dBm, and is hermetically sealed for military application. Removable connectors for MIC assembly.

Herotek Inc.
www.herotek.com

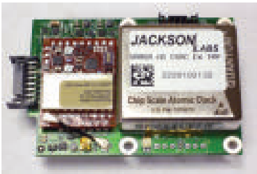
Digitizing and Signal Generation FMC IO



Innovative Integration announced the FMC-500, a high speed digitizing and signal generation FMC IO featuring two 500 MSPS A/D channels. The module also provides a dual-channel 1230 MSPS DAC plus ultra low-jitter PLL sample clock and triggering features. Support logic written in VHDL is provided for integration with FPGA carrier cards. Software tools for innovative carrier cards are included at no charge and provide C++ libraries and drivers for Windows and Linux, 32 or 64-bit.

Innovative Integration
www.innovative-dsp.com

Chip-Scale Atomic Clock



Jackson Labs Technologies Inc. announced the availability of its breakthrough product, SAASM HD CSAC combining for the first time, a P(Y) capable military SAASM dual-frequency GPS receiver with a chip-scale atomic clock on a ruggedized PC board with dimensions of only 2.0" × 2.85" × 0.6". The SAASM HD CSAC GPSDO is capable of receiving L1 and L2 GPS signals with C/A and P(Y) code, and is optimized for providing a highly accurate position, velocity, time and frequency reference under extreme environments.

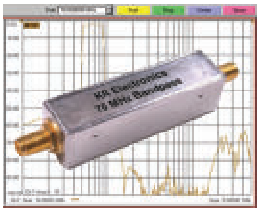
Jackson Labs Technologies Inc.
www.jackson-labs.com

Current Sensing Resistors

KOA Speer Electronics introduced two new current sensing resistors: the zero ohm SLZ and the 1W/2012 SLW07. The high current SLZ1 jumper chip offers a rated current of 44 A in a 2512 size. The SLW07 has an enhanced high power rating of 1 W in a smaller package size of 2010. The SLZ1 and SLW07 both feature a wide temperature range of -55° to +180°C. The SLZ1 has a max resistance of 0.5 m Ω and the SLW07 is

available in 0.5 mΩ ~100 mΩ in both 1 and 5 percent tolerances.
KOA Speer Electronics Inc.
www.koaspeer.com

70 MHz Bandpass Filter



KR Electronics part number 3157-1 is a 70 MHz bandpass filter. It has a min 0.5 dB bandwidth of 30 MHz. The filter is group delay and amplitude equalized. Stopband attenuation of 45 dB is maintained to 5 GHz. Elliptic type response for quick transition to the filter is supplied in a 0.6" × 0.6" × 2.25" case with SMA connectors. Other frequencies and bandwidths are available.
KR Electronics Inc.
www.krfilters.com

16-Channel, 16-Bit ±10 V SoftSpan DAC

VENDORVIEW

Linear Technology Corp. introduced the LTC2668-16, a 16-channel, 16-bit voltage output digital-to-analog converter (DAC) with SoftSpan™ outputs, each of which can be independently configured for one of five selectable unipolar and bipolar output ranges up to ±10 V. Each rail-to-rail DAC output is capable of sourcing or sinking 10 mA with guaranteed load regulation and is stable driving capacitive loads as large as 1000 pF.
Linear Technology Corp.
www.linear.com.

High Speed Absorptive Switch

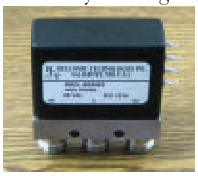
VENDORVIEW

PMI Model No. P1T-200M18G-60-T-SFF OPTION 0518 is a high speed, single pole, single throw, absorptive switch capable of switching within 25 ns. The frequency range is 0.5 to 18 GHz. This switch has over 60 dB of isolation and a maximum VSWR of 2.0:1.

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

RRDL-Series 1P2T Relay

RelComm Technologies compliments its product line by offering a high power handling, high performance 1P2T relay configured with 'N' type connectors and RF performance to 1 GHz. Power rating is 1200 W continuous over the operating temperature range of -25° to +70°C. The relay measures 2.50 wide × 1.00 thick and is less than 2.3" tall. It is fitted with side launched solder terminals for ease of wire up installation and is fully RoHS compliant.



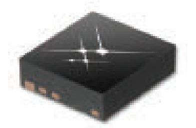
RelComm Technologies Inc.
www.relcommtech.com

Frequency Divider

RF Bay Inc.'s FBS-N-10 is a 4 to 10 GHz frequency divider that the divide ratio N can be set at the factory between 8 and 511. It is very easy to use for phase locked loop application. The unit takes -25 to +5 dBm input and output power at +4 dBm. Operating at 5 V/160 mA, the unit measured at 1.25" × 1.25" × 30.63" with SMA female connectors on both sides.
RF Bay Inc.
www.rfbayinc.com

PIN Diode Limiter Module

VENDORVIEW



RFMW Ltd. announces design and sales support for Skyworks SKY16601-555LF PIN diode limiter module covering the frequency range of 0.5 to 6 GHz. The SKY16601-555LF addresses a growing need for receiver low noise amplifier (LNA) protection in microwave applications. It is a fully integrated PIN diode, low-threshold limiter module in a 2.5 × 2.5 mm SMT package. Capable of handling 230 W pulsed power, the SKY16601-555LF insertion loss is only 0.1 dB while return loss is specified at 27.5 dB.
RFMW Ltd.
www.rfmw.com

Lowpass Filters

RLC Electronics' high power lowpass filters are designed for high power systems in the frequency range of 100 to 8000 MHz These filters are designed to handle 2500 W average under extreme temperature and altitude conditions, while offering low loss (0.15 dB typical) and 1.5:1 VSWR (max). RLC filters offer the flexibility of choosing cutoff frequency, number of sections and connector type (N, SC, HN, 7/16) for a truly custom high power lowpass product.
RLC Electronics Inc.
www.rlcelectronics.com.

V-Band Eight-Way Power Combiner

VENDORVIEW

Model SWP-50366308-15-C1 is a V-Band waveguide eight-way power combiner that operates from 50 to 66 GHz. The power combiner

exhibits 2 dB insertion loss and 18 dB port to port isolations between non-adjacent ports and 13 dB between adjacent ports in the operational bandwidth. The power combiner possesses excellent phase and amplitude balance. The power combiner is equipped with WR-15 waveguides and UG385/U flanges.
SAGE Millimeter Inc.,
www.sagemillimeter.com

High Voltage Resistors

Stackpole has expanded and improved its MG Series thru hole metal glaze high voltage resistors. The value range for all sizes has been expanded to include values from 1 KΩ up to 1GΩ. In addition, working voltages have been improved and now range from 1.6 KV for the ¼ watt size to 7 KV for the 2 W and mini 3 W sizes. Metal glaze technology provides an inherently moisture proof resistive element and is less expensive than many other high voltage resistor types.

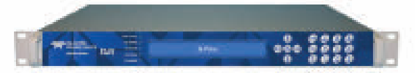
Stackpole Electronics Inc.
www.seielect.com

Wide Bandwidth 4-Way Splitter

The SPD-5-1500 power divider is capable of splitting a signal from 5 to 1500 MHz into four equal signals with not more than 0.7 dB of amplitude unbalance across the band. Featuring the company's RoHS compatible packaging, this splitter is housed in a small surface mount package of 0.8" × 0.4" × 0.2". Other performance specifications include an input power handing of 1 W when used as a power splitter.

Synergy Microwave Corp.
www.synergymwave.com

Satellite Modem and Modulator



Teledyne Paradise Datacom, a business unit of Teledyne Microwave Solutions, launched the Q-FlexV™ broadcast satellite modem/modulator, a solution designed specifically for ASI and IP DVB video broadcasts. Q-FlexV now gives broadcasters a "single-box" modem and modulator solution packed with all the advanced features they need, as well as an unmatched performance-to-price ratio when compared to competing alternatives on the market.

Teledyne Paradise Datacom
www.teledynemicrowave.com

40 dB Dual Directional Coupler

Werlatone offers the Model C9688, a 40 dB dual directional coupler, covering the full 1 to 1000 MHz band. Rated at 800 W CW, the C9688 will operate into 3:1 load VSWR, and is ideal for applications spanning multiple frequencies. This high power design, measures 6" × 2.2" × 2.2" and is designed for military and commercial applications.

Werlatone
www.werlatone.com

Fixed Frequency Synthesizer

Z-Communications Inc. announced a new RoHS compliant fixed frequency synthesizer model SFS1575D-LF in the L-Band. The SFS1575D-LF is a single frequency synthesizer that operates at 1575.42 MHz with a 10 MHz reference and features a typical phase noise of -102 dBc/Hz at 10 kHz offset. The SFS1575D-LF is designed to deliver a typical output power of 5 dBm with a VCO voltage supply of 5 VDC while drawing 20 mA (typical) and a phase locked loop voltage of 3 VDC while drawing 14 mA (typical).

Z-Communications Inc.
www.zcomm.com

Cables and Connectors

TuffSpec Wire

Carlisle introduces TuffSpec™ Wire, the latest addition to its portfolio of ruggedized wires, designed specifically for the demanding oil and gas industry. TuffSpec has been designed for downhole tooling applications, such as perforating guns and acoustical tools for borehole imaging. Manufactured using CarlisleIT's proprietary seamless tape technology, TuffSpec provides the advantages of a tape wrap with the look and feel of an extruded product.

Carlisle Interconnect Technologies
www.carlisleit.com.

Break-Over Type Torque Wrenches

Fairview Microwave Inc. released a new portfolio of break-over type torque wrenches used to precisely fasten connections between components and systems. Fairview Microwave has added a broad range of these break-over type torque wrenches suitable for multiple RF connector types including 1.0, 2.4, 2.92, 3.5, and 7 mm; SC, SMA, SMC, SSMA, SSMC, Type N and TNC designs. These RF torque wrenches are offered with hex sizes (also called bit size) of 5/16", 5/8", 15/64", 5/32", 1/4", 9/16", 13/16", 3/4" and 25/32".

Fairview Microwave
www.fairviewmicrowave.com

Low PIM Adapters and Jumpers

MECA's low PIM (-160 to -165 dBc typ) adapters and jumpers for DAS applications feature industry leading PIM performance of -155 dBc min. Available in 7/16 DIN, Type N to SMA and 4.1/9.5 Mini-DIN connectors. Ideal for IDAS/ODAS, in-building, base station, wireless infrastructure, 4G and AWS applications. Made in the U.S. and 36-month warranty.

MECA Electronics Inc.
www.e-meca.com

Pressurized Connectors

San-tron Inc. released their new, pSeries pressurized connectors which provide low loss, high stability performance through 30 GHz at ±65 psi. These pressurized connectors, which meet the IP68 standard, feature a simplified, three-piece design – body, center contact and an innovative dielectric – eliminating troublesome internal O-rings, gaskets and silicone greases. Pressurized coaxial connectors are vital where high pressure is maintained for extended periods and in environments needing protection against moisture and other contaminates – such as agriculture, aviation and marine applications.

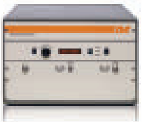
San-tron Inc.
www.santron.com

Amplifiers

Solid-state Amplifiers

VENDORVIEW

With AR's dual band amplifiers, you have freedom like never before. You pick the power from

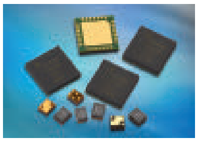


5 to 80 W. You pick the bandwidth from 0.7 to 8 GHz, 0.7 to 10.6 GHz or 0.7 to 18 GHz. AR puts it together for you in one package that costs less, weighs less and takes less space than two separate amplifiers.

AR RF/Microwave Instrumentation
www.arworld.us

RF Power Amplifiers

Four RF power amplifiers – the MGA-43003, MGA-43013, MGA-43024 and MGA-43040 – for small cell base transceiver station appli



cations and a full spectrum of LTE/Wi-Fi coexistence FBAR filters for mobile and wireless infrastructure applications have been added to the proven MGA-43xxx PA family. The small cell PAs address LTE Bands 3, 12, 13, 17 and 40 and the 2.4 GHz Wi-Fi Band. They feature high linearity, gain and power-added efficiency with integrated power detector function.

Avago Technologies
www.avagotech.com

Monolithic Amplifier

VENDORVIEW

Mini-Circuits CMA-545G1+ is a E-PHEMT based low noise MMIC amplifier operating

from 0.4 to 2.2 GHz with a unique combination of low noise and high IP3 making this amplifier ideal for sensitive receiver applications. This design operates on a single +5 V supply and is internally matched to 50 ohms. The MMIC amplifier is bonded to a multilayer integrated LTCC substrate, then hermetically sealed under a controlled nitrogen atmosphere with gold-plated covers and eutectic AuSn solder.

Mini-Circuits,
www.minicircuits.com.

Coaxial and Compact Ka-Band Linear Amplifier

Model AMF-6F-18004000-29-8P is a recent addition to MITEQ's family of low noise, wide-

band, and ultra-small coaxial LNAs in the 18 to 40 GHz band. This LNA has over 35 dB of gain in a housing that is only 0.38" long and 0.75" wide without the field replaceable 2.93 mm connectors. Gain flatness is a maximum of ±3 dB. The AMF-6F-18004000-29-8P has a maximum noise figure of 2.9 dB in the full band, though the typical value is 2.6 dB.

MITEQ Inc.
www.miteq.com

X-Band High Gain Power Amplifiers

VENDORVIEW

Pasternack Enterprises Inc. introduced a new family of coaxial X-Band high gain power amplifiers. These RF amplifiers are typically used as driver or high power output amplifiers in a wide variety of commercial, industrial and military applications including telecom infrastructure, test instrumentation, fixed microwave backhaul, radar systems, communication systems, satellite communications and commercial avionics. Pasternack's new X-Band power amplifiers are packaged inside hermetically-sealed metal enclosures and exhibit outstanding performance in high gain, gain flatness, high linearity and wide dynamic range.

Pasternack Enterprises Inc.
www.pasternack.com

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- Simulating Dynamic Load Modulated Amplifiers: An Alternative Solution to Maintaining Efficiency over a Power Range
- Unleashing 5G mm-waves: A Test & Measurement Perspective
- A Guide to the Design of Laminate PCBs at Microwave Frequencies
- Overview of FEKO Suite 7.0
- Practical Antenna Design for Advanced Wireless Products
- Antenna Measurements in Under 1 Second Using Very-Near-Field Technology
- PCB Material Selection for RF/Microwave/Millimeter-wave Design
- The Design of a 100 W, X-Band GaN PA Module
- Learn How to Select the Right RF Product Solution to Improve Overall Radar Performance
- Current Induced in Si RFIC Substrates by Spiral Inductors and Patterned Ground Shields
- Overcome LTE-A and 802.11ac Manufacturing Test Challenges with Agilent's New EXM
- Analysis of FMCW Radar Signals in Automotive Applications
- Learn to Make Power Amplifier Tests Faster!
- Overcome LTE-A UE Design Test Challenges with Agilent's New UXM
- Design and Simulation of Modern Radar Systems
- PCB Material Selection for High Speed Digital Design
- Improve Overall System Performance with New TriQuint GaN Products
- Recent Developments in Continuous Mode RF PA Design

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- Non-Standard Connection Characterization with ATE Systems
- How to Improve PA Performance and Reliability Using Electro-Thermal Analysis

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- Understanding Low Phase Noise Signals

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- IEEE 802.11ad (WiGig) PHY and Measurement Challenges
- E-Band Wireless Backhaul: System Design and Test Challenges

FieldFox Handheld Analyzers Series
Presented by: Agilent Technologies
- Techniques for Precise Cable and Antenna Measurements in the Field

RF and Microwave Education Series
Presented by: Agilent Technologies
- Techniques for Analyzing Millimeter Wave Signals Using Harmonic Mixing
- EMC Back to Basics

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NewProducts

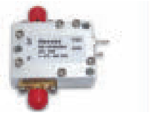
Wideband Power Amplifier

RWP17050-10 is a GaN on SiC wideband power amplifier designed for broadcasting, telecommunication and other applications. This affordable GaN wideband amplifier achieves a typical power gain of 37 dB, and an output power of 50 W over a broadband frequency range from 700 to 2700 MHz. RFHIC has already applied full in/out matching for broadband performance in this compact package.

RFHIC Corp.
www.rfhic.com

0.8 W Power Amplifier

VENDORVIEW



Arrow Electronics Inc. announced immediate availability and full design support capabilities for a new 0.8 W power amplifier from Wavelex. The WPA0409A offers wide frequency band operation, from 470 to 960 MHz, with 50 Ω impedance, and features +29 dBm P1dB, 14 dB gain and +43 dBm IP3. It is versatile for a range of applications, including VHF, UHF, PA driver amplifiers, RF bench test, and fixed wireless communications. The new device is SMA-connectorized and packaged with precision machine housings in Wavelex's IP-3 package.

Arrow Electronics
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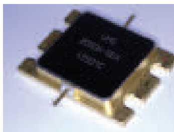
GaN High Power Quasi-MMICs

The CHZ050A-SEA and the CHZ180A-SEB are the first two products launched in a new range of internally-matched GaN high power quasi-MMIC devices that are now available in hermetic thermally enhanced metal-ceramic packages. The CHZ050A-SEA is a 50 Ω input and output internally matched packaged GaN C-Band HPA. It exhibits a high power of 50 W with more than 15 percent bandwidth and features a 12 dB associated gain with > 40 percent PAE, suitable for pulsed radar and satcom applications.



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1 W Broadband Power Amplifier

Model ABP1800-11-3830 is a MMIC based power amplifier offering 38 dB of linear gain and 30.5 dBm typical output power at 1 dB gain compression point over the frequency range from 2 to 18 GHz with excellent gain flatness and VSWR. The amplifier has built-in DC voltage regulator and requires a single +15 V DC power supply. The package size of the amplifier is 1.9" × 1.5" × 0.5".

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Software

FEKO Suite 7.0

VENDORVIEW

FEKO Suite 7.0 sees the addition of a Finite Difference Time Domain (FDTD) solver to its comprehensive set of powerful computational methods as well as the hybridization of the Multilevel Fast Multipole Method (MLFMM) with Physical Optics (PO). Three new import file formats are also now available. FEKO reaches a new milestone with the inclusion of the finite difference time domain (FDTD) solver to its comprehensive set of powerful computational methods

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Test Equipment

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LadyBug Technologies' "Gemini" line of platform-independent RF power sensors consists of five new True RMS sensors with coverage from 9 kHz to 40 GHz. Their exceptional frequency flatness, match and measurement speed are complemented by USBTMC and USBHID

connectivity making them compatible with Linux, Windows and most other computers with a USB port. In addition to the USB IO, the products offer TTL (SPI and I2C) interfaces. The high-accuracy sensors are designed to operate in un-attended applications using their built-in real-time clock and internal storage.
LadyBug Technologies
www.ladybug-tech.com

RF/Microwave Switch Matrix

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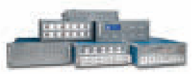

SenarioTek's new standard off-the-shelf RF switch matrix products offer high performance over the broadest range of standard input and output configurations. They offer frequencies from DC to 40 GHz, a wide range of standard configurations, over 10 million switching cycles, delay matching to ± 1 ps, expedited delivery option and a three-year standard warranty.
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Radio Interferometry and Satellite Tracking

Seiichiro Kawase

Worldwide growth of space communications has caused a rapid increase in the number of satellites operating in geostationary orbits, causing overcrowded orbits. *"Radio Interferometry and Satellite Tracking"* was written to help professionals overcome this problem by providing a solid understanding of the use of radio interferometers for tracking and monitoring satellites in overcrowded environments. Practitioners learn the fundamentals of radio interferometer hardware, including antennas, receiving equipment, signal processing and phase detection, and measurement accuracies.

This book describes the nature of the targets to be tracked by the interferometer, helping to clarify the movement of target satellites and what specific information has to be caught by the interferometer. Additionally, engineers find details on applications to practical cases of satellite tracking, covering different types of interferometers, recent technical developments, orbital monitoring and safety control.

This book covers the topic in three parts: 1. radio interferometers, receivers, RF-phase measurements, noise suppression, correlation; 2. satellites in geostationary orbits, fundamentals, Kepler rules, orbit perturbation, station position keeping; 3. Interferometric tracking, orbit estimation and simulation, azimuth-elevation tracking, turnable baseline, differential interferometry.

"Radio Interferometry and Satellite Tracking" gives aerospace and telecommunications engineers very useful practical insight in radio interferometry application for satellite tracking including correlation and reports on 15 years of Japanese, U.S. and ESA experience in these fields. It is a good reference piece on the subject

This review is based on a submission from Dr. Ing. Rudolf Wohlleben.

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IEEE AUTOTEST (formerly known as AUTOTESTCON) is an annual technical interchange meeting sponsored by the Institute of Electrical and Electronic Engineers (IEEE). This year it celebrates 50 years in which it has gathered the military/aerospace automatic test industry together to share new technologies, discuss innovative applications, and exhibit products and services. IEEE AUTOTEST 2014 will be in St. Louis, Missouri, September 15–18, 2014.

The technical program will be determined by the interests of those participants submitting for publication and presenting a high quality technical paper, or organizing a technical session oriented toward an appropriate topic dealing with system readiness, in general, and automatic test technology, in particular. Technical papers are now being solicited, as are proposals for technical sessions, addressing topics such as:

Artificial Intelligence in Test, ATS/TPS Management, BIT/BIST, Closed-Loop Diagnostics, Commercialization of Military Maintenance, Condition-Based Maintenance, Data Acquisition, Diagnostic Maturation, Design-For-Test, Diagnostic Strategies, Fault Tolerant Systems, Future Logistics Approaches, Information Frameworks, Interoperable Test Systems, Maintenance Architectures, Measurement Science and Uncertainty, MEMS Technology, Next Generation Test Systems, Prognostics and Health Management, Remote Diagnostics, Safety Issues, Sensor Technology, Synthetic Instruments, Test Generation, Test Requirements, Test Standards, TPS Transportability, Vehicle Health Management.
Website: **http://www.ieee-autotest.com/**

AUTOTEST 2014 Master Schedule

Activity \ Day		Sunday 14-Sep	Monday 15-Sep	Tuesday 16-Sep	Wednesday 17-Sep	Thursday 18-Sep
Exhibit Hall	Exhibitor Set-Up	1:00 PM – 10:00 PM	8:00 AM – 10:00 PM			
	Exhibitor Access	1:00 PM - 10:00 PM	8:00 AM – 10:00 PM	7:00 AM – 5:00 PM	8:00 AM – 5:00 PM	8:00 AM – 10:00 PM
	VIP Tour			10:00 AM		
	Open to Attendees			10:45 AM – 5:00 PM	10:00 AM – 5:00 PM	9:00 AM – 11:30 AM
	Exhibitor Reception			6:00 PM – 8:00 PM		
	Exhibitor Move Out					12:00 N – 10:00 PM
Registration (Washington Street Lobby)		2:00 PM – 5:00 PM	7:00 AM – 6:00 PM	7:00 AM – 6:00 PM	7:00 AM – 5:00 PM	8:00 AM – 11:00 N
Keynote and Plenary Sessions (Tues) Panel Discussions (Weds) (Renaissance - Landmark Ballroom 1 & 2)				8:00 AM – 11:45 AM	8:00 AM – 10:00 AM	
Product Displays and Demonstrations (America Center - Halls 1 & 2)				10:45 AM – 5:00 PM	10:00 AM – 5:00 PM	9:00 AM – 11:30 AM
Technical Program (America Center Rooms 100, 101, 104 and 105)			8:00 AM – 5:00 PM Seminars	1:00 PM – 5:00 PM Technical Sessions	10:00 AM – 5:00 PM Technical Sessions	8:00 AM – 11:30 AM Technical Sessions
Refreshments () * Landmark Ballroom /** Technical Paper Area	Morning		** 7:00 AM – 11:00 AM	* 7:00 AM – 10:30 AM	* 7:00 AM – 9:00 AM ** 9:00 AM - 11:00 AM	** 7:00 AM – 11:00 AM
	Mid-Afternoon		** 2:30 PM – 5:00 PM	** 2:30 PM – 5:00 PM	** 2:30 PM – 5:00 PM	N/A
Luncheons			12:00 N – 1:00 PM (Room 102 - Seminar attendees only)	12:00 N – 1:00 PM (Exhibit Hall 1 & 2)	12:00 N (Renaissance Hotel - Statler Ballroom)	
Wednesday Dinner (Renaissance - Statler Ballroom)					6:00 PM	

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Satellite [sat-l-ahyt]

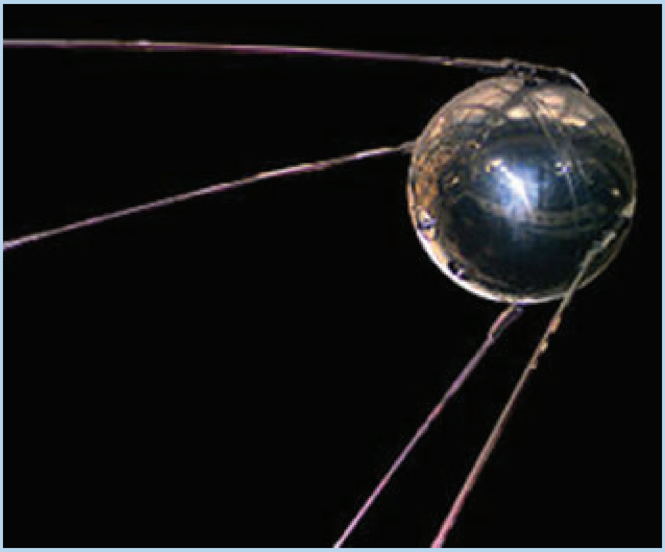
A satellite is an artificial object, which has been intentionally placed into orbit. Common types include military and civilian Earth observation, communications, navigation, weather and research. Satellite orbits vary greatly, depending on the purpose of the satellite, and are classified in a number of ways including low Earth orbit, polar orbit and geostationary orbit.

1945 English science fiction writer Arthur C. Clarke, "Space Odyssey: 2001", provides a detailed description of the possible use of communications satellites for mass communications in a wireless world letter to the editor entitled, "Peacetime Uses for V2".

1955 John R. Pierce of AT&T's Bell Telephone Laboratories elaborates on the utility of a communications "mirror" in space that includes a medium-orbit and a 24-hour-orbit "repeater."

1957 The Soviet Union opens the space age with the launch of Sputnik 1, the world's first artificial satellite.

1958 The United States launches its first artificial satellite, Explorer 1, from Cape Canaveral, Fla. Congress passes the Space Act a few months later, officially creating NASA.



1961 NASA awards a competitive contract to RCA to build a medium-orbit (4,000 miles high) active communication satellite (RELAY). AT&T builds its own medium-orbit satellite (TELSTAR) on a cost-reimbursable basis with NASA. NASA commissions Hughes Aircraft Co. to build a 24-hour (20,000 mile high) satellite (SYNCOM).

1976 AT&T and COMSAT launch the first of the COMSTAR series, to be used for voice and data, but television quickly became a major user.

1979 The UN International Maritime Organization sponsored the establishment of the International Maritime Satellite Organization (INMARSAT) in a manner similar to INTELSAT.

1987 Motorola conceives the Iridium satellite constellation, consisting of 66 active satellites in low Earth orbit. Iridium provides voice and data coverage to satellite phones, pagers and integrated transceivers over the entire surface of the Earth.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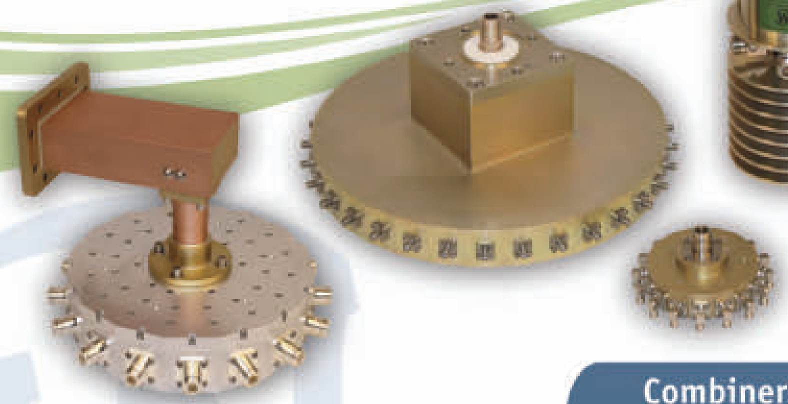

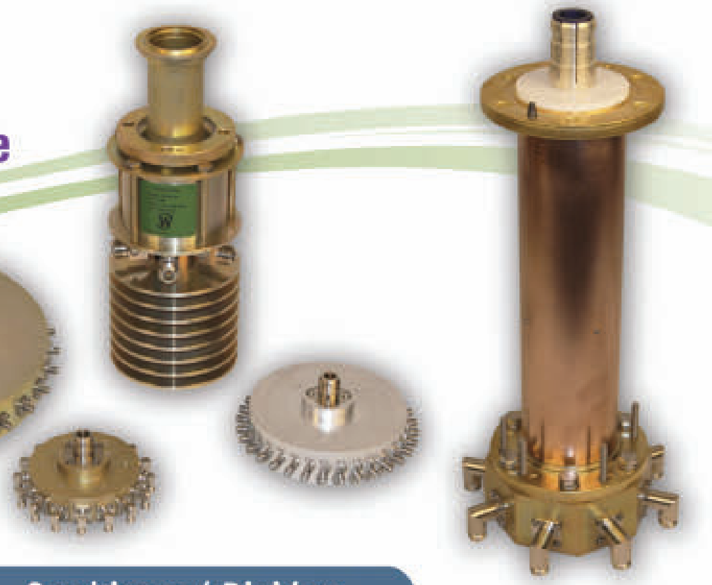

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D9710	8-Way	1000-2500	2,000	0.3	1.40:1	1 5/8" EIA, N Female
D9529	8-Way	2305-2360	1,000	0.2	1.15:1	7/16 Female, N Female
D9528	8-Way	2305-2360	2,000	0.2	1.15:1	7/8" EIA, N Female
D5320	12-Way	470-860	500	0.3	1.30:1	All N Female
D9194	16-Way	2305-2360	1,000	0.2	1.15:1	7/16 Female, SMA
D9527	16-Way	2305-2360	2,000	0.2	1.15:1	7/8" EIA, N Female
D9706	16-Way	2700-3500	6,000	0.35	1.35:1	Waveguide, N Female
D6857	32-Way	1200-1400	4,000	0.5	1.35:1	1 5/8" EIA, TNC

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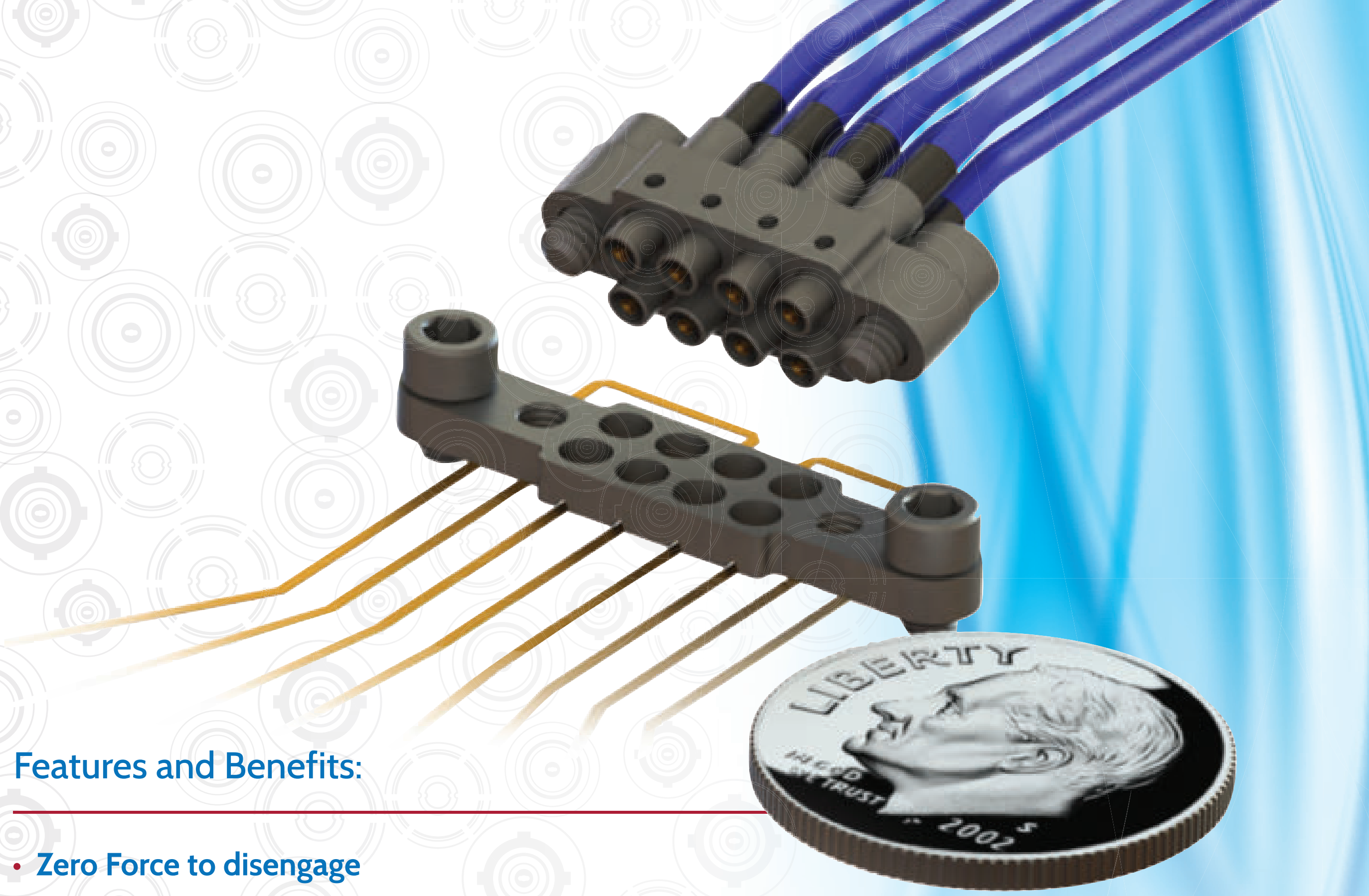

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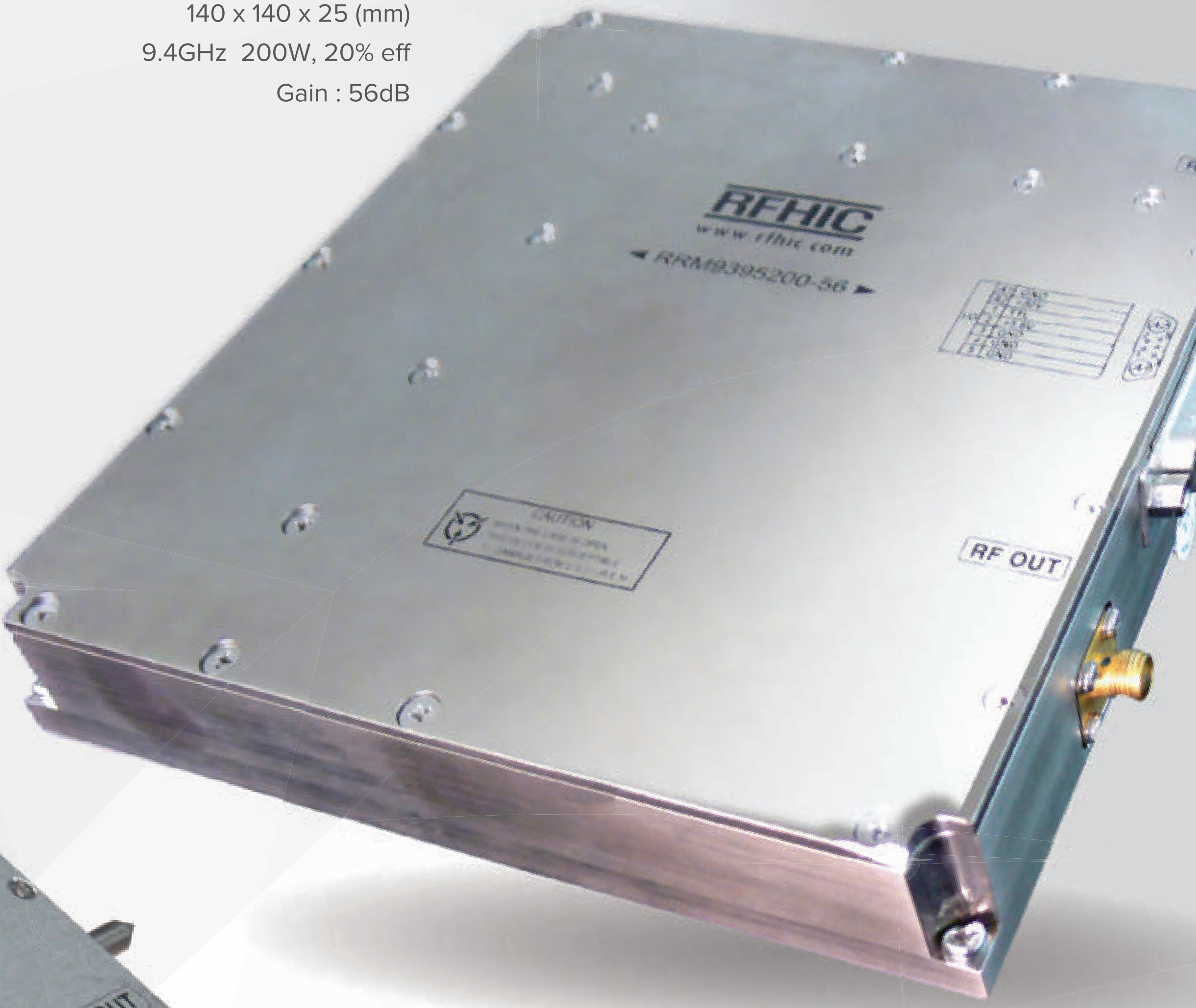

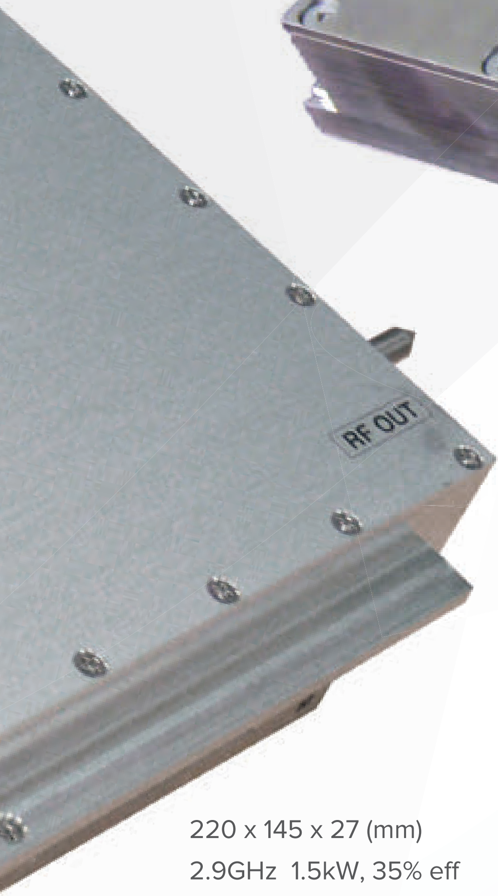

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Modular Platform Approach for UWB Radar System Design and Verification Challenges

Bertalan Eged, Raffaele Fiengo and David A. Hall
National Instruments, Austin, Texas

Ever since the 1940s, the design of radar systems has been subject to continuous innovation and experimentation. Today, radar systems use technology ranging from ultra-wide bandwidths (UWB)[1] to phased arrays and even passive radar. Some of the emerging technologies under investigation from the radar community include: cognitive radar[2], waveform diversity[3] and compressive sensing.[4] In addition, multifunction radars, such as DMPAR,[5] can be employed for meeting the requirements of multiple scenarios and challenges.

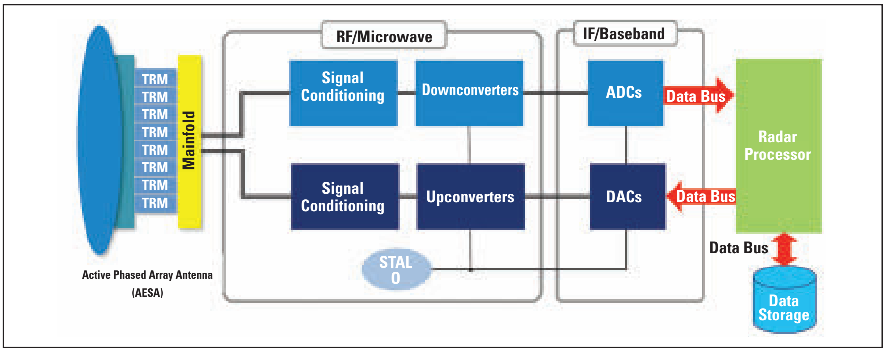
In the defense industry, there is a continuous contest between radar and electronic support measures (ESM) systems. Radar scientists are looking for new technologies that will improve the low probability of intercept (LPI) properties of radar and prevent ESM receivers from detecting and classifying signals transmitted by radar. In these applications, the requirement of ambiguity-free radar has increased interest in noise or pseudo-noise radar systems[6] that use digital transmitters and receivers with hundreds of MHz of instantaneous bandwidth.

UWB radar technology remains an attractive technology because of its ability to increase obstacle detection and tracking resolution of traditional radar systems. More importantly, UWB systems do this while spreading power over a wider signal bandwidth. As a result, they inherently transmit a lower power in any narrow band and reduce the likelihood of detection. IEEE Standard 686[7] defines ultra-wideband as any signal that either occupies more than 25 percent of the bandwidth of the carrier (called 'percentage bandwidth') or has a bandwidth greater than 500 MHz.

This article will discuss some of the design and test challenges associated with UWB radar systems with a focus on system verification and RF testing, trends in radar architecture, approaches to system design and prototyping, and typical RF measurements.

EVOLUTION TO SOFTWARE-DEFINED ARCHITECTURES

As the design of modern radars has adopted an increasingly sophisticated software-defined architecture, advanced signal processing algorithms have become an essential element of modern radar systems. ***Figure 1*** illustrates a general block diagram of a modern radar system. In this figure, high sample rate digital-to-analog converters (DAC) and analog-to-digital converters (ADC) support wide input signal



▲ *Fig. 1 Software defined radar systems.*

bandwidth. In microwave radar systems, these components enable wide instantaneous bandwidths of the radar system. In some cases, use of high sample rate DACs and ADCs also enables the design and deployment of direct sampling transmitters and receivers for L-Band radars.

In phased array radar systems, having multiple channels of the analog signal conditioning and ADCs/DACs is a key requirement. In these applications, providing tight synchronization between these elements using low-phase noise local oscillators and sampling clock sources is crucial to ensuring a high degree of system performance.

In addition to synchronization between channels, today's software defined radio systems require synchronization within elements of the processing chain, including DDCs, DUCs and channelization algorithms. The ultra-wideband architecture use of a large number of channels, in conjunction with high sampling rate converters, produces an immense amount of data. As a result, transferring this data (often multiple gigabytes/sec) introduces additional challenges in the system architecture design and verification.

The software-defined approach to radar system design is an important enabling technology in modern radar system design because it allows the engineers and scientists to continually evolve radar systems with new waveforms and architectures. As a result, engineers are increasingly adopting software defined radio platforms as a design tool for next-generation radar algorithms.

DESIGNING MODERN RADAR SYSTEMS

The instantaneous bandwidth requirements of modern UWB radar systems add considerable difficulty to the challenges of designing and prototyping modern radars. For example, with signal bandwidths of up to 500 MHz, the data associated with the single physical channel ranges from 2 to 4 GB/s – depending on ADC and DAC resolution. Not only do these extremely high data rates present a significant challenge in the design of the deployed radar, but they also introduce significant challenges when

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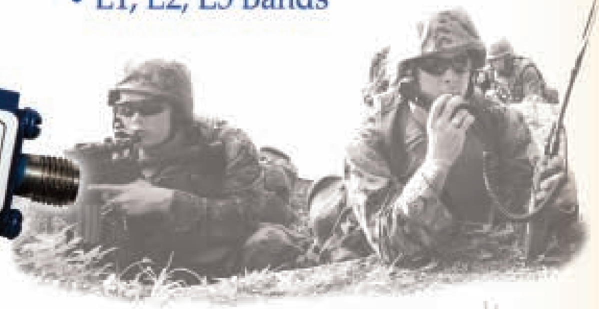

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prototyping. In order to better understand these challenges, it is worth explaining the typical design process used in the design of a radar system and how engineers are dealing with the large amount of data that modern radar systems produce.

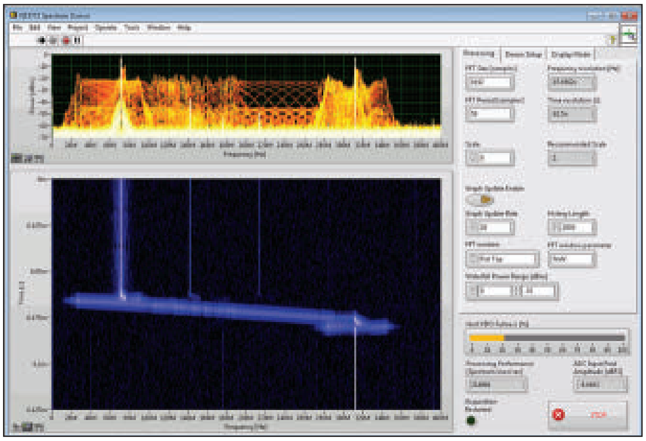
Historically, radar systems had typically been designed and integrated by a small team of hardware engineers. However, today's increasingly complex, software-defined radar systems require a mix of software, digital and analog designers. As a result, engineers face an increasing need for a highly integrated tool chain that enables them to prototype radar systems early during the design process.

An increasingly common approach to radar system verification and prototyping is the use of software defined radio technology to design and test the signal processing algorithms used in modern radar systems. When developing such systems, engineers are tasked with the challenge of designing and testing signal processing algorithms, often before the front end design is complete. An increasingly common approach to radar validation is to use instrumentation as the radio front end to validate the behavior of signal processing.

VALIDATING RADAR SIGNAL CHARACTERISTICS

Validating radar subsystems or building prototypes using instrumentation requires extremely wideband instrumentation. Not only can engineers use instrumentation to validate the behavior of complex radar signals, but they can also use it to emulate the behavior of the radar itself at either baseband or RF frequencies.

For example, consider the use of real-time spectrum analysis tools to validate the creation of a hopped or chirp waveform. At baseband frequencies, one can use an IF digitizer such as the NI PXIe-5624R IF with up to 1.7 GHz of analog bandwidth with a digital downconverter capable of up to 800 MHz of instantaneous bandwidth. Engineers can use this instrument or similar ones as either as an IF digitizer connected to existing RF front ends or as a direct sampling digitizer in L-Band radar systems. At RF frequencies, engineers can use a vector signal analyzer (VSA) such as the NI PXIe-5668R VSA that has more than 500 MHz of RF bandwidth at frequencies up to 26.5 GHz. As illustrated in ***Figure 2***, both of these instruments offer real-time spectrum analysis capabilities that execute a wideband FFT on samples. As a result, the behavior of a radar pulse can be validated using displays such as the persistence plot or the real-time spectrum analyzer.



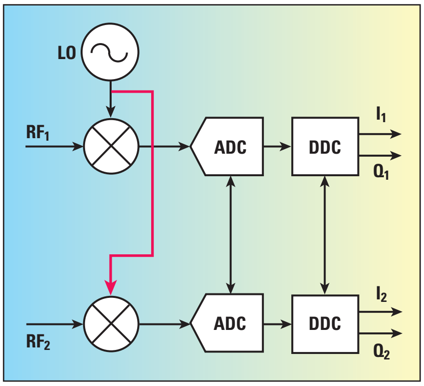
▲ *Fig. 2 Analyzing radar chirp on a real-time spectrum analyzer.*

MULTI-CHANNEL ANALYSIS

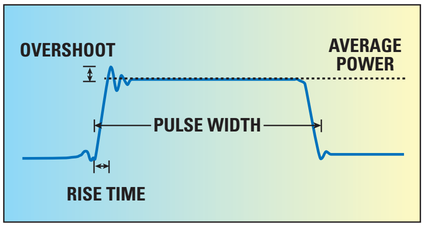
A second key verification technique of advanced UWB radar systems is the use of multi-channel instruments to verify radar behavior. Modern radar systems, that often use active electronic scanned array (AESA) technology, are increasingly utilizing multi-channel architectures. Common multi-channel implementations include phased-array and multiple-input multiple-output (MIMO) radar systems with co-located antennas.

Although the two approaches use similar radio configurations, there is a distinct difference between phased-array and MIMO radar systems. A phased-array radar transmits scaled versions of the same waveform whereas a MIMO radar system transmits different waveforms from different transmit antennas in order to achieve a large virtual array size.[2] Due to the constraints of MIMO radar design, several alternate transmission schemes have attracted much interest including: FDMA, TDMA, randomized TDMA, Doppler DMA and slow-time CDMA.

The complexity of multi-channel radar systems creates significant challenges for engineers tasked with verifying the performances of the radar system. In fact, phase-coherent RF signal acquisition systems require sophisticated synchronization technology to ensure that each downconverter/digitizer shares all timing signals, including local oscillators (LO), sample clocks and start triggers. As we observe in ***Figure 3***, a two-channel RF signal analyzer requires each channel to share a common LO.



▲ *Fig. 3 Architecture of a simplified two-channel RF signal analyzer.*

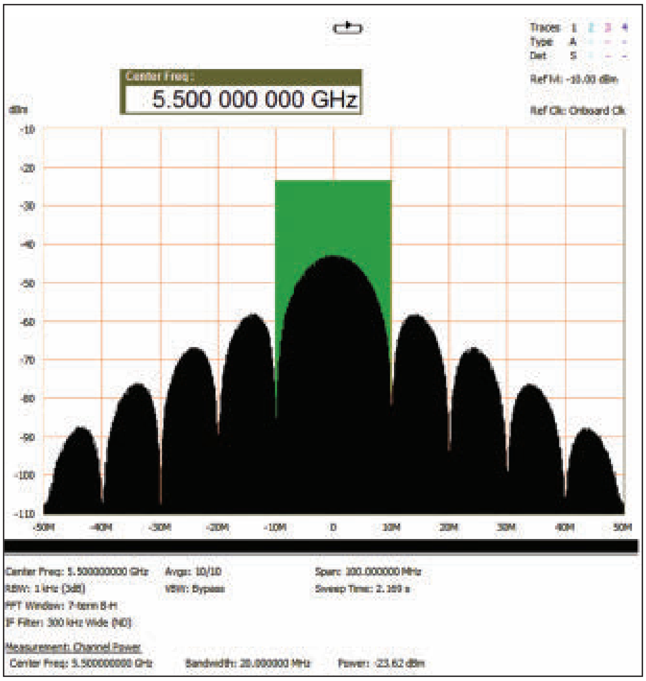


▲ *Fig. 4 Typical radar pulse measurements.*

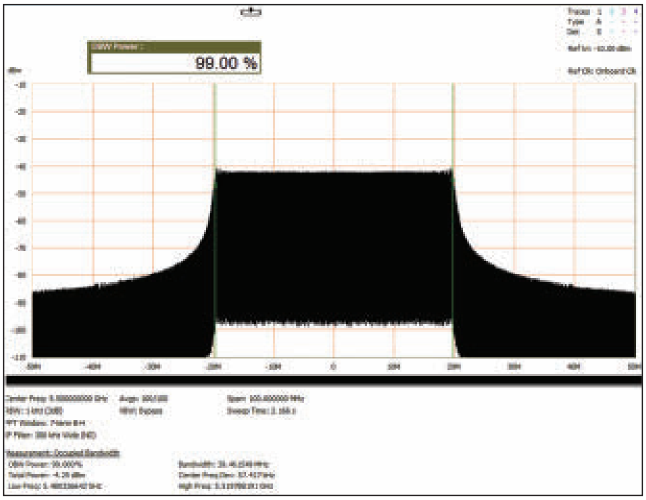
Modular instruments such as PXI have become an increasingly popular approach to testing multi-channel radar systems because of their native support of tight channel-to-channel synchronization. For example, up to 16 IF channels of a digitizer can easily be synchronized in a single PXI chassis. At RF frequencies, modular PXI RF signal analyzers feature the ability to share local oscillators between each channel. As a result, using multiple PXI chassis, it is possible to synchronize 2, 4, 8 or even more RF channels using the native synchronization characteristics of PXI.

RADAR TESTING

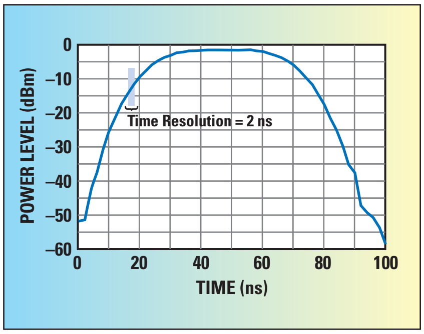
A final challenge of modern UWB radar testing is associated with the bandwidth requirements of wideband



▲ *Fig. 5 Main power lobe of a 50 ns pulse is contained within a bandwidth of 20 MHz.*



▲ *Fig. 7 Example FM chirp occupying approximately 40 MHz of bandwidth.*



▲ *Fig. 6 Time domain of a 50 ns pulse using 500 MHz of instantaneous bandwidth.*

pulsed transmissions. Today's radar systems can require extremely wide bandwidths either through extremely short pulse widths or through pulse compression. Common radar pulse measurements include rise time, fall time, overshoot and pulse width. Although extremely short pulses with a shorter pulse repetition interval (PRI) improve radar resolution (at the expense of range), they inherently require RF signal analyzers with very wide instantaneous bandwidth. All of these measurements, illustrated in ***Figure 4***, are performed using the zero span mode of an RF signal analyzer, which displays power as a function of time.

Pulsed radar signals are typically characterized by a sinc function in the frequency domain. As a result, when measuring extremely wide pulses, wide instantaneous bandwidth is required to accurately measure rise time. In ***Figure 5***, observe the frequency domain of a 50 ns pulse. The main power lobe of a 50 ns pulse is contained with 20 MHz of bandwidth. However, substantial power exists in each of the adjacent side lobes. Thus, accurately measuring pulse time also requires capturing the side lobes as well. A general rule of thumb for measuring pulse rise time is that the instrument's instantaneous bandwidth must be three times wider than 1/rise time.

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For example, in order to measure pulse rise times as low as 6 ns, the required instrument instantaneous bandwidth would be 3/(6 ns) or 500 MHz. In ***Figure 6***, we observe the same 50 ns pulse from Figure 5 in the time domain using 500 MHz of instantaneous bandwidth. This configuration shows the rise time of 20 ns given an extremely wide bandwidth and short time-domain resolution of 2 ns.

In addition to measuring short pulse rise times, engineers are increasingly using wideband instruments to test the effectiveness of pulse compression algorithms. Pulse compression techniques such as an FM chirp, shown in ***Figure 7***, can be an extremely effective mechanism to spread transmission power over an extremely wide bandwidth. However, the use of increasingly wide modulation bandwidths for modern pulse compression techniques can often push the measurement limits of modern RF signal analyzers.

For example, because an FM chirp spreads signal power over frequency, it is important to measure power variation over the duration of the pulse to ensure that transmitted power is not frequency dependent. In a traditional spectrum analyzer in swept mode, approximate pulse power is measured by averaging spectrum over a large number of traces and scaling the measured power according to the duty cycle of the transmission.

However, modern wideband vector signal analyzers often allow engineers to capture an entire wideband pulse in a single acquisition. Using this technique, engineers can measure power versus frequency and time more accurately, as well as measure additional pulse characteristics such as the linearity of an FM chirp or characterize LPI signals.

CONCLUSION

The needs and challenges of the design and verification of UWB radar systems require engineers to use sophisticated tools for radar design and test. Today, engineers are using a combination of advanced software and hardware that includes complex scenario generators, wideband signal analyzers and multi-channel modular instruments. These tools allow engineers to quickly prototype and validate advanced radar systems using a common set of hardware. ■

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A Cost-Effective Approach to Simulation for Electronic Warfare Systems

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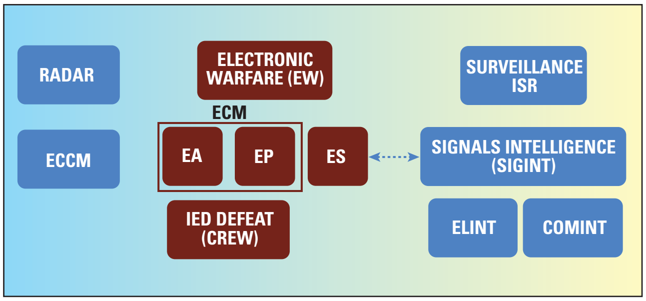
Electronic Warfare (EW), in general, involves denying an enemy use of the Electromagnetic Spectrum (EMS) or gathering intelligence of an enemy's intended actions or capabilities through analysis of electromagnetic (EM) signals they may transmit, either intentionally or unintentionally. Simulation of the spectral environments encountered by an EW system in the field is a complex undertaking and the need for an effective and validated operational test capability cannot be underestimated, while tight budgets introduce a new dimension of complexity. This article discusses the EW environment, the EW test and evaluation process, and off-the-shelf alternatives for simulation requirements.

EW comprises three areas of application: Electronic Attack (EA), Electronic Protection (EP) and Electronic Support (ES) and operates with other types of systems – specifically Intelligence, Surveillance and Reconnaissance (ISR), and radar (see ***Figure 1***). Electronic attack includes jamming of threats using everything from high power barrage techniques to selective deception techniques that offer the advantage of not jamming your own side's systems as well as your adversaries. Weapon systems are also part of electronic attack in the form of High Speed Anti-radiation missiles (HARM) in addition to actively transmitting decoys. Electronic protection involves managing the spectrum you are using to find clear and safe areas of operation and to ensure your own systems are not overly vulnerable to electronic attack from your adversaries. It also involves control of your own emissions such that your own sig-



▲ *Fig. 1 The application space and sub-elements of EW.*

nals don't provide a beacon for enemy fire. Electronic support includes systems that are termed Electronic Support Measures (ESM) that provide threat warning, Signal collection and cataloging, and direction finding (DF) where we'll use the adversary's emissions to locate them.

Radar can pose a threat in the form of a tracking or fire-control radar or a radar signal from a guided missile. The EW system must identify the threat and take mitigating action. Collectively this is known as electronic countermeasures or ECM. Processing by the radar and the actions to overcome ECM or jamming are known as electronic counter-counter measures or ECCM.

The EW application and specifically ES is closely related and overlaps with the SIGINT or signals intelligence area. The collection, identification and cataloging of various threat signals is a critical part of the EW process and receivers are specifically designed to support this mission. SIGINT is divided into several different sub-areas depending on the type of signals in which we are interested. ELINT and COMINT are the two largest with ELINT or electronic intelligence covering radar signals and COMINT dealing with communications signals.

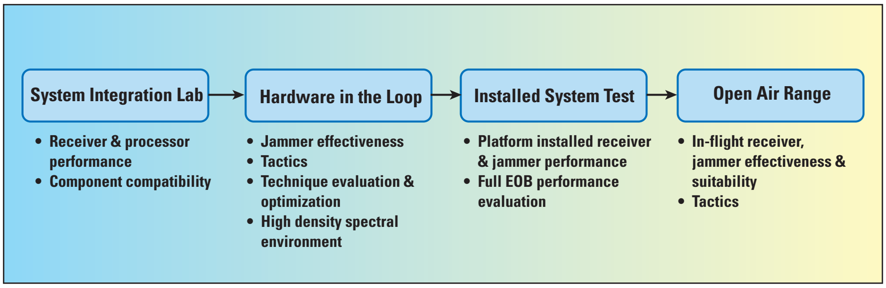
ELECTRONIC ORDER OF BATTLE

There are many terms, abbreviations and acronyms associated with EW technology and operations. One that warrants a closer look is the EOB or Electronic Order of Battle. This refers to all the activity in the EM spectrum occurring at any given time in the theater of a conflict. Generating an EOB requires the identification of all emitters in an area of interest using SIGINT techniques to determine their geographic locations or ranges of mobility, characterizing their signals, and wherever possible, determining their roles in the broad organization and configuration of the conflict. The EOB details all known combinations of emitters and platforms in a particular area of responsibility for both sides of the conflict. The simulation and analysis systems that provide this capability are large and expensive. The magnitude of the signal environment they are designed to simulate drives complexity, making them difficult to modify and program. The solution described here is somewhat simpler but also less capable. The assumption is that many of the steps in the test and evaluation process of different types of EW systems do not need to simulate an entire electronic order of battle but various subsets at any one time.

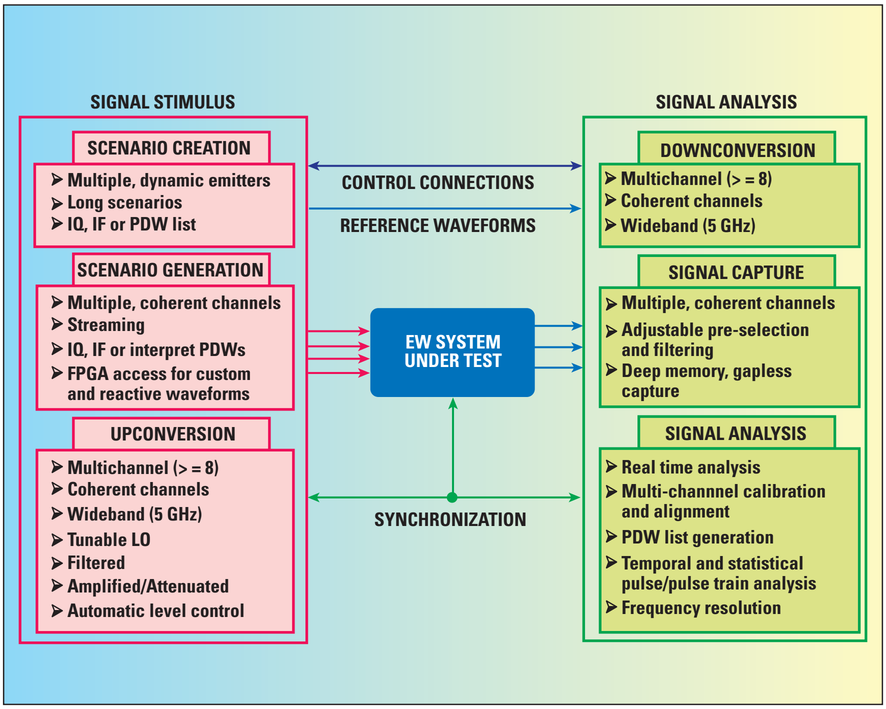
One example of an EW system we want to characterize the performance of is the Radar Warning Receiver (RWR). The primary purpose of the RWR is to issue a warning when a radar signal that might be a threat is detected. The warning can then be used, in conjunction with other systems, to manually or automatically evade the detected threat. Radar warning systems are often capable of classifying the source and type of radar by the signal's strength, phase and waveform type.

EW SYSTEM TEST AND EVALUATION

The test and evaluation of an EW system involves several distinct steps (see ***Figure 2***) that progress through different levels of integration with the system by itself and then the system within the host platform such as an



▲ *Fig. 2 The EW system test and evaluation process.*



▲ *Fig. 3 The basic building blocks of an off-the-shelf EW simulation and analysis solution.*

aircraft or ship. As we move up this continuum of integration the simulation becomes more complex until a full EOB environment is simulated or operational testing is conducted in the field or on a test range. It starts in the systems integration lab where we ensure the various components and subsystems interoperate together and that system performance meets specification in terms of RF and environmental parameters. The next step is hardware-in-the-loop (HWIL) testing where the full EW system is stimulated with a high fidelity RF scenario providing a simulation of the operational spectral environment to functionally characterize its performance. This is also a good point at which to optimize EW algorithms and evaluate different jamming tactics. After HWIL testing, the system is installed on the operational platform(s) and functionally stressed in a full EOB environment. Finally, testing moves to an open air range to ensure high performance operation in all situations using a variety of tactics. This stage of testing is very costly and the also the least repeatable, so it is critical to push as much of the evaluation activity as possible to the earlier stages of the test process.

The types of test systems and measurements methods used through the process vary beginning with the use of discrete off the shelf instruments in the system integration lab such as spectrum and network analyzers, oscilloscopes and signal generation equipment. Moving into the HWIL stage a higher degree of automation is applied to construct the needed spectral scenarios, synchronize measurements and record results. At the installed system test facility generally large and somewhat customized test systems are used to generate the very complex and dynamic spectral environment required. At the open air range a variety of equipment is employed from off the shelf instruments to customized automated systems.

Complex multi-emitter simulators are well suited for EW testing in a complex electromagnetic environment and perhaps an entire EOB; however they can be overkill for simple and iterative system integration and HWIL testing or RWR/ESM threat identification evaluation. Scheduling time on such a system may be difficult as such an expensive asset may be in use up to 24 hours a day. ***Figure 3*** shows the elements required in an EW test system to support a variety of EW receivers and jammer types. These elements can be realized with current off the shelf technology. The core of the simulation side of the system is the arbitrary waveform generator (AWG) enabling playback of any waveform file that can be generated mathematically with software or recorded. Multiple coherent AWG channels may be needed to provide appropriate environment simulation for distributed aperture systems. Upconversion to the frequency range of operation is a critical step in the simulation process as the fidelity of the signals must be maintained.

Often the signal scenarios used for EW testing are long and take time to evolve. Waveform memory will be used up quickly when bandwidths are wide and sample rates are high. This means a huge amount of waveform memory beyond what is available internal to the AWG may be required to play the scenario. Different methods of streaming the waveform data may be employed to expand the possible signal scenario length to seconds, minutes or hours. The waveform data could be stored on a deep memory device such as a RAID (redundant array of independent disks) that allows access to a very large memory space. The rate at which data can be streamed is generally limited by the interface between the AWG and the RAID such that the signal bandwidth is well below what is needed for a wideband multi-emitter simulation. Another method is to describe the different pulsed signals contained within a waveform by their temporal parameters such as pulse width and amplitude. This becomes a compressed set

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A recent study conducted for the aerospace industry showed that more than 29 percent of microwave assemblies fail during installation, and aircraft manufacturers have accepted the practice of simply replacing them. However, with the need to decrease costs, they can no longer afford the total cost associated with assemblies that cannot withstand the installation process and the extreme conditions of aerospace. Manufacturers need assemblies that provide the same level of electrical performance before and after installation as well as throughout their service life.

Performance Testing with an Installation Simulator

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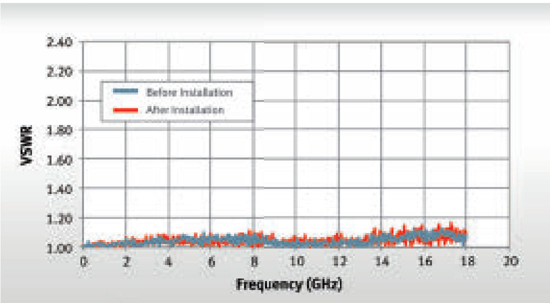
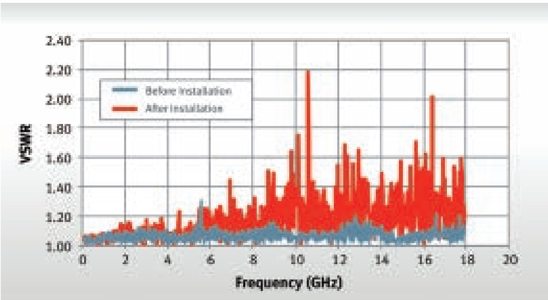
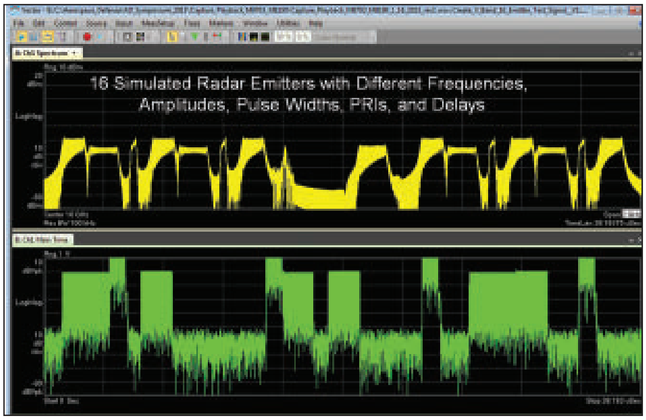
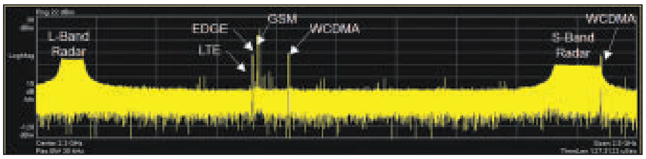


Alternative Airframe Assembly VSWR





▲ *Fig. 4 16 radar emitter waveforms combined and generated from a single AWG channel.*



▲ *Fig. 5 Mixed communications and radar emitters combined into a single waveform file.*

of information of what is termed pulse descriptor words (PDW) which are much more manageable, particularly for off-the-shelf tools.

Multiple threat emitters with different characteristics are shown in ***Figure 4***. Here the 16 unique signals have different frequencies, amplitudes, bandwidths and pulse repetition intervals (PRI). The drawback of adding multiple uniquely modulated emitters to a single AWG waveform file is that the dynamic range of the generated signal will be reduced.

Figure 5 shows a measured multi-emitter spectral environment on an oscilloscope using vector signal analysis (VSA) software. The L-Band radar signal is on the far left. Several communication signals including LTE, EDGE, GSM, and WCDMA signals are near the middle of the spectrum, and the S-Band radar signal is on the far right. A second WCDMA signal has been placed within the S-Band radar's bandwidth. This will allow potential interference effects between the radar signal and the WCDMA signal to be investigated using the VSA software. These various emitters were generated using a single AWG by combining multiple waveform files created using both SW tools and recordings. This was all accomplished using off-the-shelf equipment and software tools.

CONCLUSION

Very sophisticated threat signal and scenario simulation can be produced using commercially available off-the-shelf equipment and software tools; however, there are limitations when attempting to create scenarios with a very large number of threat emitters. In this case, a more costly custom system capable of generating perhaps thousands of emitters may be needed; but for many simpler EW simulation needs, a cost effective solution is right there waiting on the shelf. ■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Co-existence Tests for S-Band Radar and LTE Networks

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Air traffic control (ATC) radar, military air traffic surveillance (ATS) radars and meteorological radars operate in the S-Band frequency range. The excellent meteorological and propagation characteristics make the use of this frequency band beneficial for radar operation – but not just for radar. These frequencies are also of special interest to 4G wireless communications systems such as UMTS long-term evolution (LTE). The test and measurement of co-existing S-Band radar systems and LTE networks is absolutely essential, as performance degradation of mobile devices and networks or even malfunction of ATC radars has been proven.

The Third Generation Partnership Project (3GPP) and standardization body behind LTE started its work on this new technology back in 2004. Four years later, in December 2008, the work on the initial version of the standard was finished and published as part of 3GPP Release 8 for all relevant technical specifications. As of February 2014, 263 LTE networks are on air in 97 countries. The majority of Time-Division (TD) LTE frequency bands are in the S-Band frequency range where ATC, ATS and meteorological radars operate. A dedicated co-existence study for TD-LTE and S-Band radars is therefore recommended.

This article describes potential issues concerning S-Band radar systems and LTE networks from base stations, mobile devices and radar operating in close proximity to one another. It addresses frequency allocation of these systems, explains the performance degradation or malfunction that can be expected and describes measurement solutions for interference testing of radar and LTE networks. Measurements completed at airports demonstrate possible interference and significant performance degradation of both radar systems and LTE networks.

SPECTRUM ALLOCATION

The S-Band has been defined by IEEE as all frequencies between 2 and 4 GHz. Besides aviation and weather forecast, several other maritime radars worldwide also operate in this frequency band. LTE is supposed to operate in two different modes, frequency division duplex (FDD) and time division duplex (TDD). Both duplex modes use different frequency bands worldwide. The latest version of the LTE standard specifies a total of 29 frequency bands for FDD and 12 frequency bands for TDD.

Table 1 lists the LTE FDD frequency bands, whereas the ones in the S-Band frequency range are marked in light blue. The frequency bands that are fairly close to any op-

TABLE I

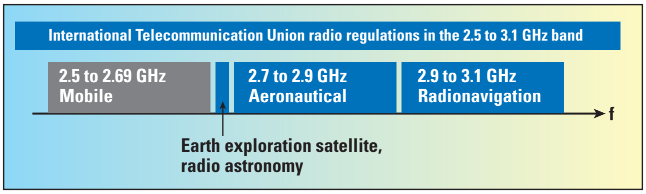
LTE FDD FREQUENCY BANDS; FREQUENCY BANDS WITHIN THE S-BAND ARE MARKED IN BLUE

E-UTRA Band	Uplink in MHz	Downlink in MHz
1	1920 to 1980	2110 to 2170
2	1850 to 1910	1930 to 1990
3	1710 to 1785	1805 to 1880
4	1710 to 1755	2110 to 2155
5	824 to 849	869 to 894
6	830 to 840	875 to 885
7	2500 to 2570	2620 to 2690
8	880 to 915	925 to 960
9	1749.9 to 1784.9	1844.9 to 1879.9
10	1710 to 1770	2110 to 2170
11	1427.9 to 1447.9	1475.9 to 1495.9
12	699 to 716	729 to 746
13	777 to 787	746 to 756
14	788 to 798	758 to 768
17	704 to 716	734 to 746
18	815 to 830	860 to 875
19	830 to 845	875 to 890
20	832 to 862	791 to 821
21	1447.9 to 1462.9	1495.9 to 1510.9
22	3410 to 3490	3510 to 3590
23	2000 to 2020	2180 to 2200
24	1626.5 to 1660.5	1525 to 1559
25	1850 to 1915	1930 to 1995
26	814 to 849	859 to 894
27	807 to 824	852 to 869
28	703 to 748	758 to 803
29	N/A to N/A	717 to 728
30	2305 to 2320	2345 to 2360
31	452.5 to 457.5	462.5 to 467.5

erational S-Band radar system are highlighted in dark blue. One of the highlighted bands in Table 1 is Band 7, which is used throughout Europe. Due to the rapid deployment of base stations and the addition of small cells to increase system capacity, for example at airport terminals; the co-existence of LTE base stations and ATC radar is of major interest.

Another example in terms of LTE and radar co-existence is the anticipated commercialization of the 3.5 GHz spectrum in the U.S. by the Federal Communications Commission (FCC). The FCC hosted a technical workshop this past January that explored the possibilities of using 100 MHz of spectrum in the 3550 to 3650 MHz band for small cell deployment based on shared spectrum access.[1] Today, this spectrum is owned by the Department of Defense (DoD) and is being used, for example, by maritime radar.[2]

The 2.5 to 2.69 GHz band is allocated by terrestrial mobile services organized in two 70 MHz blocks of paired spectrum (FDD) and one 50 MHz block of unpaired spec-



▲ *Fig. 1 International Telecommunication Union radio regulations in the 2.5 to 3.1 GHz band.*[3]

trum (TDD), see ***Figure 1***. With FDD, the uplink communications frequencies that could be used by the mobile device to transmit to the base station are allocated from 2500 to 2570 MHz. The 2570 to 2620 MHz block is reserved for TDD, and the 2620 to 2690 MHz block is intended for the downlink, where the base station would transmit to the mobile device. 3GPP adopted these frequencies as band 7 (FDD) and as band 38 (TDD). The 2.7 to 2.9 GHz frequency band is primarily allocated to aeronautical radio navigation, i.e., ground-based fixed and transportable radar platforms for meteorological purposes and aeronautical radio navigation services, shown in Figure 1.

Carrier frequencies of the radars mentioned are assumed to be uniformly distributed throughout the S-Band.[4] As depicted in Figure 1, the two frequency bands for mobile communications and aeronautical radio navigation are located very close to each other. As an example, some ATC radar systems operate at 2.7 to 2.9 GHz; others, such as the AN/SPY-1 radar operated by the U.S. Navy, operate at a frequency of 3.5 GHz. Most of these types of radar apply pulse and pulse compression waveforms.

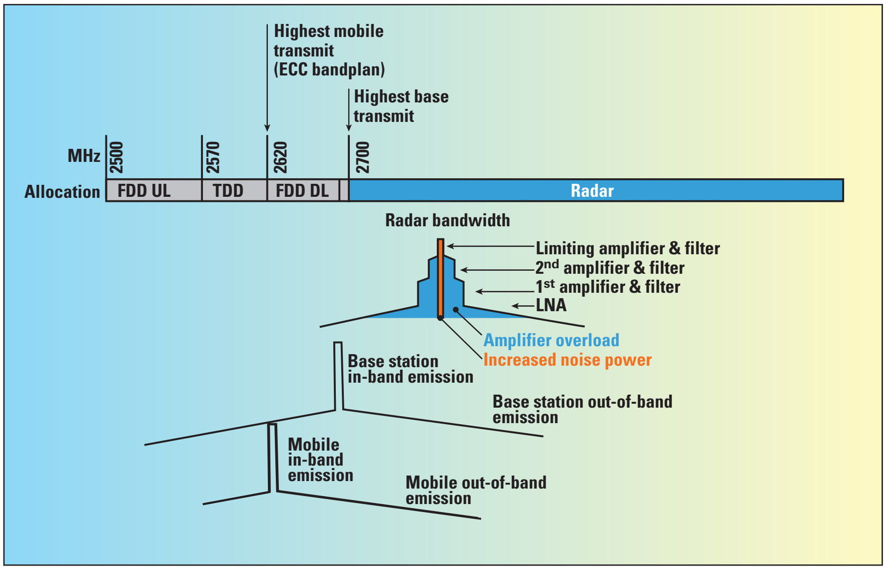
After pulse transmission, the radar switches from transmitter to receiver and receives the radar echo pulses from targets inside the observation area. Receivers use low noise front ends because echo signal power is extremely low. This high sensitivity makes receivers susceptible to interference signals. LTE networks using nearby frequencies can cause these interferences and may significantly degrade the radar performance.

CO-EXISTENCE OF LTE AND S-BAND RADAR

Disturbance of LTE networks may occur through S-Band radar, such as degradation of performance due to lower throughput, indicated by an increasing block error rate (BLER). On the first view, this is not a major drawback, but spectral efficiency, power reduction and cost are of great importance for any mobile network operator.

3GPP specifications find solutions, e.g., dynamic frequency selection or transmit power control, in order not to disturb other signals. However, radar parameters such as transceiver bandwidth, spurious emissions, transmit power, transmit antenna pattern, polarization and waveform may limit the performance of mobile services, because these systems obey different regulations.

ITU Recommendation M.1464-1[4] mentions ATC radar systems operating in mono-frequent or frequency diversity. The RF emission bandwidth of these radars ranges from several kHz to 10 MHz while transmitting power of up to 91.5 dBm. Since the mobile network has standardized filtering in line with 3GPP, disturbance must not occur. Yet measurement results show that 4G user equipment and base stations are influenced by radar signals and should be tested to ensure proper functionality, efficient power and spectrum usage.



▲ *Fig. 2 Radar amplifier chain in the frequency domain and out-of-band and in-band interference.*

On the other hand, the presence of LTE signals and less selective filters in the radar receiver can cause significant interference or even damage to the radar system. This may be indicated by false target detection or by the high power state of the receiver protector. The latter can occur when LTE signals and spurious emissions are very strong and received by the radar. In the case of weaker signals or signals outside the nominal receiver bandwidth, the radar could go into compression and produce nonlinear responses or react by raising the constant false alarm rate (CFAR) threshold (see ***Figure 2***). Targets that are present can thereby be lost in consecutive measurements and targets with low power echoes cannot be detected.

The performance degradation depends strongly on the type of signal disturbing the radar. Continuous-wave or noise-like modulation signals with constant power disturb azimuth sectors of the radar in which the interferer is located. Pulsed interference strongly depends on synchrony with the radar and the design of the receiver, signal processing and mode of operation, e.g., frequency agile radar systems may be less influenced than non-frequency agile ones.

Interference entering the receiver chain and finally the detector of the radar is depicted in Figure 2. While in-band interference will raise the noise floor, out-of-band interference may overload the amplifiers and decrease the signal power. Either way, the signal-to-noise ratio (SNR) of a target echo signal at the detector is reduced, which is why the probability of detection is reduced.

According to 3GPP Technical Specification (TS) 36.101 and TS 36.104, LTE base stations are allowed to transmit a maximum of 46 dBm with additional antenna gain of approximately 15 dBi. Antenna height may be up to 30 m above ground. To estimate the disturbance of radar caused by mobile services, technical radar parameters such as radar receiver sensitivity, noise figure, recovery time, bandwidth, antenna pattern and polarization have to be known.

The large variety of radar systems, their inherent design and technical parameters cause different and nearly unpredictable reactions to LTE signals in their environment. Additionally, antenna steering direction and output power of base stations can increase radar interference. Radar, as an extremely security-relevant system, therefore has to be tested in the presence of 4G networks.

TEST SOLUTIONS AND MITIGATION

Test and measurement solutions have been developed to apply different synthetic as well as recorded signals to both LTE networks and S-Band radar systems. These test solutions allow verification of proper functionality and, in the case of interference or even malfunction, development of mitigation techniques.

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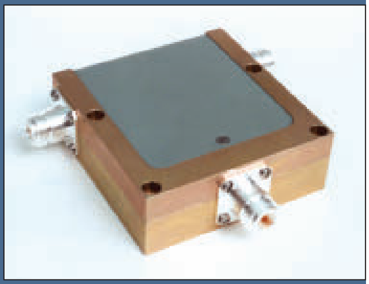

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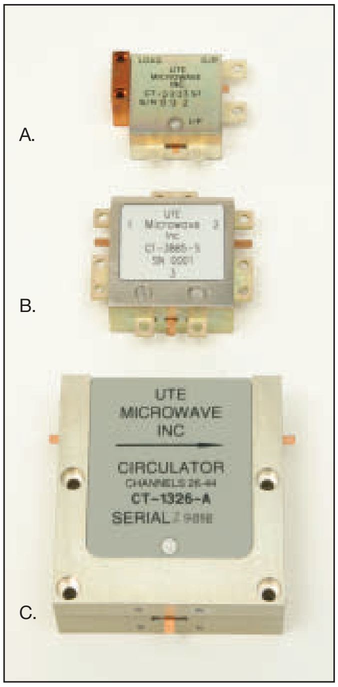

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CT-3838-N	5 Kw Pk 500 W Av	N Conn.	2.7–3.1 GHz
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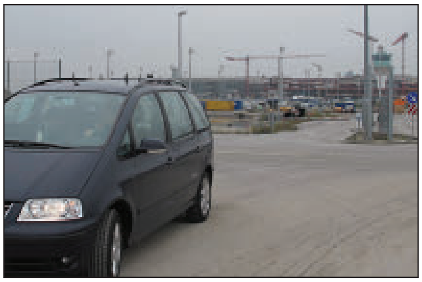


Fig. 3 *Vehicle with measuring equipment recording I/Q data at a German airport.*

Performance and Interference Testing of LTE Terminals

For chipset and wireless device testing, a wideband radio communication tester is widely used. Engineers use it for protocol, signaling and mobility tests as well as for RF parametric tests of transmitter and receiver performance of a mobile terminal. 3GPP has defined multiple test cases for all three test areas: protocol/signaling, mobility and radio resource management (RRM), as well as RF conformance.

This ensures minimum compliance with the current 3GPP standard. However, the majority of receiver and performance tests for LTE only assume the presence of another LTE signal or 3G signals, such as WCDMA (UMTS). There are no tests defined by 3GPP for the presence of an S-Band radar signal in adjacent frequencies to the received signal from an LTE base station.

In order to test real-world conditions, it would be beneficial to record an S-Band radar signal and play it back on an adjacent frequency while performing a throughput test or receive sensitivity test on an LTE-capable terminal that is, for example, operational in Band 7 (detailed description in reference 8). The ATC radar signal from an airport could be recorded. Therefore a universal network scanner would be tuned to the desired S-Band radar frequency to capture the RF signal, perform the downconversion and thus convert the RF signal to I/Q data. ***Figure 3*** shows a picture taken at the airport recording an ATC radar signal.

The recorded I/Q data can now be used in the lab and played back as an arbitrary waveform (ARB) using the embedded signal generator functionality in the wideband communication tester. At the same time, the wideband communication tester acts as a network emulator, simulating an LTE cell at e.g. frequency Band 7, where the device under test (DUT) registers in (see ***Figure 4***).

To carry out a co-existence test, the recorded radar signal can now be applied during a receive sensitivity level test of the DUT, while measuring the BLER for a given LTE signal. To verify the above assumptions of LTE and S-Band radar interfering with each other, several measurements were carried out. The recorded radar signal that was used for these tests originated from an operational ATC radar at a distance of approximately 1.5 km from a major German airport.

As described, the I/Q data is played back using ARB functionality embedded in the wideband radio communication tester at a carrier frequency of 2.69 GHz and in a second test at 2.693 GHz. The measured radar transmitted consecutive pulses at different frequencies using a total bandwidth of 10 MHz. As the radar rotates during operation, radar signals arrive at the receiver in an equidistant time of 1.1 ms (see ***Figure 5***). In the measurement data, a maximum power level of 0 dBm was detected by the spectrum analyzer, and the total SNR varied between 10 to 70

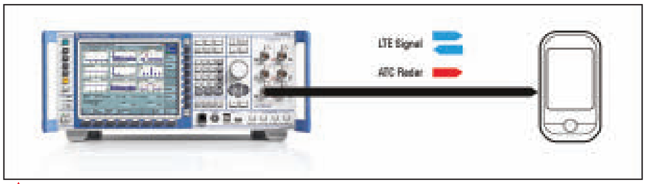


Fig. 4 *Test setup for LTE and S-Band radar co-existence tests, using a wideband radio communication tester.*

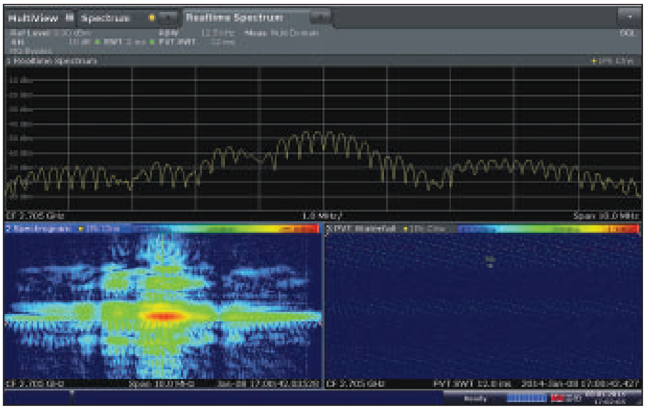


Fig. 5 *Captured S-Band radar signal (10 MHz) analyzed with R&S FSW signal and spectrum analyzer in real-time mode.*

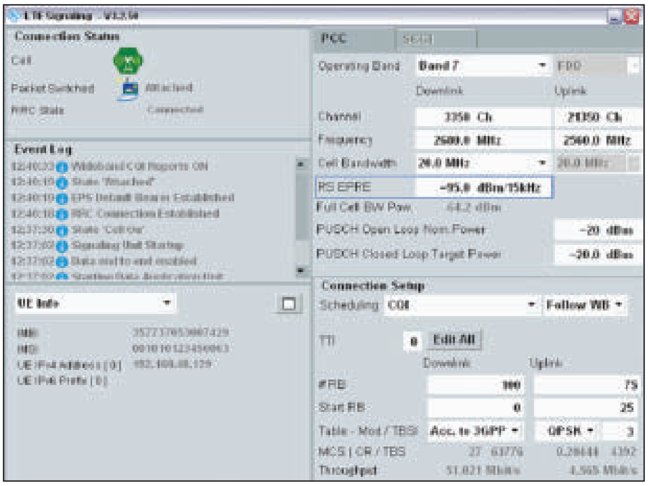


Fig. 6 *LTE signaling configuring for modified reference sensitivity level test (BLER measurement).*

dB depending on the measurement position.

To analyze receiver performance of an LTE-capable terminal in the presence of an S-Band radar signal, the receive sensitivity level test estimated with help of a BLER measurement and described in section 7.3 in 3GPP's TS 36.521-1 for UE RF conformance was adopted and slightly modified. The test described in this section requires the device to transmit at maximum output power, which is defined for LTE for all commercial frequency bands with +23 dBm.

In addition, the orthogonal channel noise generator (OCNG) on the downlink has to be enabled to emulate other users being active within this bandwidth. In general, the receive sensitivity test is designed to verify QPSK modulation only for a full resource block (RB) allocation in the downlink, but no MIMO. Dependent on the frequency band and bandwidth being tested, the reference sensitivity level varies.

For Band 7 and 20 MHz, it corresponds to a reference signal power level of -91.3 dBm full cell bandwidth power. In the

uplink, an allocation of 75 RB is used with an offset of 25 RB and is as close as possible to the downlink. The following sensitivity test is based on a BLER measurement. The wideband radio communication tester counts the reported acknowledged (ACK) and non-acknowledged (NACK) data packets, from where an average throughput is calculated.

For the test, specific test signals (reference measurement channels (RMC) for the downlink and uplink), are standardized. These test signals allow a maximum throughput based on the specified signal configuration in terms of bandwidth allocated, modulation scheme being used and transport block size (TBS). The standard test is only specified for QPSK modulation, where the maximum achievable throughput is relatively low, compared with any higher-order modulation scheme. Higher modulation schemes would require a better SNR.

Any interference would impact the achievable throughput using, for example, 16QAM and/or 64QAM – which would result in a much higher BLER and a much lower throughput. To verify this assumption, the standardized test in 3GPP TS 36.521-1, section 7.3, was changed in such a way that the scheduling type was changed from RMC to channel quality indicator (CQI) and, in particular, follow wideband CQI mode (see ***Figure 6***). This ensures more real-world conditions during the tests.

With this test method the LTE device measures the channel quality on the downlink signal using the embedded reference signals. The measured signal receive quality is translated to a CQI value that is reported back to the network. The scheduler in the LTE base station can now use this feedback to basically adopt the resource allocation, modulation and coding scheme being used based on actual channel conditions as seen by the device. This results in better performance, namely average throughput.

In terms of any interference present, the device would measure a lower received signal quality, translating into a lower CQI value being reported, which would result in the usage of a lower modulation and coding scheme by the base station. ***Figure 7*** shows the results for the first test without the radar signal being present. There was 100 percent acknowledged packets with an average throughput of 13.29 Mbit/s achieved.

In comparison, ***Figure 8*** shows the result for the reference sensitivity level test with the radar signal being present at a carrier frequency of 2690 MHz at an output power of -7.00 dBm, comparable to the power levels measured at an airport. All other test parameters are the same. The NACK rate has increased to almost 3 percent and there is a massive drop in data throughput (blue curve, upper graph) in the presence of a pulse radar signal. The throughput drops when the radar signal points toward the mobile terminal.

For the second measurement, the power level of the base station was increased to -83 dBm/15 kHz. As depicted in ***Figure 9***, the block error rate increased even for a higher output power for the LTE downlink signal. Additional tests showed that the throughput and CQI decreased even when the radar was operating at a frequency of 2700 MHz, depending on the DUTs.

The results presented in Figures 8

and 9 show that there are co-existence issues when an LTE-capable terminal has an active data connection running and comes close to an S-Band radar signal. In the real world, the receive power levels of the serving LTE base station might even be lower than the ones used in the test, in which case we would see a higher BLER resulting in lower throughput or even connection loss and thus impacting mobile services.

▲ *Fig. 7 Reference sensitivity level test (BLER measurement) without S-Band radar signal present.*

▲ *Fig. 8 Modified reference sensitivity level measurement (BLER) while S-Band radar signal is present.*

▲ *Fig. 9 BLER measurement with S-Band radar signal present.*

Radar Interference Test

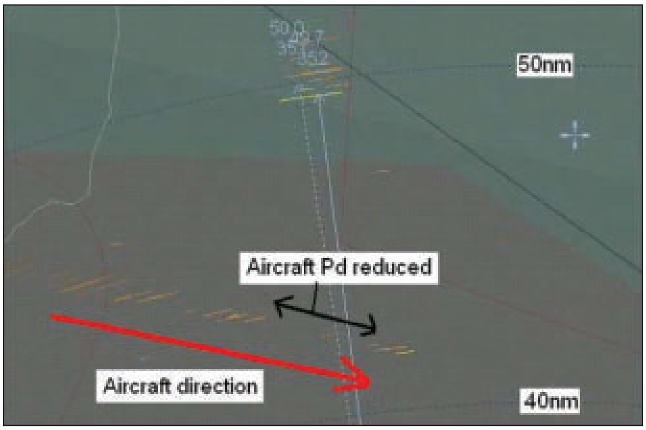
When a radar system is being designed or a 2.6 GHz base station is being set up, several aspects have to be considered to ensure efficient functionality, robustness and co-existence of both systems. For test and measurement, an interference test system for S-Band radar systems to counter interference from LTE signals (see ***Figure 10***) was developed.[5]

The system is able to generate realistic 4G scenarios in the frequency range of 2.496 to 2.69 GHz, including the generation of multiple base and mobile stations. The test system can be set up at a distance of 100 to 300 m in front of a radar system that is in normal operating mode. The radar operator is then able to immediately test and measure the ATC radar in the presence of LTE signals.

Measurements performed using the radar test system have shown that out-of-band and in-band interference mechanisms can become critical and cause ATC radar to become blind in certain azimuth sectors and under certain conditions, e.g., when broadcasting an LTE[6] or WiMAX™ [7] signal towards the radar. This reduces the probability of detection and causes the radar to lose targets. Reference 6 addresses "challenging case" and "typical case" scenarios of 4G networks at airports and describes mitigation techniques.

Dominant interference occurs due to both mobile and base stations, which cause the noise floor to rise. Reference 7 describes tests in which the radar was disturbed using continuous-wave and pulsed signals. The study shows degradation in the probability of detection depending on the applied signal. ***Figure 11*** shows where the probability of detection (Pd) is reduced due to the presence of a 4G signal; the aircraft even disappeared from the radar screen.[7] Due to these results, co-existence of radar and 4G networks should be tested.

▲ *Fig. 10 Radar interference test system R&S TS6650.*



▲ *Fig. 11 4G signal at 2685 MHz.[7]*

Mitigation Techniques

Different approaches can mitigate disturbances on radar and 4G base stations. One approach is to reduce transmit power at the base station and radar. However, this would reduce the maximum range of the radar and coverage of the base station. Another approach would be to increase frequency separation or distance between the two services, but frequency selection may be impossible due to technical restrictions. There are also less expensive techniques, such as not pointing mobile service base station antennas towards S-Band radar. Basic approaches involve improving receiver selectivity, filtering transmitter signals, and reducing unwanted spurious emissions on both sides. These steps would allow co-existence. In order to validate mitigation techniques, test and measurement is necessary.

CONCLUSION

Up-and-coming 4G networks such as LTE and WiMAX™ operate in the 2.6 GHz frequency band, as well as ATC S-Band radar systems. To ensure proper functionality of the radar and efficient 4G networks, co-existence has to be proven. The tests and measurements explained in this article were conducted at airports to test radar as well as LTE mobile terminals in the presence of disturbing signals and found that performance degradation can occur on both sides. This causes reduced probability of detection of the radar and reduced throughput of 4G mobile networks. ■

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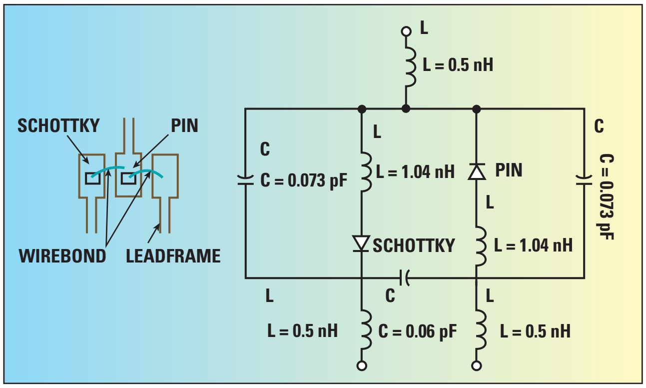
Low Loss Configuration for Integrated PIN-Schottky Limiters

Chin Leong Lim
Avago Technologies, San Jose, Calif.

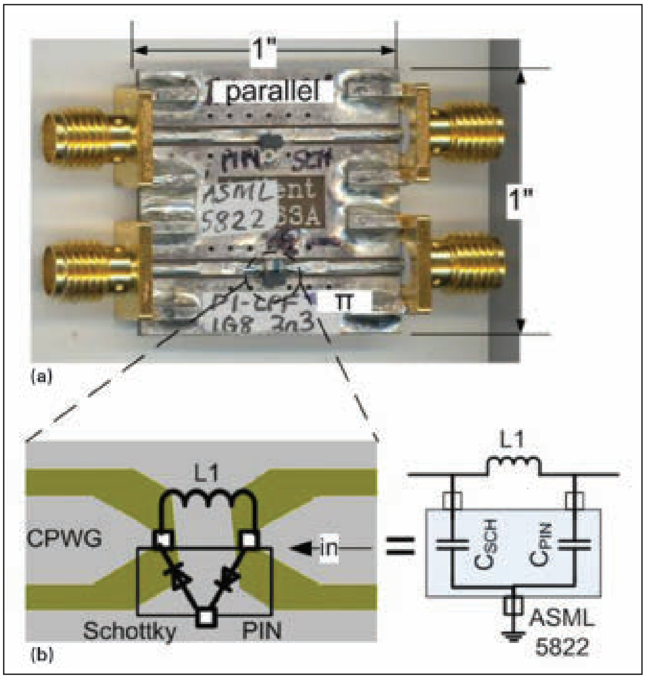
The Schottky-PIN limiter provides better receiver protection than a PIN diode-only limiter because it has a ~10 dB lower limiting threshold; however, its insertion loss has a strong impact on the overall noise figure because it typically precedes the gain stages. The extra diode in the Schottky-PIN limiter results in higher loss than the PIN diode-only limiter. The main loss contributors are the diodes' parasitic capacitances, which load the signal path. In addition, the use of low cost, plastic packaged diodes introduces substantially more loss than either bare chips or hermetically packaged diodes.

Aside from reducing diode parasitic capacitance by either stacking[1] or mesa construction,[2] limiter loss can be minimized using circuit techniques. The loading effect of the Schottky diode on the RF path can be reduced with either a high-impedance, quarter wavelength line[3] or a directional coupler,[4,5] but these passive components add to either the size or cost, and furthermore, they detrimentally increase the limiting threshold. A new design recently demonstrated that a PIN-Schottky limiter's insertion loss can be improved by integrating the two discrete diodes' parasitic capacitances into a lowpass ladder network.[6] The ladder configuration preserves the low limiting threshold, but requires that the PIN diode have two anode connections.

Traditionally, the PIN-Schottky limiter is fabricated using separate diodes, but we recently combined two diodes in a SOT-323 package to achieve greater miniaturization[7] and demonstrated its viability in a microwave limiter application.[8] The three-pin package, however, limits the PIN diode to one anode connection (see ***Figure 1***). To reduce the insertion loss of microwave limiters fabricated with this device, a lowpass π configuration for absorbing the parasitic capacitances was devised. This article summarizes resulting performance improvements using the lowpass π configuration in a 1.8 GHz limiter.



▲ *Fig. 1 SOT-323 packaged PIN-Schottky diode pair (left) and package equivalent circuit model.*



▲ *Fig. 2 Test fixture for evaluating the PIN-Schottky diode pair (a); External inductor (L1) forms a π lowpass network with diodes' parasitic capacitances (b).*

TABLE I

SCHOTTKY DIODE'S SPICE PARAMETERS

Parameter	Mean
n	1.067
Is (A)	1.48E-8
Rs (Ω)	7.8
Cj0 (pF)	0.649
BV (V)	26.7

TABLE II

PIN DIODE'S APLAC PARAMETERS

Parameter	Mean
R_{MAX} (kΩ)	5
I_S (A)	3.80 E-10
N	1.77
TT (ns)	70
C (pF)	0.6
A	0.0337
K	0.513
R_{MIN} (Ω)	0.35
L (nH)	2

HYBRID LIMITER WITH PIN AND SCHOTTKY DIODES

The PIN diode, which forms the signal-attenuating half of the limiter component, can be functionally described by its 1.5 μm I-layer and a 100 μm diameter.[9] The first dimension determines the limiter's turn-on threshold,[10] transient response time[11] and spike leakage;[12,13] whereas, the second dimension caps its power dissipation. The APLAC simulation parameters (see ***Table 1***) complete the PIN diode description. The Schottky diode, which constitutes the signal detecting half of the limiter component, can be described by a 250 mV barrier height at 1 mA[14,15] and a set of SPICE parameters (see ***Table 2***).

Electrical connections between the diode chips and the package leads are made using a combination of conductive epoxy and bond-wires (see Figure 1). A low thermal resistance of 150°C/W, achieved by attaching the diode chips directly to the copper lead-frame, improves power dissipation. The package leads and bondwires contribute ~0.5 and ~1 nH, respectively, to the component's equivalent circuit model. The plastic encapsulation adds ~73 fF parasitic capacitances across the diodes. Measured at the package terminals, the PIN and Schottky diodes' zero bias capacitances at 1 MHz are ~0.9 and ~0.7 pF, respectively. When the two diodes are connected in parallel in the limiter circuit, they present a combined ~1.6 pF capacitance in shunt with the RF path.

EVALUATION FIXTURE

The evaluation fixture consists of a 30 mil thick FR-4 PCB containing two 50 Ω co-planar waveguide (CPWG) with ground transmission lines (see ***Figure 2***). The first line is continuous, but the second line has a narrow gap in the middle. The PIN-Schottky diode pair mounted on the continuous line acts as an experimental control; the circuit arrangement, two diodes connected in parallel, is the one originally envisaged for this component. The second PIN-Schottky diode pair is mounted on the gapped line with its adjacent leads straddling the gap. The diodes' capacitances form the shunt arms of a lowpass π network. A chip inductor L1, which bridges the same gap, forms the series arm. Following the norm for this class of limiter, the PIN diode side is defined as the signal input.

SIMULATION

Through simulation, L1 is optimized for minimum loss at the operating frequency. To model the PIN-Schottky diode pair, APLAC and SPICE parameters from Tables 1 and 2 are combined inside the symbol X3 in ***Figure 3a***. The frequency of 1.8 GHz is chosen for evaluation because it is the device's upper limit. ***Figure 3b*** shows that an inductance of 3.2 nH results in the lowest insertion loss (~0.4 dB), while the best return loss occurs at a slightly higher inductance of 3.4 nH. The physical realization uses a standard value of 3.3 nH from the Toko LL1608 series.

The limiter circuit containing the paralleled diodes is represented by the condition L1 = 0. A higher loss of 1.2 dB is obtained with the diodes mounted in parallel following the datasheet's recommendations. The results include an estimated fixture loss of 0.25 dB.

EXPERIMENTAL RESULTS

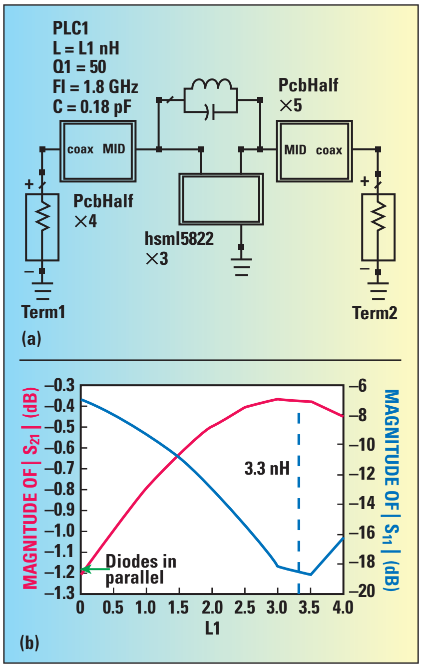
Experimental results confirm im-

proved performance of the π configuration over the parallel connection (see ***Figure 4***). After 0.25 dB of fixture loss is removed from the raw data, a 0.9 dB difference is recorded between the two configurations at 1.8 GHz. Despite optimization at 1.8 GHz, improvement is maintained over a 1 GHz bandwidth.

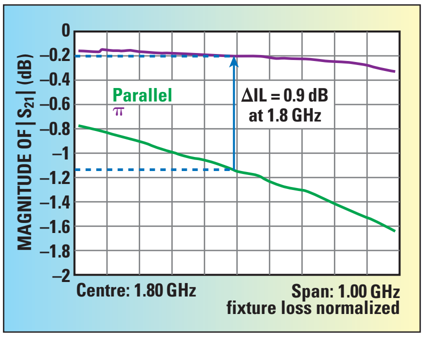
The π configuration can be optimized for reduced loss at other frequencies via L1, however, in addition to increasing insertion loss with frequency, isolation also degrades. Isolation degrades with frequency due to parasitic inductance in series with the PIN diode. This particular Schottky-PIN pair has ~2 nH of parasitic series inductance (see Figure 1). This limits its isolation to approximately 8 to 10 dB at 1.8 GHz. Components with lower parasitic inductance should produce better performance at higher frequencies.

The π-configured limiter is also significantly less reflective than the parallel-connected ‘control’ (see ***Figure 5***). At 1.8 GHz, the π configuration achieves ~13 dB lower return loss than the control. The largest improvement occurs at ~2.4 GHz or ~33 percent higher than the design frequency, although we are not able to explain the responsible mechanism.

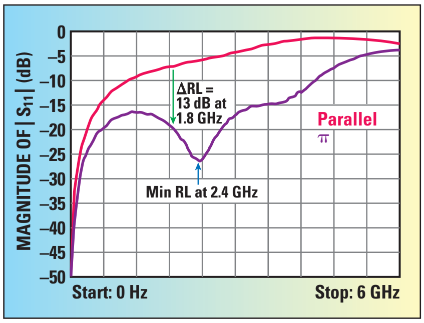
The measured noise figure of a



▲ *Fig. 3 Simulation shows lower loss for the π configuration at 1.8 GHz (a); simulated results (b).*



▲ *Fig. 4 New configuration reduces 1.8 GHz insertion loss by 0.9 dB.*



▲ *Fig. 5 New configuration increases 1.8 GHz return loss by 13 dB.*

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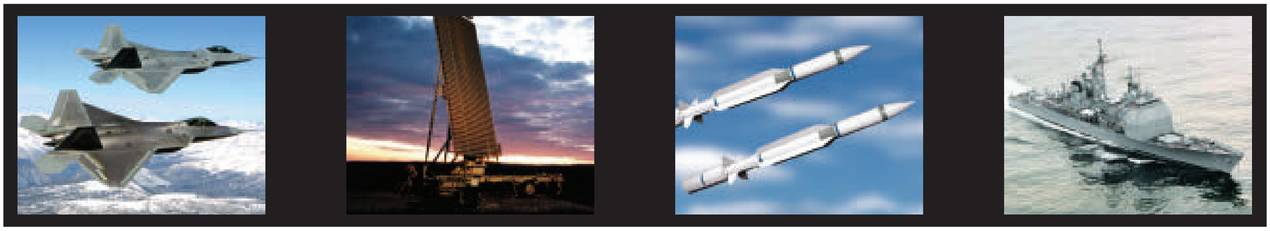

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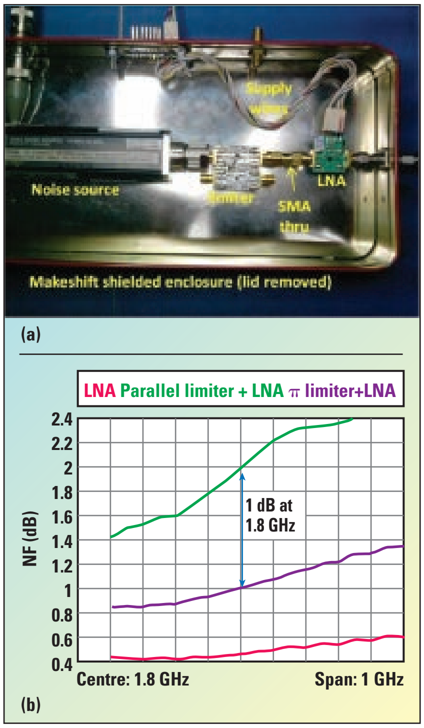
cascaded limiter and low noise amplifier (LNA) confirms the π configuration's lower loss. The test setup replicates the configuration of a limiter to protect an LNA input. The 1.8 GHz LNA uses a MGA-634P8 GaAs ePHEMT MMIC[16] and has a ~ 0.5 dB NF at its connectors.[17] The first combination of π limiter and LNA achieves ~1 dB NF, whereas, the second combination consisting of a parallel limiter and the LNA is significantly noisier at ~2 dB NF (see ***Figure 6***). The difference between the two can be predicted from the limiters' insertion loss. In a final product, the cascaded NF should be < 0.8 dB because the limiter fixture and the SMA 'through' adapter add ~0.25 dB loss to the experimental results.

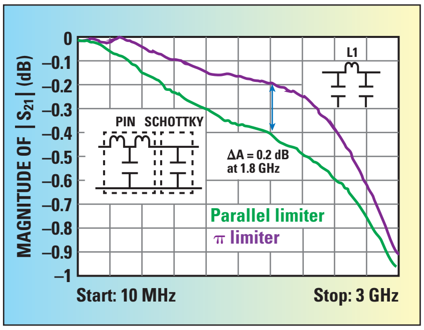
The π configuration also outperforms the alternative loss mitigating scheme based on the ladder network.[6] To ensure a fair comparison, the ladder-configured limiter is fabricated from the same PIN and Schottky diode chips as the π limiter, but the former's diodes are assembled into separate SOT-323 packages so that its PIN diode can have the required dual anodes. At 1.8 GHz, the π configuration has ~0.2 dB insertion loss versus the ladder configuration's ~0.4 dB (see ***Figure 7***). Besides providing lower loss, the π configuration occupies approximately half the PCB space of the ladder configuration.

CONCLUSION

A 1.8 GHz limiter based on a three-pin hybrid Schottky-PIN diode component can benefit from lower loss and better matching when the diodes' parasitic capacitances are configured into a π network, as compared to the manufacturer rec-



▲ *Fig. 6 Cascaded π limiter/LNA NF reduces NF by 1 dB versus parallel limiter/ LNA; physical circuit (a), measured performance (b).*

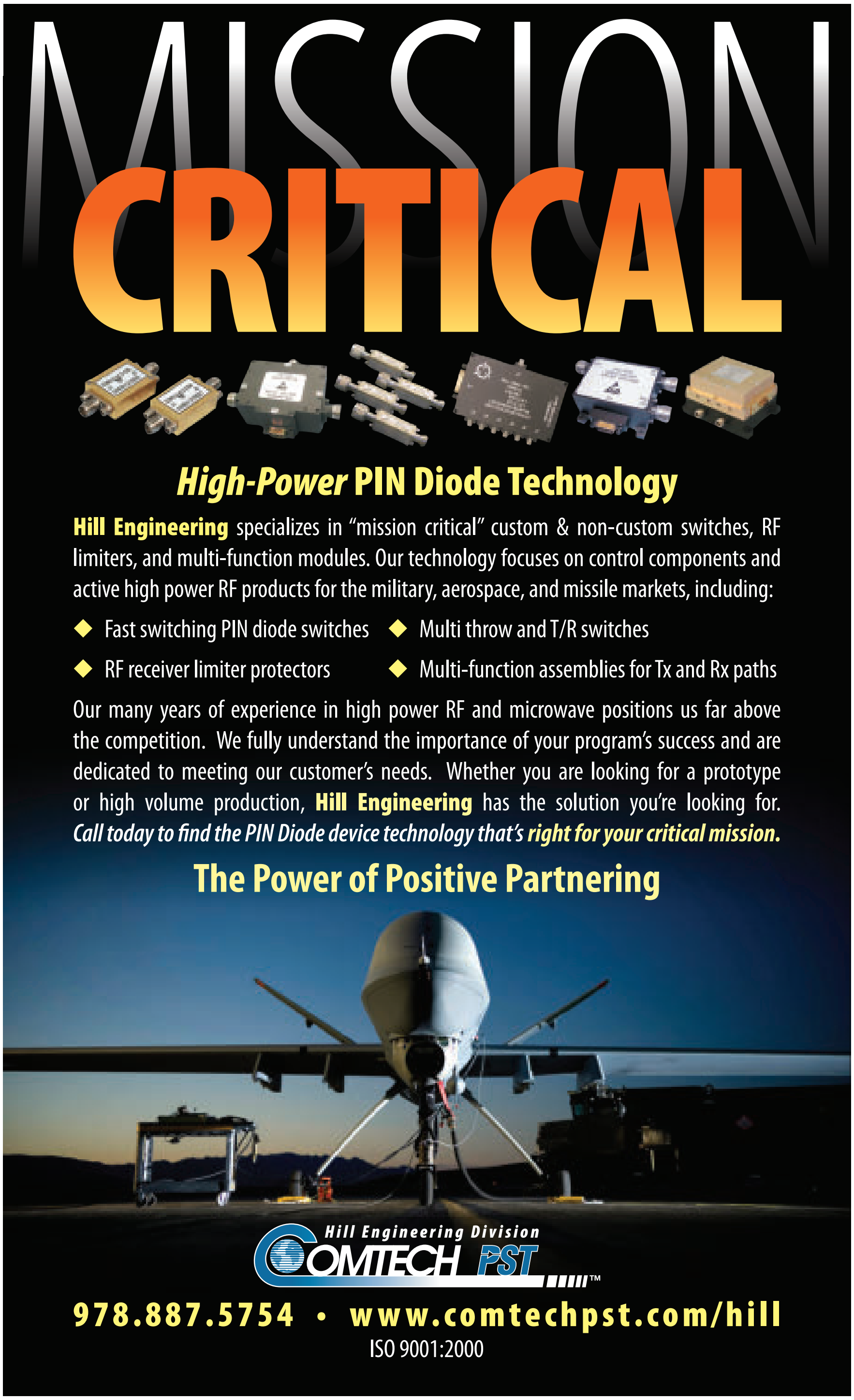


▲ *Fig. 7 π limiter exhibits 0.2 dB lower insertion loss than the ladder limiter at 1.8 GHz.*

ommended parallel diode connection. Although demonstrated with an ASML-5822 PIN-Schottky diode pair, the proposed configuration has general utility. Since most packaged PIN diodes are available only in single-anode styles, (e.g. SOD-323, SOD-523, beam lead and glass diodes) and two anodes are required in the competing ladder configuration, the π configuration expands the number of usable devices. Moreover, the π configuration achieves lower loss than the ladder configuration when fabricated with a similar set of PIN and Schottky diode chips. Future work will investigate large-signal (limiting) and transient performance of the π configuration. ■

ACKNOWLEDGMENT

The author thanks L.L. Vong measuring the package parasitics, R.W. Waugh for designing the PCB, and, S.A. Asrul and the management of Avago Technologies for approving the publication of this work.



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Multi-Channel Antenna Calibration Reference Solution

Keysight Technologies Inc., formerly Agilent Technologies electronic measurement business
Santa Rosa, Calif.

Precise cross-element phase and magnitude measurements and increased measurement bandwidth and system flexibility dramatically speed up large antenna array combinations

The market for multi-channel, phased-array antennas is growing and bringing increased pressure on manufacturers to reduce costs and increase test capacity. At the same time, manufacturers of these antennas need to expand test system flexibility to cover broad use cases and provide options for future upgrades, while facing multi-channel phased array antenna calibration and test challenges including:

- An increase in test times and test complexity due to a growing number of array elements
- Phase coherent sampling across all input channels, providing relative amplitude and phase measurements is critical for precise beamforming
- Advancements in antenna and radar technologies require a flexible and upgradeable test system

The multi-channel antenna test Reference Solution, the second in a series of modular-based Reference Solutions introduced by Keysight Technologies earlier this year, is a combination of hardware, software, and measurement expertise providing the essential components of a narrow-band antenna calibration test system. With this Reference Solution, engineers have the ability to meet antenna test and calibration challenges with a new test approach and enhance or modify a test system to meet specific test application requirements. They include scalable channel count, options for downconversion of antenna receive channels, selectable analysis BW and choice of RF/microwave sources and LO. The Reference Solution also allows a test system to be extended to wide-band measurements as needs change. To facilitate evaluation and integration in a test environment the Reference Solution provides test code examples to set up receiver channels, including DDC, make phase and magnitude measurements, add channel-channel correction factors and export measurements for post-processing.

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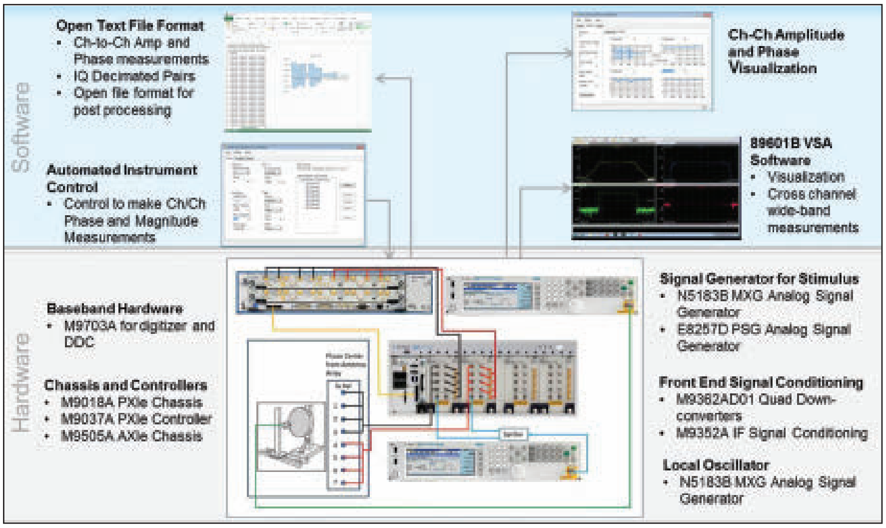
REFERENCE SOLUTION ARCHITECTURE

Antenna Calibration Example Software

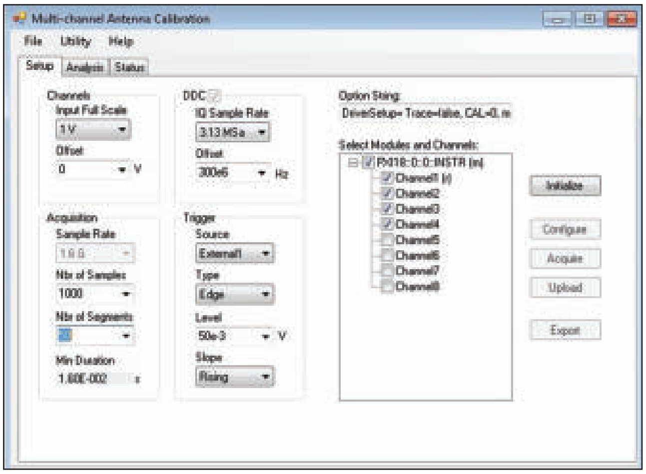
This Reference Solution contains a C# test code example, specifically designed to collect data from an antenna under test and compute cross-channel magnitude and phase data. To accelerate test development and facilitate integration into a test environment, example software source code is provided in the form of a .NET class library. This allows the example to be built-upon (using Microsoft Visual Studio or National Instruments LabVIEW) and the collection and processing of data is customized for specific application needs. The Reference Solution antenna calibration example software provides a number of unique features and capabilities that facilitate and speed calibration and testing, including test setup and control, utility and file functions, cross-channel measurement computation, and measurement interval isolation (see ***Figure 1***).



▲ *Fig. 1 MAC block diagram.*

Test Setup And Control

The Reference Solution's example GUI allows users to set up the measurements made with the M9703A digitizer, including control over DDC parameters (see ***Figure 2***). It includes settings such as initial sample rate, number of samples/segments, trigger control and decimated IQ sample rate. It also allows the user to select which digitizer channels are used for the test and the reference channel for cross-channel measurements. Once the test conditions are set the hardware is configured, data is acquired, and the decimated I-Q data record is uploaded to the host computer (see ***Figures 3*** and ***4***).



▲ *Fig. 2 Test setup and control.*

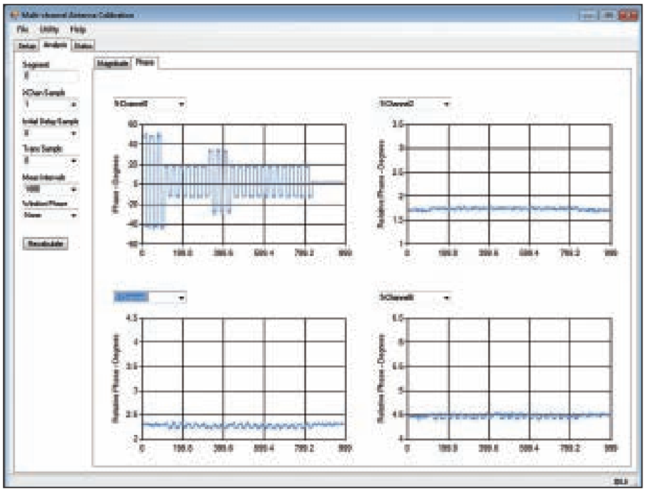
Computing Cross-Channel Measurements

The analysis tab allows quick visualization of absolute or relative phase/magnitude measurements for all measurement intervals in a selected segment.

Isolating Measurement Intervals

The analysis tab also allows mea-

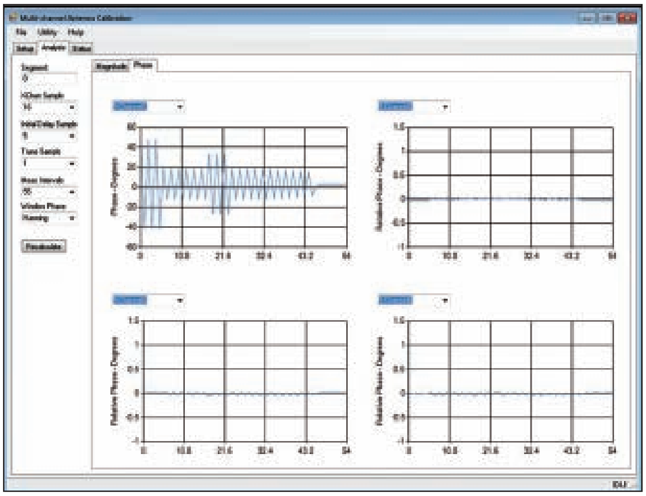
surement intervals to be isolated by selecting the number of samples to integrate over and setting the interval delay and transition time (samples) between intervals. After recalculating, the software will generate a single I-Q measurement for each interval. Again, the plots can be used to visualize either relative or absolute measurements (see Figure 4). Results can also be exported for post-processing in a test environment (see ***Figure 5***).



▲ *Fig. 3 Cross-channel phase measurements for all I-Q samples with absolute (reference channel) and relative (other channels) values.*

Utility and File Functions

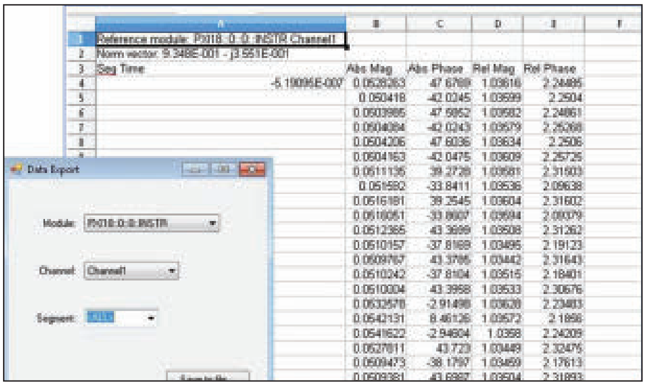
The example software also has utility and file functions to help improve and utilize test results. For example, a cal table containing channel-channel magnitude/phase correction factors can be loaded for use when calculating the cross-channel measurements. Results can also be exported for post-processing in a test environment.



▲ *Fig. 4 Absolute and relative phase plots, after computing a single I-Q pair for each interval and applying a calibration table.*

CONCLUSION

The Keysight multi-channel antenna calibration Reference Solution provides antenna manufacturers greater testing flexibility for more applications and can be quickly integrated into a receiver channel calibration test environment, using near-field, narrow-band testing of the array. The solution allows antenna manufacturers to meet the demand for reduced costs and increased test capacity by making more antenna measurements per second; measuring multiple, phase-coherent channels in parallel; and optimizing the amount of data though real-time digital downconversion (DDC). ■



▲ *Fig. 5 Exporting cross-channel I-Q measurement.*

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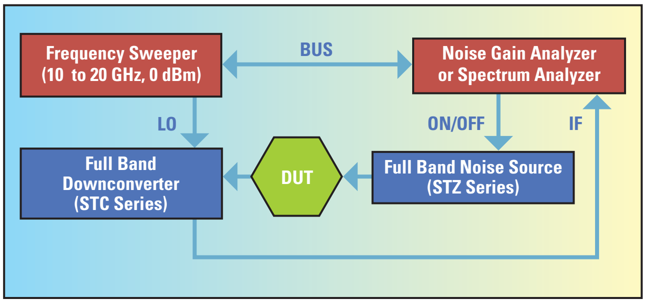
Many system integrators are recognizing the increasing number of commercial and consumer applications for the millimeter-wave frequency spectrum. Applications like automotive radar, local area and last-mile communication systems, portal security systems, traffic control infrastructures, and UAVs have encouraged those in the millimeter-wave industry to address the manufacturing costs of V-, E- and W-Band – and even higher frequency bands – devices, components and subassemblies. RF performance testing for products is one key part of the manufacturing process and often requires expensive test equipment that drives up costs. While many test equipment leaders continually introduce new test equipment that pushes frequencies higher, noise figure measurement systems are still limited to 50 GHz or lower.



▲ *Fig. 1 Interface block diagram.*

SAGE Millimeter has introduced a series of full waveguide band noise figure and gain test extenders (STG series) to extend industrial standard noise figure test equipment to 50 GHz and higher. ***Figure 1*** illustrates how the noise figure and gain test extender interfaced with standard test equipment. According to the diagram, the noise figure and gain test extender consists of two parts: the full band downconverter (STC series) and the full band noise source (STZ series).

The function of the downconverter is to convert high millimeter-wave frequency (50 GHz or higher) by mixing it with a low frequency signal (20 GHz or lower) to produce IF frequency which can be measured by a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Connectors

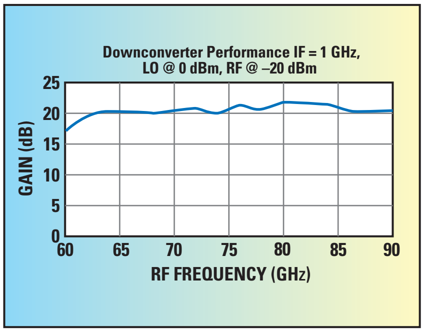

Fig. 2 Downconverter gain versus frequency.

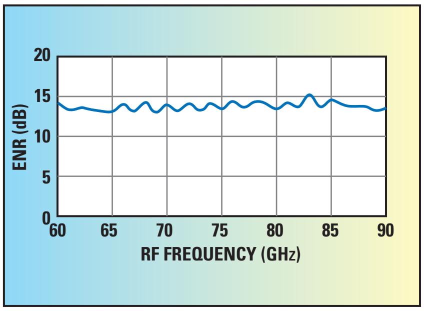

Fig. 3 Noise source ENR versus frequency.

low frequency analyzer or receiver (10 MHz to 1.6 GHz for example). The downconverter includes many high performance SAGE Millimeter components, such as a Faraday isolator (STF series), full band balanced mixer (SFB series), waveguide filters (SWF series), passive and active multipliers (SFP and SFA series) and an IF low noise amplifier (SBL series). While the standard model offers 10 dB input noise figure based on direct downconversion technique, the advanced model with integrated millimeter-wave low noise amplifier is offered as an option to further improve the input noise characteristics. A typical gain versus frequency of an E-Band downconverter is shown in ***Figure 2***, demonstrating very flat gain performance.

The full band noise source is a silicon IMPATT diode-based solid state noise source. The noise source implements high performance diode and proprietary circuit designed to yield high ENR with extreme flatness in the entire waveguide bandwidth. While the standard model offers moderate ENR, the model with higher ENR up to 20 dB is also available as an option. The noise source integrates a Faraday isolator at its output to further improve the port VSWR, resulting in a more stable and reliable noise figure measurement. A typical ENR versus frequency of an E-Band (60 to 90 GHz) noise source is shown in ***Figure 3***. From the curve, very flat ENR figures across the entire E-Band are observed. The flat ENR level is highly desired for any measuring system.

TABLE I
SPECIFICATIONS OF STG MODULE

Extender Model Number	STG-15-S1	STG-12-S1	STG-10-S1
Downconverter	STC-15-S1	STC-15-S1	STC-15-S1
RF Waveguide Size	WR-15	WR-12	WR-10
RF Frequency Range (GHz)	50 to 75	60 to 90	75 to 110
LO Frequency Range (GHz)	12.5 to 18.75	10.0 to 15.0	12.5 to 18.33
LO Power (dBm)	0 to +5	0 to +5	0 to +5
IF Frequency Range (MHz)	10 to 1,600	10 to 1,600	10 to 1,600
Noise Figure (dB, typical)	10.0	10.5	11.0
Conversion Gain (dB, typical)	20.0	20.0	20.0
IF and LO Connectors	SMA(F)	SMA(F)	SMA(F)
DC Bias (VDC/mA, typical)	+12/450	+12/450	+12/450
DC Bias Port Connector	Banana Jack	Banana Jack	Banana Jack
Noise Source	STZ-15-I1	STZ-12-I1	STZ-10-I1
RF Waveguide Size	WR-15	WR-12	WR-10
RF Frequency Range (GHz)	50 to 75	60 to 90	75 to 110
ENR (dB, typical)	13.5	13.0	12.5
ENR Variation (dB, Max)	±1.4	±1.5	±1.5
Port VSWR (Max)	1.4:1	1.4:1	1.4:1
AM Modulation Trigger	TTL	TTL	TTL
AM Modulation Rate (kHz, Max)	1.0	1.0	1.0
AM Modulation Connector	SMA(F)	SMA(F)	SMA(F)
Temperature Stability (dB/°C)	0.01	0.01	0.01
Long Term Stability (dB/Day)	0.05	0.05	0.05
Bias (VDC/mA, Typical)	+18 to +28/60	+18 to +28/60	+18 to +28/60
Bias Port Connector	BNC (F)	BNC (F)	BNC (F)

Table 1 shows the main electrical and interface specifications of the featured noise figure and gain test extenders. The RF interface of the extenders is equipped with standard waveguide. SAGE Millimeter's SWC series waveguide to coax adapters can be used to convert the interface to 1 mm coaxial interface.

In addition, the standard extenders can also be tailored to offer lower input noise figure, higher ENR or various conversion gain options.

VENDOR**VIEW**

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Compact Waveguide-to-Coaxial Transition

The Neat Adaptor, No Connector (NANo) waveguide-to-coaxial transition is designed to provide a direct, compact transition between a 50 ohm coaxial pin interface and waveguide; replacing the need for the bulky approach of semi rigid cable to conventional waveguide transition. The NANo solution offers improved mechanical integrity and optimizes the signal path while minimizing space envelope and reducing the number of possible failure points.

Building on the BSC Ultra Short End Launch Transition (USELT) range, the patented NANo design has comparable performance to precision right-angled transitions with more than 20 dB return loss (VSWR of 1.22:1) for most models. Band-optimized or wideband versions are available, the latter achieving typical bandwidths of above 60 percent of the standard waveguide operating band for the wideband versions.

Typical applications include direct integration of low noise amplifiers to waveguide-based systems. Testing of the LNA can be carried out using field-replaceable coaxial connectors, which are removed and replaced by the NANo. The NANo is then securely fixed to the LNA module, forming one mechanically integrated unit.

The NANo design interfaces directly to a hermetically sealed pin (glass to metal seal) hence fine leak sealing of the LNA or module can be achieved. The standard range of coaxial pin diameters can be accommodated (0.012, 0.015, 0.018 and 0.020 inch).

The NANo range is available in either brass or aluminium with silver plate or passivated finish. Devices can be provided painted, unpainted or primer-finished to allow painting once integrated into the final assembly.

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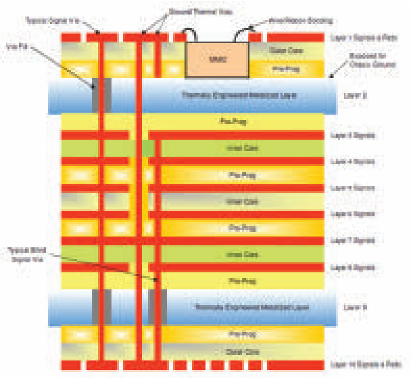

PCB Embedded Cooling Layer System

Cirexx has developed the ECLIPS™ PCB systems based on a Lockheed Martin patented and licensed technology. ECLIPS (Embedded Cooling Layer Interactive Power System) is an advanced PCB system employing a specially developed, thermally engineered, metalized copper graphite composite with a ceramic-matched CTE. The engineered material has superior thermal conductivity properties and CTE values matched with Si, SiC, GaAs and GaN. This provides a reduced overall PCB weight, higher power density and heat dissipation capabilities while maintaining the PCB structure in a stable form for direct die-attach of advanced components, such as GaA and GaN. Due to the stability and construction of the ECLIP PCB, all supporting components are standard SMT plastic packages. This can significantly reduce the cost of advanced designs by allowing for standard SMT assembly and eliminating ceramic die component sourcing, procurement and assembly of non-essential parts.

Cirexx has developed the ECLIPS manufacturing technique and process to incorporate this material into a standard PCB structure.

Common PTFE laminates can be selected to support advanced signal integrity along with variable thickness dielectrics. Heavy copper core layers for additional power and ground use are also available. The thermally engineered composite is currently stocked in 10, 20 and 40 mil thickness for use in PCB structures as a heat sink and stabilizer. Cirexx will help customers design an ECLIPS PCB to solve their high power packaging challenges.

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The operating voltage is 30 to 32 V with a current of 12 A maximum. Maximum input power is 8 dBm. It has a small form factor (285 × 106 × 27 mm – excluding connectors) and is light weight. The SSPA also features built-in protection circuits with high reliability and ruggedness. Exodus produces high power amplifiers featuring LDMOS, GaN and GaAs-FET discrete transistors and die on ceramic substrates covering frequency ranges from 1 MHz up to 26.5 GHz and power levels exceeding 500 W.

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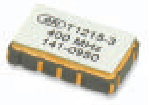

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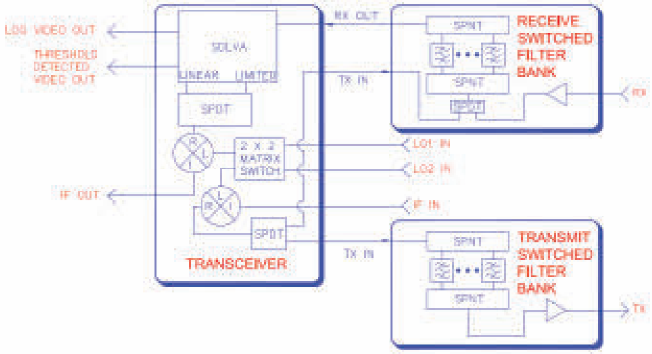
Simplified Functional Block Diagram



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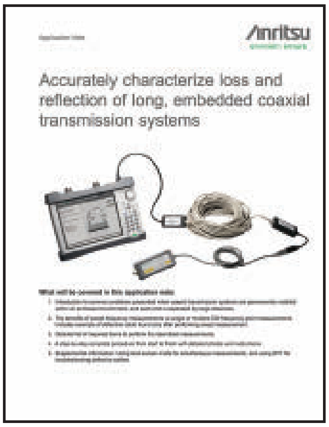
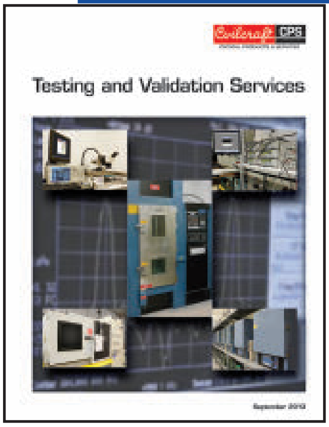


RF Network Testing Application Note

VENDORVIEW

Transmission line and antenna testing has become a common test of RF network integrity over the past few years. This relatively new testing methodology is a result of new test equipment evolutions and the need to fully understand the integrity of RF networks after installation. This application note establishes some basic guidelines for the tests and methods of procedure in an effort to improve these valuable tests and establish consistency in the results and conclusions.

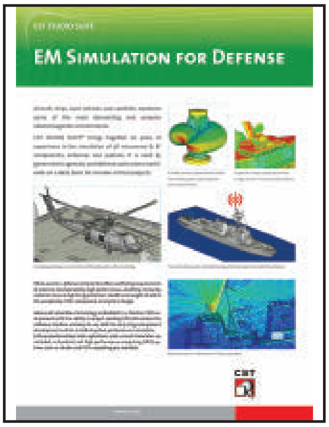
Anritsu
www.anritsu.com/en-US/coaxial-transmission-mwj



Testing & Validation Services

Coilcraft Critical Products & Services (CPS) offers a full range of product testing and validation services to help you determine the reliability, repeatability and/or compliance of the electronic components and assemblies you manufacture or procure. Coilcraft CPS's testing capabilities include vibration and mechanical shock to MIL-STD-202, as well as complete electrical testing, elemental analysis, radiographic inspection, thermal shock and cycling, and other environmental and analytical lab services. Screenings can be modified from an existing Coilcraft document or customized to meet your specific needs.

Coilcraft CPS Inc.
www.coilcraft-cps.com/pdf/testing.pdf



Electromagnetic Simulation for Defense

VENDORVIEW

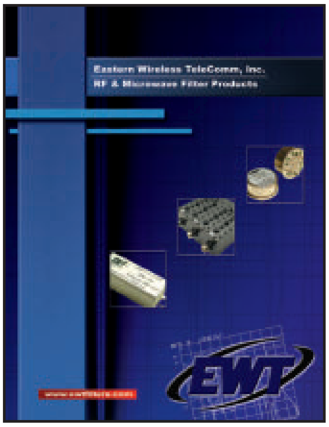
Aircraft, ships, land vehicles and satellites exist in complex electromagnetic (EM) environments. EM simulation tool, CST STUDIO SUITE®, helps development engineers address challenges unique to the field such as radar cross section and electromagnetic pulse. The transient solver, frequency solver, integral equation solver and asymptotic solver are suitable for a broad range of problems. This brochure details the use of EM simulation to analyze antenna placement and co-site interference, electromagnetic environmental effects and radar. Download it at www.cst.com/defenseflyer.

CST
www.cst.com

Power Amplifiers Catalog

CTT announced a new four-page power amplifiers short form catalog. The catalog features more than 75 models developed for radar, EW and multi-function systems design. The amplifiers feature narrowband CW, narrowband pulsed, wideband (CW) and ultra-wideband (CW) coverage. Frequency coverage is from 0.1 to 18 GHz. CTT's family of solid-state amplifiers are finding applications in many of the next generation of high-performance communications, instrumentation and medical systems where high power is required.

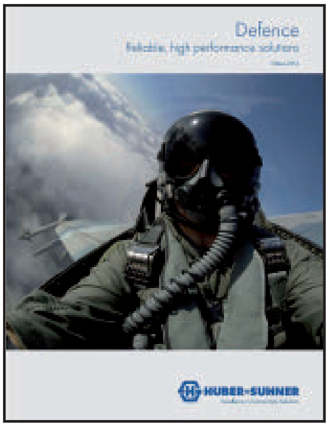
CTT Inc.
www.cttinc.com



Filter Catalog

This new short form catalog features a sampling of the company's RF and microwave filter products to 40 GHz utilized in military, commercial and wireless applications. The catalog also highlights some of the company's diverse filter design and manufacturing capabilities.

Eastern Wireless TeleComm Inc.
www.ewtfilters.com



New Defence Brochure

As a leading international manufacturer of components and systems for electrical and optical connectivity, HUBER+SUHNER unites technical expertise for the defence market in radio frequency technology, fiber optics and low frequency. The new defence brochure provides an overview of HUBER+SUHNER solutions. The first part particularly focuses on defence-specific applications such as airborne, gimbal, radar, naval, command and vehicles. The second part shows detailed information of the corresponding RF products like SUCOFLEX, minibend, EACON, cable and connectors, lightning protectors and fiber optic solutions.

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www.hubersuhner.com


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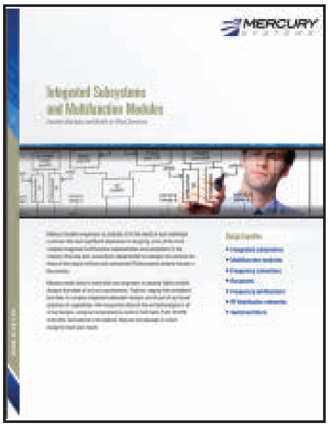
Low PIM Components & D.A.S. Equipment Catalog

VENDORVIEW

MECA's new 12-page catalog features an extensive line of low PIM RF/microwave components with industry leading performance including RF loads, attenuators, directional couplers, power splitters, divider/tappers, adapters, jumpers and D.A.S. equipment. MECA's low PIM loads are considered a benchmark for the industry and are currently the only terminations capable of handling full rated power at 85°C. Visit www.e-meca.com/pdfs/MECA_catalogo-2014.pdf to download a copy.

MECA Electronics Inc.
www.e-MECA.com

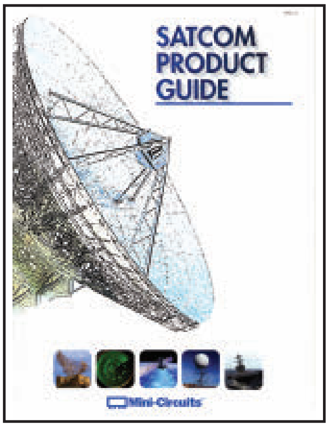


Integrated Subsystems Flyer

VENDORVIEW

Mercury offers a broad spectrum of design, manufacturing and testing services for complex integrated multifunction assemblies and subsystems. Working hand-in-hand with your engineers, the company helps develop highly reliable designs from 10 MHz to 40 GHz for narrowband or broadband. Manufacturing capabilities include vacuum lamination of substrates, surface mount solder assembly, chip and wire assembly, and hermetic sealing. Test capabilities include static and dynamic phase noise measurements and detailed automated test routines to ensure compliance to all of your requirements.

Mercury Systems
www.mrcy.com/engineering



SATCOM Product Guide

VENDORVIEW

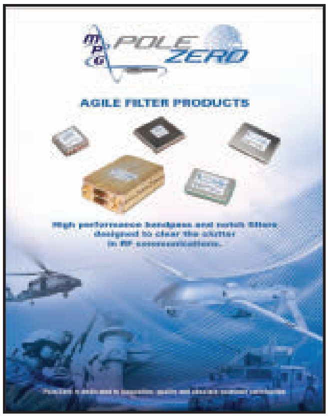
Mini-Circuits has released a new SATCOM product guide in print and for download from their website. This 32-page guide features a full survey of components and assemblies for satellite and earth station systems. With selected products from over 20 different product types to 40 GHz, the guide provides key performance parameters for each product and serves as a handy reference for engineers evaluating parts for their design needs.

Mini-Circuits
www.minicircuits.com

RF and Microwave Filters and Assemblies

NIC celebrates 28 years of uninterrupted service to the military and space markets. This catalog features NIC's design and manufacturing capabilities from DC to 40 GHz and showcases a broad range of filter technologies including: LC, crystal, ceramic, cavity, delay equalized and phase matched filters, as well as NIC's integrated assemblies such as: switch filter banks, filter/amplifiers, and phase shifters. NIC is ISO 9001:2008 certified and AS-9100C certified for aerospace applications.

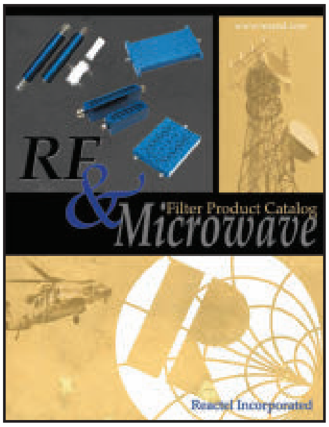
Networks International Corp.
www.nickc.com



Product Brochure

Pole/Zero's latest brochure details their newly-designed, lower-cost Mini-Pole® Series; Extended Range Frequency (ERF™) Series for applications needing a single filter with 30 to 520 MHz tunability and up to 5 W average in-band power handling; MINI/3 ERF filter providing 30 to 520 MHz tunability with enhanced selectivity by use of a three-pole filter architecture; Microwave Series of digital and voltage tuned bandpass filters offering tuning ranges beyond 4 GHz; and MINI-SMT, a surface mount version of the company's Mini-Pole Series.

Pole/Zero Corp.
www.polezero.com



Filters, Multiplexers and Multi-function Assemblies

VENDORVIEW

When being first to react makes all the difference in the world, choose Reactel for your mission-critical filter requirements. This catalog features RF and microwave filters, multiplexers and multi-function assemblies for the military, industrial and commercial industries. To request your copy, please email reactel@reactel.com, or visit www.reactel.com.

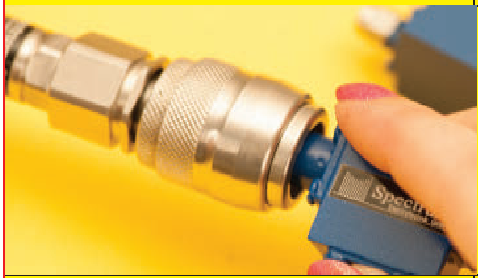
Reactel Inc.
www.reactel.com

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

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

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

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

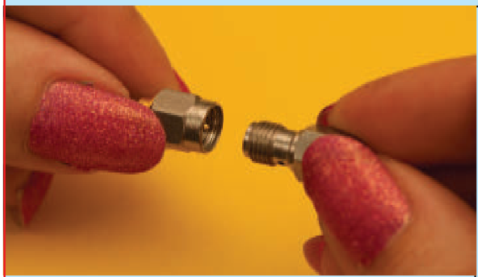


4. The Connection has been completed, easy and fast. The connector has been locked on safely.

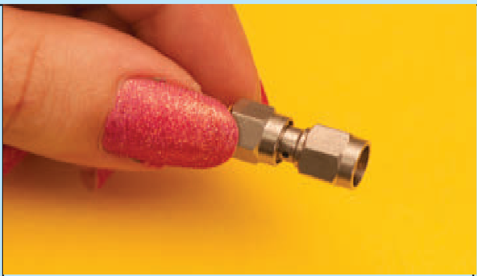
5 . To unlock (when "Back Nut" is in unlocked mode) push the "Lock Nut" forward and stop reverse movement by setting your fingers onto the "Back Nut".

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

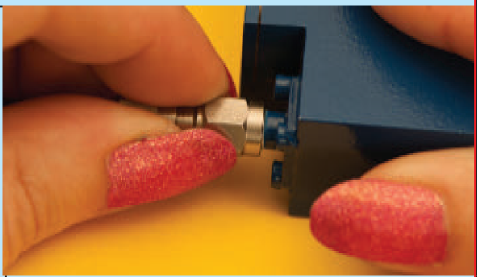
Procedure for how to use the SMA male and SMA female Push-On connectors. SMA Push-On Connectors mate with any standard connector of the same but opposite connector style.



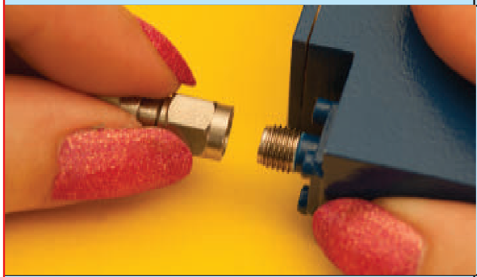
1. Convert your standard cable assembly into a Push-On Assembly by threading the standard female side of the adapter onto the male connector of the assembly.



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



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



4. To disconnect, just pull the connector off.

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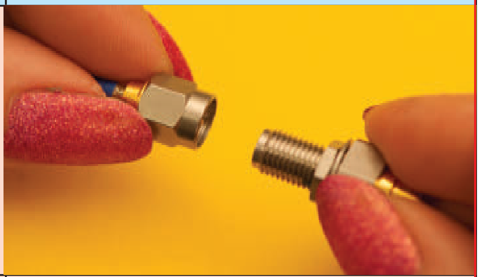
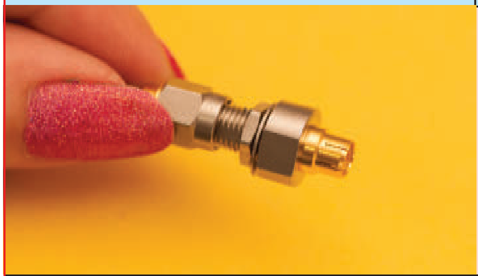
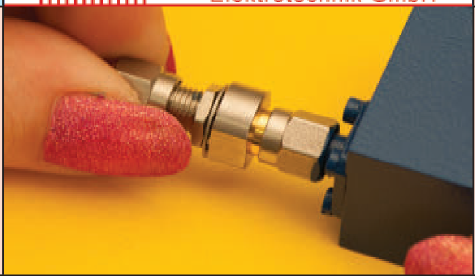


1. Convert your standard cable assembly into a Push-On Assembly by threading the standard female side of the adapter onto the male connector of the assembly.



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



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

4. To disconnect, just pull the connector off.

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EM Simulation of Automotive Radar

Trends in automotive safety are pushing radar systems to higher levels of accuracy and reliable target identification. Consequentially, engineers need to better understand how mounting brackets, fascia, paint color and bumper assemblies affect automotive radar systems. This paper outlines the advantages of FDTD EM simulation for analyzing designs that include both the antenna package and the automobile body features surrounding the device. An XFdtd simulation of radar mounted in the rear bumper of a sedan is demonstrated.

Remcom
www.remcom.com/automotive-radar

RF & Microwave Product Selector Guide for Aerospace & Defense

VENDORVIEW

This guide features a broad range of all the latest products by leading suppliers including ADI, Anaren, Freescale, MACOM, Microsemi, Nitronex, Peregrine, Skyworks, STMicroelectronics, TriQuint, UMS, Wavelex and WanTcom. A&D applications supported by these products include electronic warfare, communications, jammers and radar (including commercial). Brought to you by Richardson RFPD, your global source for RF, Wireless & Energy Technologies.

Richardson RFPD / Arrow RF & Power
www.richardsonrfpd.com

Precision Microwave Components Catalog

RLC Electronics is a leader in the design and manufacture of RF and microwave components. In this catalog, you will find standard RLC products, including coaxial switches and filters up to 65 GHz, as well as power dividers, couplers, attenuators and detectors up to and beyond 40 GHz. As you will see, many of these components are available in surface mount or connectorized packages. RLC can also provide customized designs to meet specific customer requirements not shown in the catalog.

RLC Electronics
www.rlclectronics.com

T&M Instruments That Meet Your Needs

VENDORVIEW

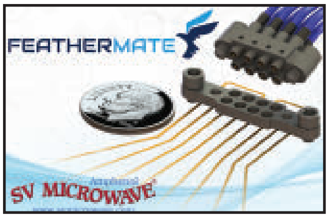
Whatever your job is, you do not always need the ultimate high-end T&M equipment. What you need are precise, reliable, universal measuring instruments. That is what you get with Value Instruments from Rohde & Schwarz: they combine practical features with excellent measurement characteristics; they are easy to use and are easy on the budget. Find out more in the Value Instruments Catalog 2014 from Rohde & Schwarz.

Rohde & Schwarz GmbH & Co. KG
www.rohde-schwarz.com

Hermetically Sealed Adapters

Spectrum Elektrotechnik GmbH offers a wide range of hermetically sealed adapters to the hermeticity of 10^{-8} atm cm^3/s minimum. The adapters use fused-in glass seals between the center contact and outer conductor. This ensures complete hermeticity of the units. The adapters are normally used at vacuum chambers testing products that are intended for outer space, with the testing equipment and personnel staying at regular environment. Available connector styles 1.85, 2.4 and 2.92 mm; N and TNC.

Spectrum Elektrotechnik GmbH
www.spectrum-et.com



Precision Light as a Feather to Flock Together

SV Microwave's new FeatherMate RF interconnect system combines a high density (0.100" center-to-center spacing), 40+ GHz multiport concept with a zero disengagement force mating mechanism. Direct connection to board trace, solder-free board mounts and small diameter coax cable connectors are available. Ideal for high density, low-force applications. Get more bandwidth and signal density in your application without worrying about destructive demating forces with SV Microwave's FeatherMate.

SV Microwave
www.svmicrowave.com

The 2014 Defence, Security and Space Forum

At European Microwave Week

EuMA · Microwave Journal — Frequency Matters.

Wednesday 8 October • Room Flavia, Fiera di Roma Conference & Exhibition Centre, Rome

A one day Forum addressing the application of RF integrated systems to defence & security infrastructure

Programme

09:00 - 10:40 Microwave Journal Industry Panel Session

The session offers an industry perspective on the key issues facing the defence, security and space sector. In accordance with the theme for 2014, the Panel will address: *Defence and security infrastructure*.

11:20 - 13:00 EuRAD Opening Session

13:10 - 14:10 Strategy Analytics Lunch & Learn Session

This session will add a further dimension by offering a market analysis perspective, illustrating the status, development and potential of the market.

14:20 - 16:00 Integrated RF solutions and its enabling and disruptive technologies on critical infrastructures and civil protection

Speakers from industry and academia present RF solutions and systems that contribute to civil protection, the protection of our critical infrastructures and disaster relief. The topics will be:

- The domino effects in critical infrastructures
- Civil protection, protection of critical infrastructures, disaster relief: vertical applications over a common architecture with heterogeneous communications
- Threats and countermeasures in the homeland security scenario
- Security at European institutional level

The three most highly rated unsolicited papers will complete the analysis of the main session topic.

16:40 - 18:20 EuMW Defence, Security & Space Executive Forum

Two executives from space industry and governmental institutions present their view on defence and space systems for our security. The titles of these two VIP talks will be announced closer to the event on the EUMW2014 website.

These two presentations will be complemented by three pitch presentations:

- Joint Applications of Airborne and Spaceborne Radars
- Instrumented fuzes for aero-ballistics diagnostics of large-caliber projectiles
- New Technologies and Innovative Payload for Space Q/V-Band Telecommunications

The session will conclude with an open forum discussion with all speakers.

18:20 - 19:00 Cocktail Reception

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

Registration fees are €10 for those who have registered for a conference and €50 for those not registered for a conference.

Register online at www.eumweek.com

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Harness Capabilities Brochure

The Teledyne Storm Microwave Multi-Channel Microwave Solutions brochure details the company's capabilities in the design and manufacture of both standard and custom multi-channel microwave harness assemblies. The harnesses, found in a wide range of airborne, ground and sea-based military and commercial applications, are backed by Teledyne Storm's more than 30 years of microwave cable design and manufacturing expertise. The brochure includes a case study.

Teledyne Storm Microwave
www.teledynestorm.com

GORE-FLIGHT™ Microwave Assemblies

GORE-FLIGHT™ Microwave Assemblies, 6 Series are lightweight cable solutions for airframe assemblies in military and civil aircraft applications. These new assemblies deliver the lowest insertion loss before and after installation, ensuring reliable performance for the life of the system. Their robust construction reduces total costs by withstanding the challenges of installation, reducing costly production delays, field service frequency, and the need for purchasing replacement assemblies. The 6 Series are also lighter in weight, which improves fuel efficiency and increases payload.

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