Vol. 52 • No. 1

January 2009

Microwave Journal

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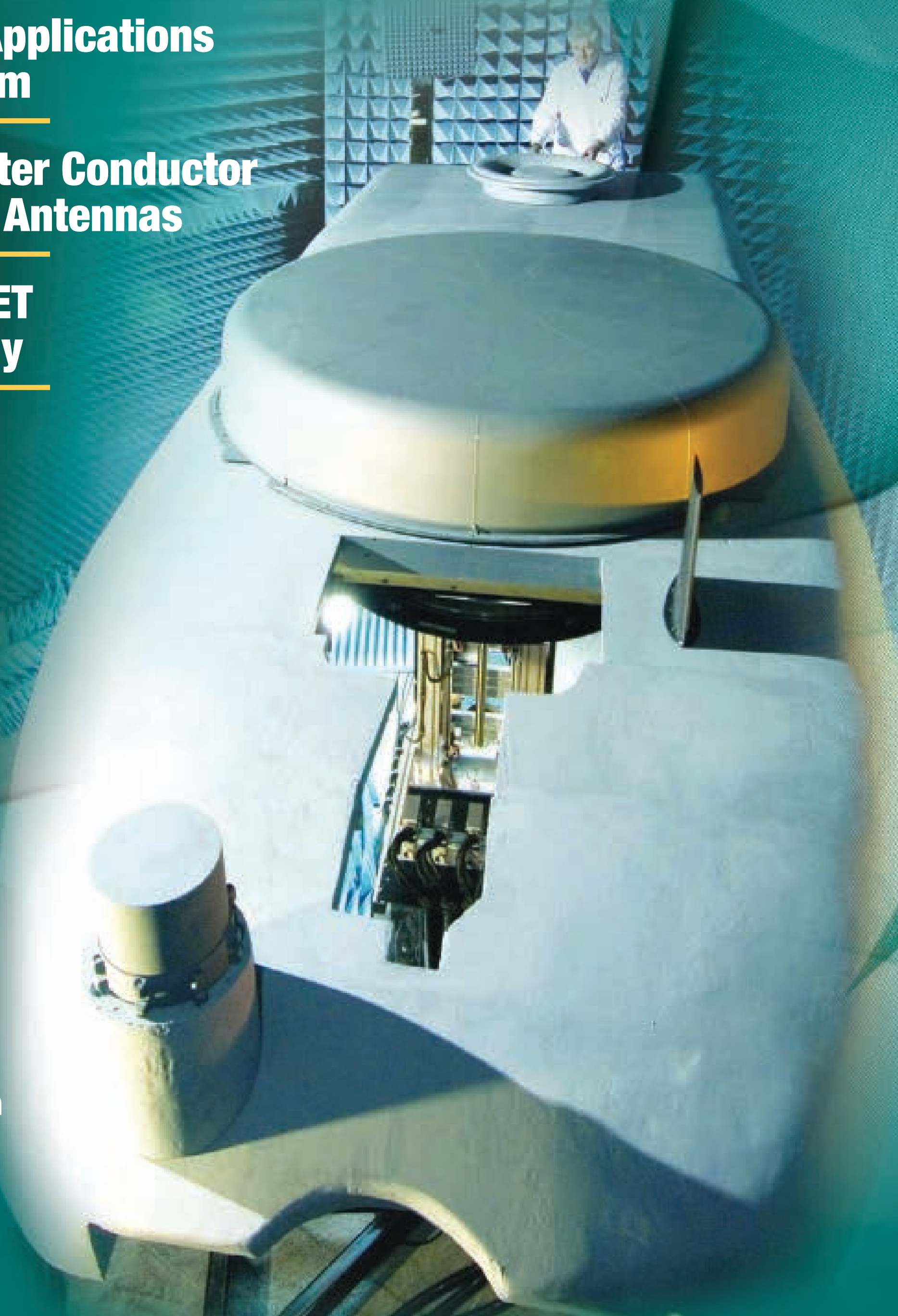
Radar/Antennas

Antenna Applications Symposium

Virtual Outer Conductor for Linear Antennas

Vertical FET Technology



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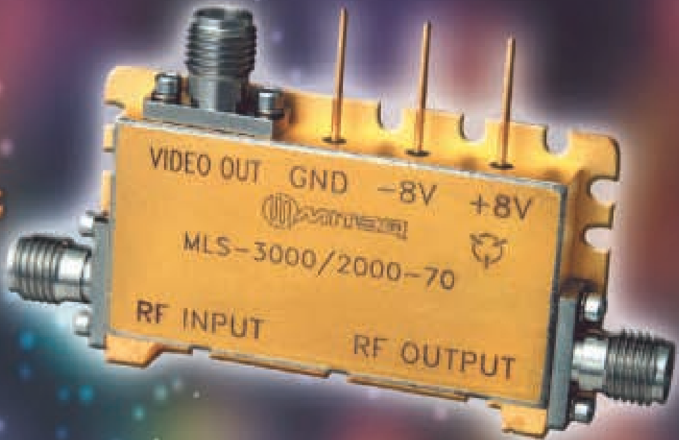

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MLS-375/250-70	250 to 500	-70 to 0	-75	±1.0	15	30	40
MLS-550/500-70	300 to 800	-70 to 0	-73	±1.5	10	25	35
MLS-1000/500-70	750 to 1250	-70 to 0	-73	±1.5	10	25	35
MLS-2000/1000-70	1500 to 2500	-67 to +3	-70	±1.5	15	30	40
MLS-3000/2000-70	2000 to 4000	-70 to 0	-72	±2.0	10	25	35
MLS-5000/2000-65	4000 to 6000	-60 to +5	-63	±2.0	10	25	35
MLS-6000/4000-60	4000 to 8000	-55 to +5	-60	±2.0	10	25	35

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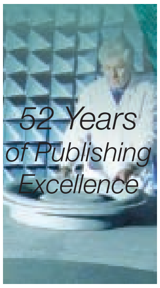

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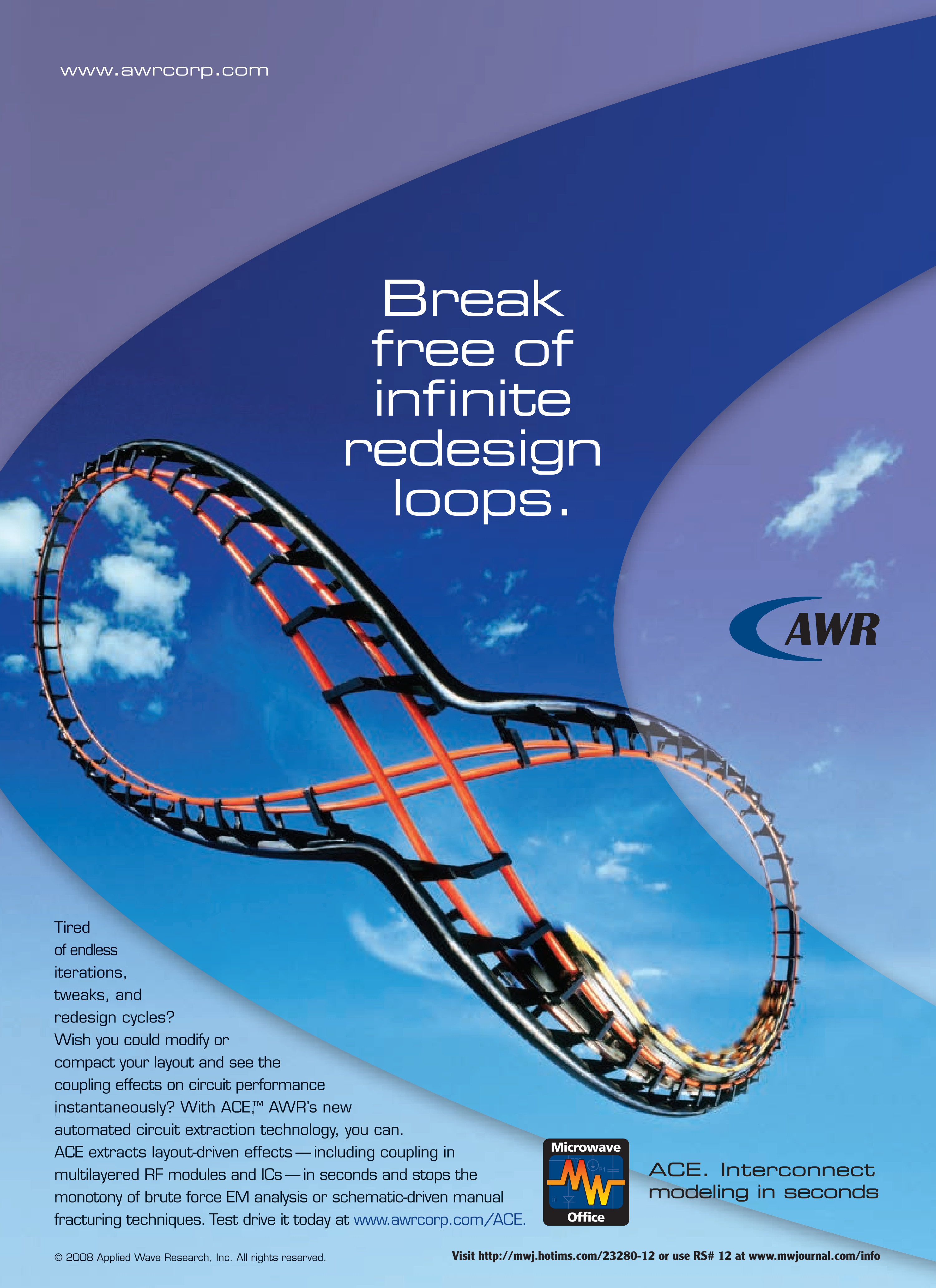
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FEATURES

PRODUCT FEATURES

DEPARTMENTS

In "Link Budget Calculation for UHF RFID Systems," a December Technical Feature by Hyungoo Yoon and Byung-Jun Jang, Mr. Jang's affiliation was listed incorrectly. He is a professor at Koomin University, Seoul, South Korea, not Myongji College.

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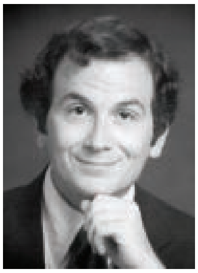
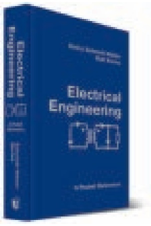


Dr. Jeremy Keith Raines is a registered professional engineer and consultant with a focus on electromagnetics. Raines muses on new thinking in antenna analysis and design.



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MWJ Blog

2009 starts off with much uncertainty in the global economy, which will undoubtedly have an impact on our industry. In this month's blog we will look at related news items, offer opinions on what the future may have in store and include other newsworthy odds and ends. Read **http://microwavejournal.blogspot.com/** and add your comments.

Online Technical Papers

Buying a Signal Analyzer
Mark Elo, Keithley Instruments Inc.

DC to 85 GHz TWA and Ka-band 4.9 W Power Amplifier Using an Optical Lithography-based Low Cost PHEMT Process
Kohei Fujii, John Stanback and Henrik Morkner, Avago Technologies

GaAs in Space
Graham Teague, TriQuint Semiconductor GmbH

Generating Advanced Radar Signals Using Arbitrary Waveform Generators
Tektronix Application Note

Executive Interviews

MWJ talks to Jim Cashman, President and CEO of **Ansys Inc.**, and Zol Cendes, Founder and General Manager of **Ansoft LLC**. In 2008, Ansys acquired Ansoft and entered the RF/microwave market. Cashman and Cendes discuss the strategy behind this acquisition and talk about the synergy between these companies.

NEW FOR 2009

Last month marked the conclusion of our 50th anniversary celebration. I hope that you enjoyed the special monthly features, including the "Then and Now" cover stories and Editor David Vye's series titled "A Microwave Journey." I would like to thank our esteemed authors who committed their time and expertise to write on the current state of RF and microwave technologies and to our guest authors who contributed to our special July anniversary issue. It proved to be a fitting tribute to fifty years of RF/microwave history and an insightful glimpse into the future.

In 2009 we continue to enhance and expand our portfolio of products and the platforms in which we deliver information to you, our readers. You'll notice several changes to the print magazine this month. When you flip to the next page, you'll see the industry events for next month laid out in an easy-to-read calendar format. This calendar includes trade shows, conferences, workshops, courses and online events. At the back of the magazine, you'll find the new "MWJ Puzzler," a crossword puzzle aimed at testing your RF/microwave knowledge. You can find the answers on www.mwjournal.com.

Debuting on our website this month, you'll find a collection of "White Papers" from industry leading companies, including Agilent, Keithley, TriQuint, Tektronix and Avago. New papers will be added every month, expanding our online technical library with information designed to assist you in your design challenges. Also debuting soon will be the MWJ China web site (www.microwavejournal.cn).

The MWJ/Besser Associates webinar series has been a huge success, as thousands of professionals have viewed these highly informative and free tutorials presented by industry experts and moderated by MWJ editors. You can now access the archive of past webinars or sign-up for upcoming events on the newly redesigned "Resources" section of our site.

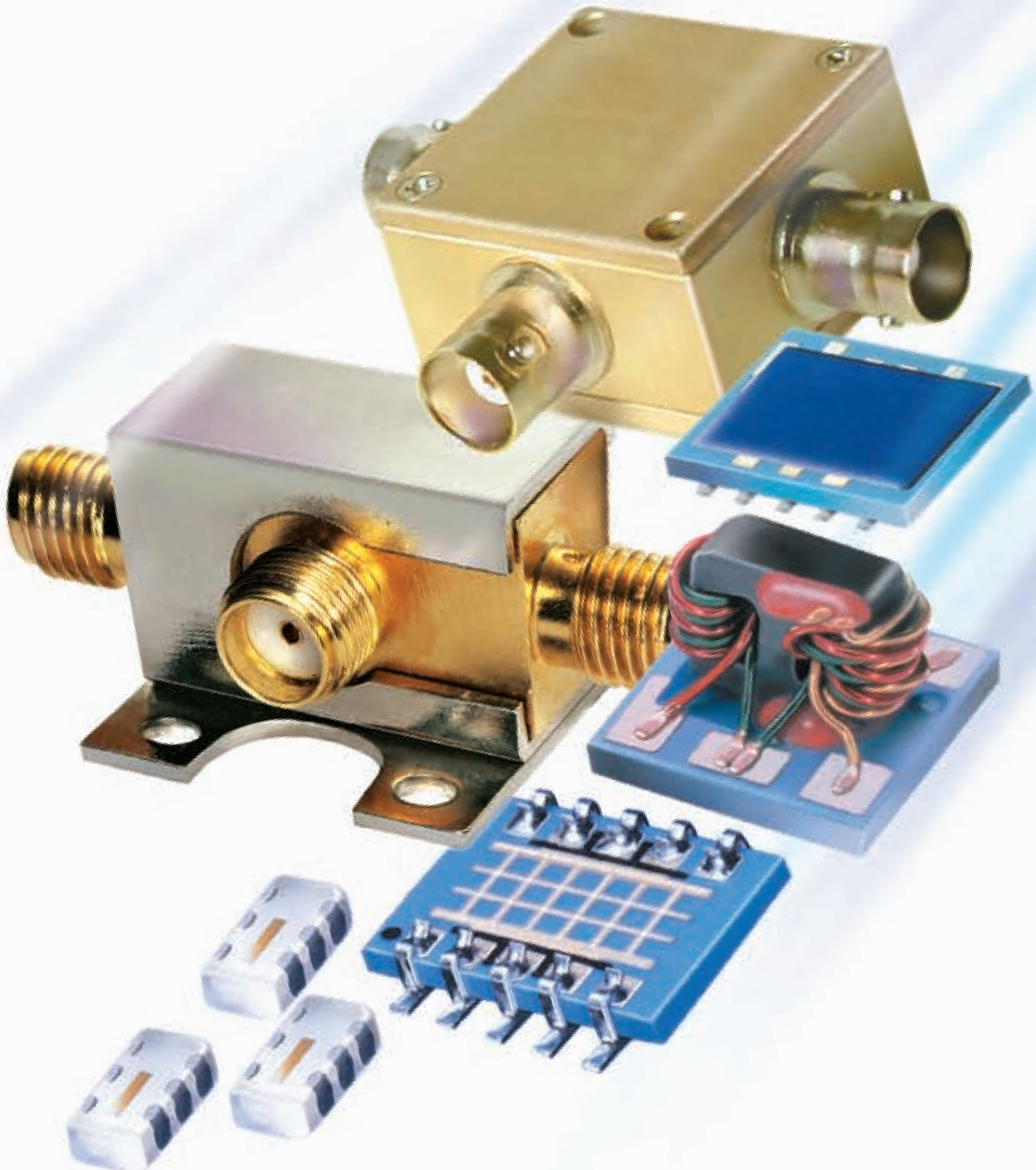
Our "Online Show Daily" feature will be expanded again this year as we bring you daily news from the IEEE MTT-S IMS (Boston) and the European Microwave Week (Rome) events. We preview the shows, shoot live video from the show floor and provide a post-show wrap-up of the events.

I'm excited to announce the debut of the "RF/Microwave Zone" pavilion at this year's CTIA wireless event. The CTIA is a major wireless trade show, attracting more than 40,000 professionals from over 125 countries. *Microwave Journal* has partnered with CTIA to provide a dedicated space for RF/microwave companies to promote their products. Instead of searching among the more than 1,100 exhibiting companies to find RF/microwave products, you can now find them all in one centrally located pavilion. Visit our online "Events" section for more information.

We had fun last year, chronicling the past, reporting on current trends and projecting future advances. This year promises to bring many challenges and we'll continue to deliver the information that helps you meet these challenges in a variety of formats. I hope that you find these information resources to be a valuable asset in your work.

Wishing you a successful year ahead,

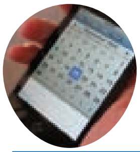
Carl Sheffres



FEBRUARY 2009

SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
1	2	3	4	5	6	7
8	9	10 **International Solid-state Circuits Conference (ISSCC 2009)** San Francisco, CA	11	12 **EMC Lab Techniques for Designers** Oxford, UK	13	14
15	16  *Richard Mumford*	17 **GSMA Mobile World Congress** Barcelona, Spain **MWJ/Besser Webinar: Radar Fundamentals**  *David Vye*	18	19 **IEEE MTT-S International Microwave Workshop Series (IMWS 2009)** Guadalajara, Mexico	20	21
22	23	24 **Near-field Communication (NFC 2009)** Hagenberg, Austria	25 **National Association of Tower Erectors** Nashville, TN **Directed Energy Weapons** London, UK	26  **Besser Associates RF Transceiver Architecture, Design and Evaluation** San Diego, CA	27	28

Visit www.mwjournal.com/events for more information.



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IEEE Radio and Wireless Symposium
January 18–22, 2009 • San Diego, CA
http://rawcon.org

FEBRUARY

GSMA Mobile World Congress
February 16–19, 2009 • Barcelona, Spain
www.mobileworldcongress.com

NATE 2009
National Association of Tower Erectors
February 23–26, 2009 • Nashville, TN
www.natehome.com

Directed Energy Weapons
February 26–27, 2009 • London, UK
www.defenceiq.com/uk/directedenergy/ediary

MARCH

IWCE 2009
March 16–17, 2009 • Las Vegas, NV
www.iwceexpo.com

CST European User Group Meeting
March 16–18, 2009 • Darmstadt, Germany
www.cst.com

Satellite 2009
March 24–27, 2009 • Washington, DC
www.satellite2009.com

APRIL

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CTIA with RF/Microwave and M2M Zones
April 1–3, 2009 • Las Vegas, NV
www.ctiawireless.com

CST North American User Group Meeting
April 15, 2009 • Dallas/Fort Worth, TX
www.cst.com

WAMICON 2009
IEEE Wireless and Microwave Technology Conference
April 20–21, 2009 • Clearwater, FL
www.wamicon.org

MAY

NCMMW 2009
National Conference on Microwave and Millimeter Wave in China
MIE 2009
Microwave Industry Exhibition in China
May 23–26, 2009 • Xi'an, China
www.cnmw.org

JUNE

RFIC 2009
IEEE Radio Frequency Integrated Circuits Symposium
June 7–9, 2009 • Boston, MA
www.rfic2009.org

IMS 2009
IEEE MTT-S International Microwave Symposium
June 7–12, 2009 • Boston, MA
www.ims2009.org

AUGUST

EMC 2009
IEEE International Symposium on Electromagnetic Compatibility
August 17–21, 2009 • Austin, TX
www.emc2009.org

SEPTEMBER

EuMW 2009
European Microwave Week
September 28–October 2, 2009 Rome, Italy
www.eumweek.com

4G World 2009
September 15–18, 2009 • Chicago, IL
http://global.wimaxworld.com

OCTOBER

RF & Hyper 2009
October 6–8, 2009 • Paris, France
www.rfhyper.com

AOC 2009
Association of Old Crows International Symposium and Convention
October 18–21, 2009 • Washington, DC
www.crows.org

NOVEMBER

AMTA 2009
Antenna Measurement Techniques Association
November 1–6, 2009 • Salt Lake City, UT
www.amta.org

COVER FEATURE
INVITED PAPER

STATE-OF-THE-ART ANTENNA TECHNOLOGY: THE 2008 ANTENNA APPLICATIONS SYMPOSIUM

The Antenna Applications Symposium and its predecessor, the Air Force Antenna Symposium, have for more than 50 years provided a unique forum for exchange of ideas and information about the practical aspects of antenna design, development and use in systems. The Antenna Applications Symposium is held annually at the Retreat Center in Robert Allerton Park, a century-old Georgian mansion just outside of Monticello, IL (see ***Figure 1***). The elegance of the facility, a single-track technical program with stimulating presentations, and ample networking opportunities contribute to fruitful group and one-on-one interactions.

Fig. 1 Afternoon break at the annual Antenna Applications Symposium.

The Antenna Applications Symposium emphasizes antenna design and application to systems. It is a unique forum, where industrial engineers are encouraged to present practical solutions to problems that are encountered during development and implementation of antennas and antenna systems. The symposium features technical presentations from industry, government and academia. Attendees at the 2008 symposium represented all three military services, law enforcement, companies

DANIEL SCHAUBERT
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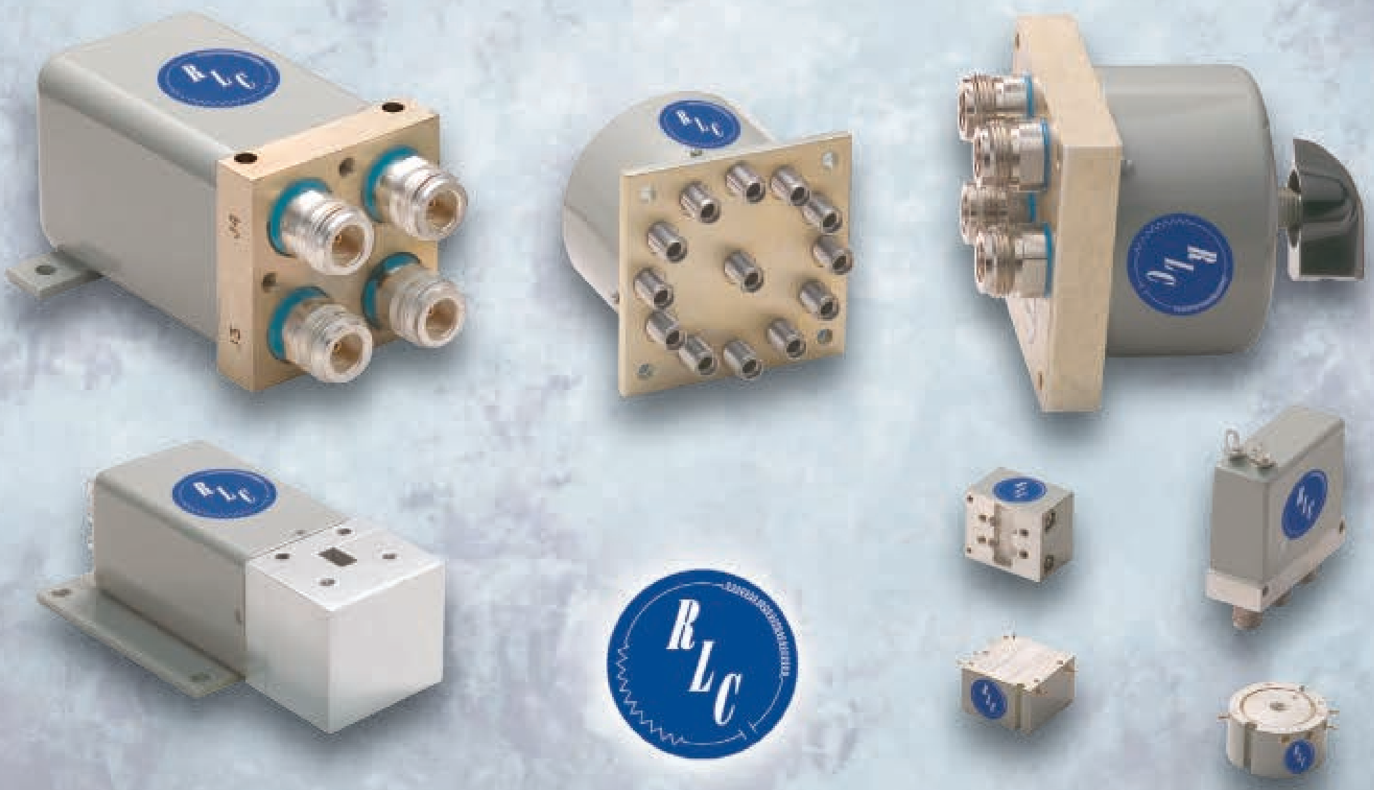


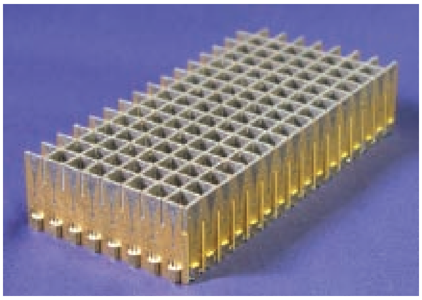
from the US and abroad, and universities from across the country. The presentations exemplify the breadth of antenna applications, ranging from arrays for radar, communication, navigation and remote sensing, to innovative, multidisciplinary basic research concepts for antenna reconfigurability and multifunctionality, to numerical modeling techniques. The conference includes technical focus sessions on timely, compelling topics, and showcases exceptional young engineers through the annual Student Paper Contest.

Topics at the 2008 symposium included many of the technologies that are at the forefront of current R&D: arrays, antenna design methods, cost reduction, performance enhancement and platform interactions. A focus session provided stimulating discussions about applications of metamaterials to practical antenna problems on military and aerospace vehicles.

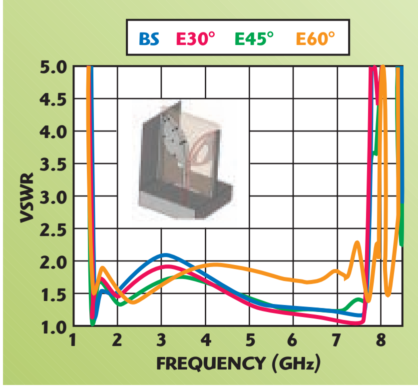
TECHNOLOGY HIGHLIGHTS OF THE 2008 SYMPOSIUM

Array Antennas

Wide bandwidth phased arrays continue to be an area of intense interest. Experienced designers of Vivaldi antenna elements and end-coupled dipoles can achieve 10:1 bandwidth while scanning to 45° or more.[1,2] However, these wideband array designs have unsolved problems related to low-cost manufacturing and maintenance, easy integration with the array back plane, size, weight and materials. The paper by Stasiowski[1] is a useful primer for anyone planning to build a Vivaldi array that operates above 10 GHz (see ***Figure 2***). The problems of connector attachment and PC board shrinkage were overcome to successfully fabricate 128-element printed circuit boards for a large array designed to operate from 2 to 18 GHz. The lessons learned during the fabrication of this array were applied to a large array.



▲ *Fig. 2 Prototype dual-polarized Vivaldi antenna array 6 to 8 GHz.[1]*

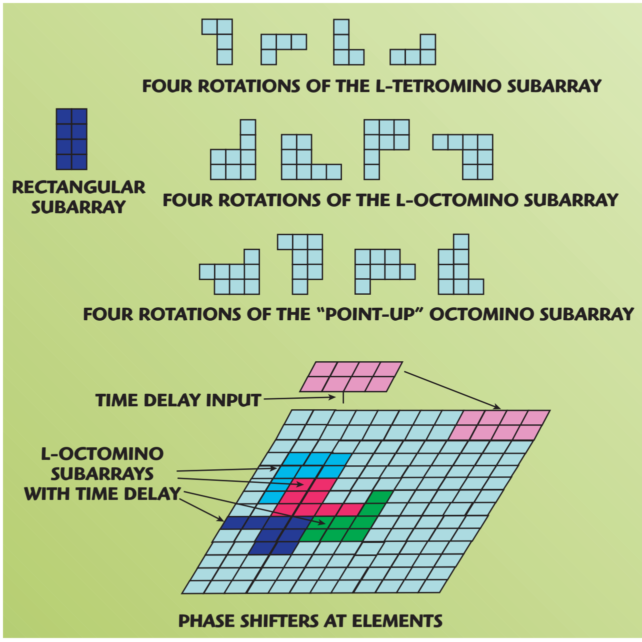


▲ *Fig. 3 Balanced Antipodal Vivaldi Antenna in a singly polarized array configuration.*

The Balanced Antipodal Vivaldi Antenna (BAVA) has many features of traditional Vivaldi and of coupled-dipole arrays, but is more amenable to low-cost modular construction. BAVA arrays do not require electrical contact or close proximity to adjacent elements, so arrays can be assembled by using individual elements or small subarrays. The BAVA phased-array element is based on the original BAVA design,[3] but is modified to perform well in scanning arrays. Elsallal described BAVA arrays utilizing modular elements.[4] ***Figure 3*** shows a typical BAVA element and its VSWR in an infinite array environment. The simulated VSWR, for four angles in the E-plane of an infinite array, was computed by using a periodic cell approach.[4]

Despite advances in the capability and manufacturing of T/R modules, their cost, efficiency and thermal dissipation remain key drivers in the overall cost of phased-array antennas. In a typical array configuration, one T/R module is needed for each array element, and the element spacing must be no more than one-half wavelength to avoid grating lobes. Thus, the array requires four T/R modules per square wavelength of aperture and eight for dual-polarized arrays. The module count might be reduced by partitioning the aperture into subarrays and feeding the elements of a subarray by a single T/R module. However, the use of uniform subarrays on a periodic grid introduces grating lobes into the array pattern. Randomizing the subarray shapes, sizes and locations can eliminate the grating lobes (the average sidelobe level is increased as a result of redistributing the grating lobe power), but the randomized array cannot take advantage of low-cost manufacturing of multiple, identical subarrays.

Polyomino-shaped subarrays can eliminate grating lobes from the array pattern while retaining the advantages of uniform subarray shape. The paper by Mailloux, et al. described arrays of four-(tetromino) and eight-(octomino) element subarrays that can be fed by lossless power dividers.[5] In this case, the subarrays are used for the purpose of introducing time delays into a phase scanned array. Although all subarrays are identical, randomization is obtained by rotating the subarrays and fitting them into place so that their phase centers form an irregular pattern. ***Figure 4*** shows examples of rotated



▲ *Fig. 4 Polyomino-shaped subarrays can be used to completely fill a prescribed aperture.*

tetromino and octomino subarrays, and illustrates how they can be fitted into an array. In this way, the authors demonstrated grating lobe suppression of up to 20 dB for large arrays of tetromino and octomino shaped subarrays with only a few tenths of a dB gain reduction in most cases.

Manufacturing and assembly techniques that are appropriate for microwave frequency antenna arrays may not be viable for millimeter-wave arrays. Array feed networks require signals to be distributed over areas spanning several wavelengths. Fabrication tolerances and material losses of ordinary printed circuits make them less attractive for frequencies above 30 GHz. Also, connections between components are problematic at these frequencies.

Micro-fabrication techniques, however, become practical when the circuit sizes shrink to a few centimeters. Three-dimensional, micro-electromagnetic RF systems (3-D MERFS) demonstrate yields above 99 percent and few effects from surface roughness and strata misalignments.[6] Agreement between computer simulations and circuit performance is excellent, illustrating that this technology is maturing for system implementation. A comprehensive list of microwave components can be assembled with three-dimensional micromachined rectangular coaxial lines of micron scale. Filipovic, et al.[6,7] demonstrated the use of micro-fabricated coaxial lines for a Ka-band array. ***Figure 5*** shows the upper surface of a 3-D 16 x 16 butler matrix connected to a Ka-band array operating at 36 GHz. The cavity-backed patch antenna elements (left) are fed with a recta-coax 16 x 16 Butler matrix. The system includes integrated resistors and power dividers/combiners.

Advances continue to be seen in the application of arrays. Daly and Bernhard[8] presented an array of reconfigurable elements for multi-directional communication with built-in security. The presentation considered an array of reconfigurable square spiral antennas with switches to make the elements radiate in two modes, one near broadside and the other near end-fire. These elements were used in a 1 x 4 array with no other

▲ *Fig. 5 Micro-coaxial Ka-band phased array operating at 36 GHz.*

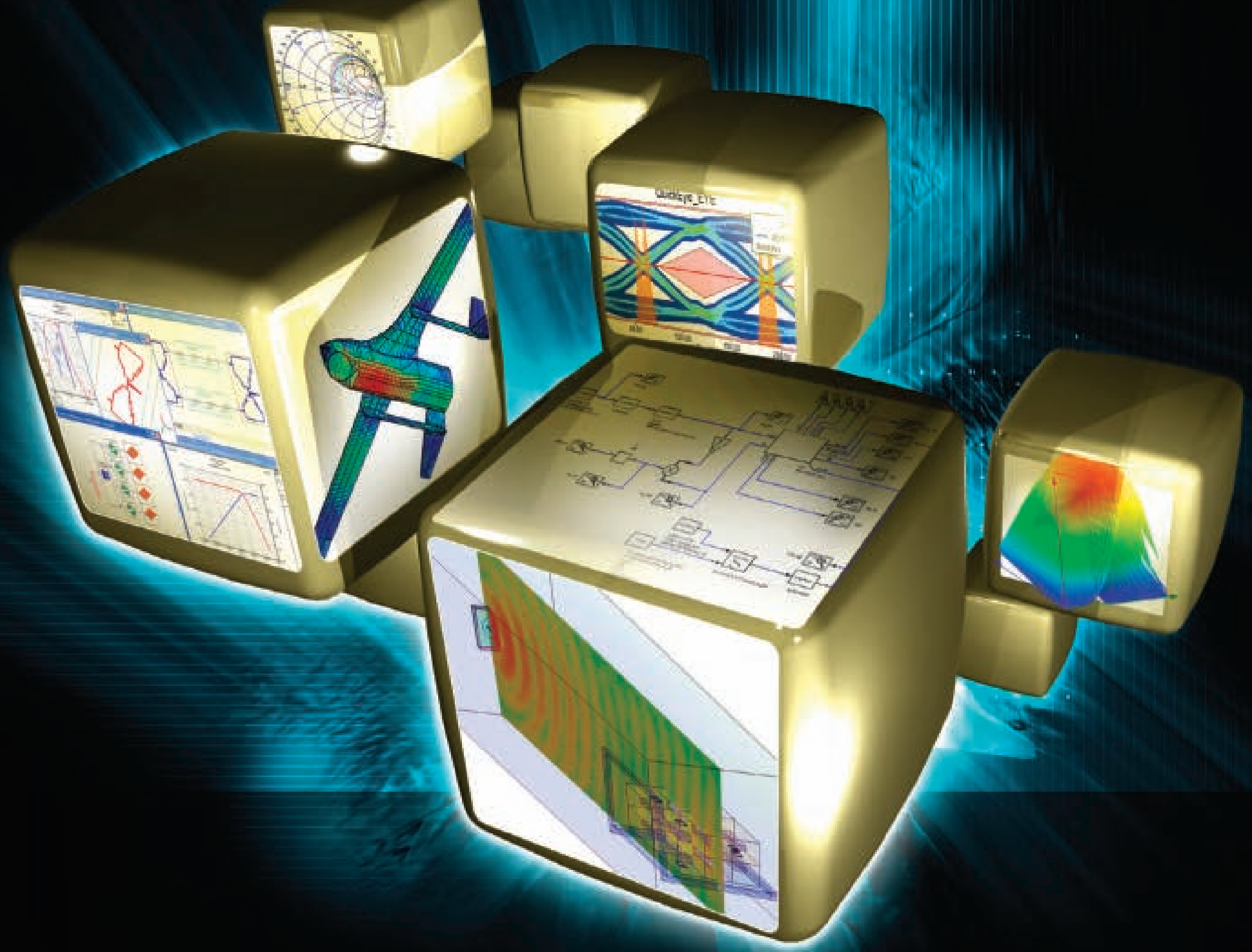
phase or amplitude control. This degree of element pattern change provides directional modulation so that, at one angle, there can be 16 possible transmitted signals. At angles outside of the desired transmission region the transmitted modulation is significantly distorted, thus providing a degree of communication security. If extended, this new application for reconfigurable arrays could provide independent, secure communication in multiple directions.

The paper by Herting, et al.[9] is an excellent example of the symposium's traditional emphasis on solid, practical engineering. The authors revisited the design of a waveguide edge slot array, with a view to reducing manufacturing costs by relaxing mechanical tolerances wherever permitted by the design and the performance requirements. To this end, they developed a Monte Carlo-based tolerance analysis method utilizing a standard transmission line model for the edge slot waveguide. The shunt admittances were derived from full-wave electromagnetic simulations using Ansoft HFSS™. By analyzing the array performance for many variations of the slot tilt angle, depth, width and location, it is possible to determine the tolerance requirements for these parameters. The efficiency of the procedure was shown to make this a useful tool in selecting the lowest cost manufacturing process for an edge slot waveguide array.

Design Techniques and Performance Enhancement

Throughout its history, the symposium has been a forum for presentation and discussion of cutting-edge antenna concepts, with a focus on application-oriented design and analysis. In keeping with this heritage, the 2008 symposium featured a number of papers on emerging antenna technologies.

In the area of reconfigurable antennas, Huff, et al.[10] presented concepts for biologically-inspired antennas based on the rapidly adapting cuttlefish. The cuttlefish controls its



outward appearance through neural manipulation of a complex, multi-layered skin structure. The skin contains microfluidic elements that include colloidal materials and periodic gratings to reflect, refract and polarize light, enabling the cuttlefish to dramatically alter its appearance. The proposed antenna analog to this system relies on electromagnetically functionalized colloidal dispersions, or EFCDs, that have specified dielectric, magnetic and/or conductive properties.[10] In the example of ***Figure 6***, EFCDs flow through capillaries embedded in the substrate of a microstrip patch antenna. Measured results indicate that significant frequency reconfiguration can be achieved using a range of mixtures of colloids with varying electric and magnetic properties. Other biologically-inspired mechanisms create pattern reconfigurable antennas.

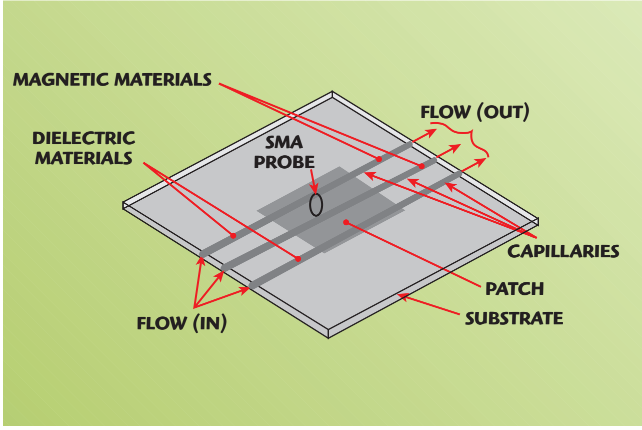


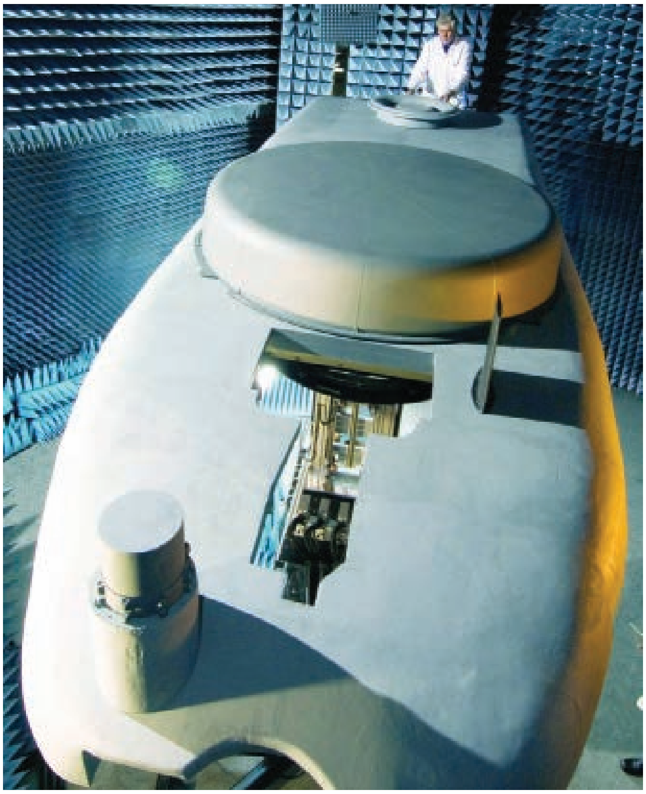
Fig. 6 Microstrip patch with substrate-embedded capillaries through which EFCDs flow.

Answering the constant call from commercial and government users for antennas to fit into smaller and smaller packages while working at lower and lower frequencies, the symposium routinely contains several papers on development of electrically small antennas. Steven Best presented his work on the study of a number of electrically small antennas that have wide operating bandwidths.[11] These include designs by Goubau, Friedman, Ravipati, Nakano and Best. The behavior of each of these designs is carefully modeled to better understand their fundamental operating principles. The paper also provides an insightful discussion of metrics that might be used to assess the relative merits of wideband electrically small antennas, including the critical tradeoff between size and operating bandwidth. Sussman-Fort and Rudish[12] showed that non-Foster matching can yield 2:1 improvement in power efficiencies, compared to passively matched small antennas over a frequency range 1.2 to 20 MHz. Average power levels of 1.2 W were realized over this frequency band.

Antenna packaging and platforms have rightly garnered a great deal of attention over the years, with these critical system aspects often becoming the key drivers in overall system performance. For example, McCartney described the performance of a helicopter-mounted radar system, shown in ***Figure 7***, and presented simulated and measured results of the electromagnetic effects of the helicopter body.[13] Accurate characterization of the antenna performance requires an exact replica of the vehicle. McCartney also presented an after-dinner talk on radome development for a number of well-known aircraft, especially the nose radome for the Concorde SST. The talk provided an excellent inside view of the electromagnetic design and manufacturing processes for such a high-profile, high-technology product. The talk included a number of photos as well as interesting and often humorous anecdotes about the development team, the other technology innovations that went into the aircraft, and of course the multi-national bureaucracy that oversaw the whole operation.

Other papers that focused on packaging and platforms generated a great deal of discussion among the participants. For example, Kerby and Bernhard[14] described the use and analysis of integrated ground plane structures to reduce mutual coupling between antennas on a platform. Lalezari, et al. illustrated through analysis and measurements that the

accuracy and false alarm rate of a portable direction finding system can be improved by exploiting interactions with the human body of the operator.[15]



▲ *Fig. 7 Partially assembled model of helicopter (inverted) with radar antenna installed for testing.*

Practical Applications of Metamaterials to Antennas

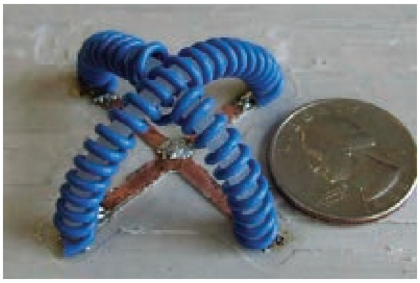
The symposium frequently includes a focus session. The 2008 focus session, chaired by David Curtis of the US Air Force Research Laboratory Sensors Directorate at Hanscom Air Force Base, explored the status of metamaterials, with respect to practical antenna designs, and identified antenna performance challenges that might be overcome by further improvements to presently available metamaterial properties. Metamaterials are a class of ordered or disordered composites (including nanostructures) that exhibit exceptional properties not readily observed in nature.[16] Those properties arise from qualitatively new response functions that: 1) are not observed in the constituent materials; and 2) result from artificially fabricated, extrinsic inclusions and inhomogeneities, often of low dimensionality. The use of metamaterial composites is not limited to electromagnetics; mechanical, acoustical and thermal properties can be tailored with metamaterials as well.

Derov, et al.[16] described the RF properties of metamaterials and discussed the results of many researchers in the field. Metamaterials often exhibit negative permittivity, negative permeability, or negative index of refraction in a particular band of frequencies. The physical structures and phenomenologies that lead to these properties are critical to the use of metamaterials in antennas and other systems. Some metamaterials that were developed for applications unrelated to antennas may impact the field. For example, high-power-density and high-temperature-resistant composite magnets were developed under the DARPA metamaterials program utilizing nano-ferrites. These magnets were designed for power generators and magnetic bearings in engines. However, they might be used for high-field, thin-film magnets to bias circulators and isolators, thus reducing the size of transmit/receive modules and thereby impacting phased-array design.

Steven Weiss and Amir Zaghloul from the US Army Research Laboratory Sensors and Electron Devices Directorate at Adelphi, MD, described communication and sensor requirements for Army platforms and suggested that metamaterials utilizing magnetic properties may provide enhancements that have been unachievable with current techniques. Steven Best showed several metamaterial-based antennas and described their performance relative to fundamental limits and to traditional antenna designs. He noted that antenna designers usually confront requirements and/or tradeoffs of antenna performance that are driven by system

goals. The realized gain of an antenna is comprised of directivity, efficiency and mismatch. The directivity of an electrically small antenna is approximately the same as a small dipole (1.8 dB) or monopole (4.8 dB), if a large ground plane is used. To optimize the performance of a small antenna, the designer must match the antenna impedance to the source or load while maintaining high efficiency. Traditional lumped element (RLC) or transmission-line matching techniques, coupled with conventional antenna design approaches, can be used to achieve these goals. Best noted that some of the published metamaterial antenna designs function primarily as impedance matching devices that are added to an otherwise familiar antenna structure. Often, the metamaterial that is added increases the structure's volume, a fact that must be considered when comparing the bandwidth to antennas without the metamaterial. Best noted that Chu's bandwidth limit for small antennas[17] applies to antennas comprised of ordinary materials and of metamaterials, provided the total volume of the antenna plus any added materials is considered. Best emphasized that when considering or designing metamaterial antennas, it is important to compare their performance relative to both fundamental limits and conventional designs.

An example of a "conventional" antenna that is well matched and achieves nearly the minimum possible Q for its volume[18] is shown in ***Figure 8***. This spherical antenna uses only ordinary materials to control the current distribution and electromagnetic fields for near-minimum Q and, hence, nearly maximum bandwidth. This low-Q antenna fits within a 24 mm radius sphere, operates at 1.03 GHz and has a 3.4 percent bandwidth for a VSWR less than 2 at 50 Ω. The single-session format of the Antenna Applications Symposium allows extended discussion of the technical presentations. The metamaterial session featured lively and informative debate.



▲ *Fig. 8 A low-Q "conventional" antenna.*

Student Paper Contest

Each year, four or five students are selected to be finalists in the Student Paper Contest. Student authored papers that describe innovative work on antenna design, fabrication, testing, analysis or related topics are eligible for the contest. The four finalists in 2008 were Rajesh C. Paryani from the University of Central Florida, supervised by Prof. Nader Behdad, Steven Holland from the University of Massachusetts at Amherst, supervised by Prof. Dan Schaubert, Matthew J. Radway from the University of Colorado, supervised by Prof. Dejan Filipovic, and Jacob Adams from the University of Illinois at Urbana-Champaign, supervised by Prof. Jennifer Bernhard. All four finalists received free registration and travel support to attend the symposium and present their work. The winning paper is selected by a panel of judges, based on the technical merit of the full-length conference paper and the quality of the student's presentation.

Rajesh Paryani won first place for his paper entitled "A Wideband, Dual-polarized, Differentially-fed Cavity-backed Slot Antenna." Paryani's advisor, Prof. Nader Behdad, also won the student paper contest when he was a student at the University of Michigan.

In ***Figure 9***, Paryani, left, receives congratulations as winner of the Student Paper Contest from W. Devereux Palmer, program manager for electromagnetics at the US Army Research Office.

▲ *Fig. 9 Rajesh Paryani receives congratulations for winning the student paper contest.*

CONCLUSION

As it has been for over 50 years, the Antenna Applications Symposium, and its predecessor the Air Force Antenna Symposium, is a meeting place for antenna engineers from around the world; a place to discuss technology in the magnificent setting of Robert Allerton Park. Phased arrays are always a significant part of the program. Wide bandwidth operation and reduced manufacturing and operating costs are two areas of ongoing work. New materials and microfabrication techniques are extending the frequency range of arrays. New applications and new techniques, such as secure communication by pattern modulation, were disclosed at the symposium.

Novel antenna designs are a common topic at the symposium. New designs presented in 2008 included a reconfigurable antenna using colloidal solutions inspired by the cuttlefish and several ways to control or to utilize antenna-platform interactions. The importance of electrically small antennas is evident from continuing work to improve their bandwidth and efficiency.

Metamaterials are composite structures that exhibit properties not achieved in nature. Despite the allure of these materials and despite several prototype demonstrations of exciting features, they are not yet widely used in practical antenna systems. A focus session at the 2008 symposium updated attendees on the status and challenges to using metamaterials in practical antenna systems.

The Proceedings of the Antenna Applications Symposium are archived by the US Air Force as technical reports that can be retrieved from the Defense Technical Information Center. With the support of the US Air

Force Research Laboratory Antenna Technology Branch at Hanscom AFB, the US Army Research Office and MITRE Corp., the Proceedings of this symposium have been archived in searchable electronic format on DVD, a copy of which is provided to each conference registrant. This portable electronic archive provides easy access to all available papers presented at the Allerton Symposium from 1952 through 2008. Abstracts are solicited annually in the spring, and are submitted to the conference web site (www.ecs.umass.edu/ece/allerton/). ■

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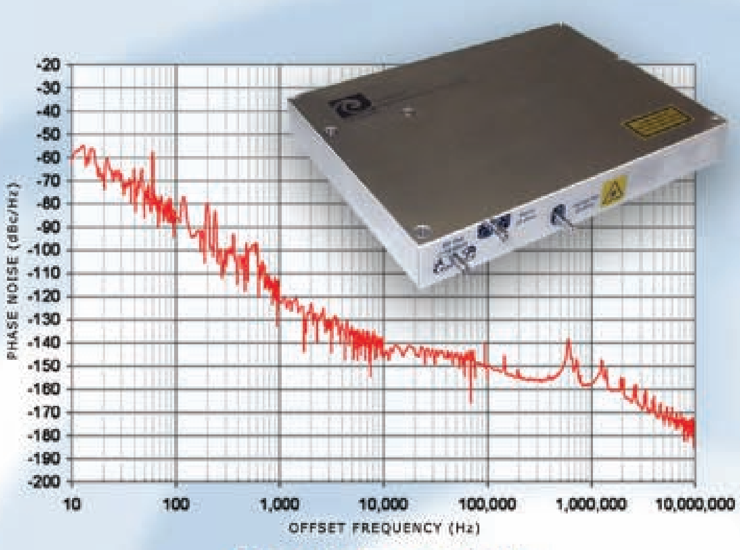

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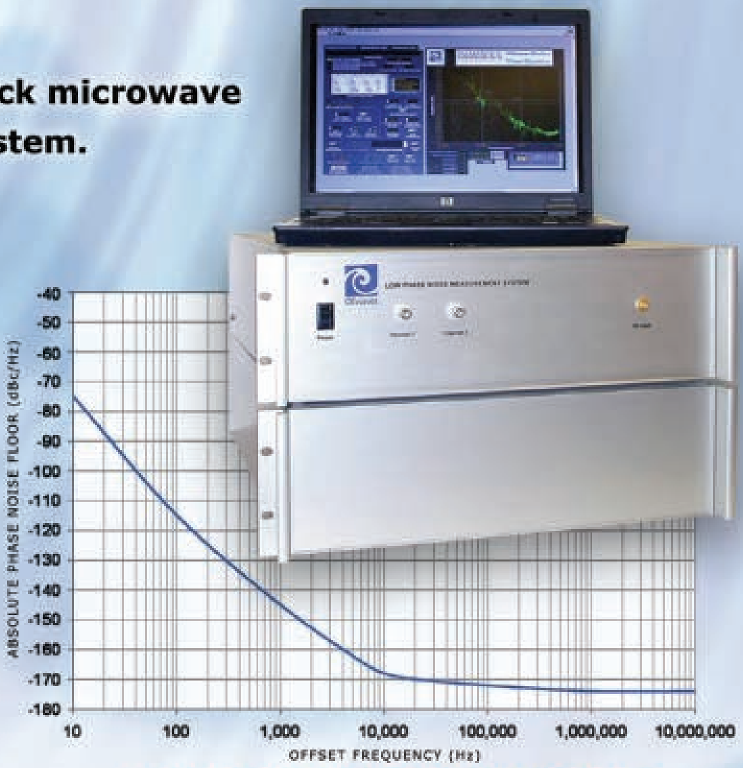

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Jennifer T. Bernhard *earned her BS degree in electrical engineering from Cornell University in 1988 and her MS and PhD degrees in electrical engineering from Duke University in 1990 and 1994, respectively. She is currently a professor at the University of Illinois at Urbana-Champaign in the Electromagnetics Laboratory. Her research interests include reconfigurable and wideband microwave antennas and circuits, high speed wireless communication and sensor networks, electromagnetic compatibility, and electromagnetics for biological applications. She served as president of the IEEE Antennas and Propagation Society in 2008.*

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W. Devereux Palmer *received his PhD degree in electrical engineering from Duke University. He is currently a program manager at the US Army Research Office in Research Triangle Park, NC, where he manages extramural basic research in computational electromagnetics, antennas and RF circuit integration. From 1991 to 2001, he served on the technical staff at the MCNC Research and Development Institute. He is engaged in antenna research as a Member of the Graduate Faculty at Duke University and occasionally teaches introductory electromagnetics. He is a registered Professional Engineer and IEEE Senior Member.*

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Northrop Grumman Awarded Joint STARS Radar Modernization Contract

The US Air Force has awarded a risk reduction study contract to Northrop Grumman Corp. for the E-8C Joint Surveillance Target Attack Radar System (Joint STARS) Radar Modernization program. The study will be performed under Northrop Grumman's existing Multi-Platform Radar Technology Insertion Radar (MP-RTIP) program. The $5.8 M study will look at risk reduction efforts involved in adapting the wide-area surveillance version of the MP-RTIP sensor, originally planned for the E-10A aircraft, for Joint STARS.

"This is a critical first step for the Joint STARS Radar Modernization program," said Tom Vice, sector vice president of Northrop Grumman Integrated Systems' Eastern Region. "A large, advanced, wide-area surveillance version of the MP-RTIP sensor integrated on Joint STARS will provide an exponential growth in information fidelity to our joint warfighters. It will also bring vastly improved situational awareness for tracking ground movement, cruise missiles and support for irregular warfare and other emerging threats."

Northrop Grumman is the prime contractor for the Joint STARS program and responsible for full system life cycle support. Work on the study will be done at Northrop Grumman facilities in Norwalk, CT, Melbourne, FL and El Segundo, CA, and Raytheon's Space and Airborne business unit. The US Air Force E-8C Joint STARS is a highly modified commercial aircraft that detects, locates, classifies, tracks and targets hostile ground movements, communicating real-time information through secure data links to ground and airborne forces.

All Joint STARS aircraft are assigned to the Georgia Air National Guard's 116th Air Control Wing, a "total-force blended wing," based at Robins Air Force Base, Warner Robins, GA. The wing comprises active-duty Air Force, Army and Air National Guard personnel. Crews from the 116th have flown more than 40,000 combat hours supporting coalition forces in the Global War on Terrorism.

Raytheon Kill Vehicle and Radars Key to Ballistic Missile Intercept

Raytheon Co. components played key roles in the destruction of a ballistic missile target during the latest flight test of the Missile Defense Agency's Ground-based Midcourse Defense system. This was the eighth intercept for the GMD system.

During the December 5 test, a Raytheon-built Exoatmospheric Kill Vehicle (EKV) intercepted a ballistic missile in space, over the eastern Pacific Ocean. While communicating with ground sensors, the EKV detected, tracked and discriminated the target. "This highly successful test of the GMD system once again demonstrates Raytheon's commitment to performance and reliability," said Taylor W. Lawrence, Raytheon Missile Systems president. "We continue to prove the maturity of our kill vehicle technology and our ability to provide this critical capability to the nation."

While in flight, the EKV calibrated its own position using the stars. The EKV then selected an aimpoint and maneuvered for a direct hit, intercepting the target at a closing velocity of more than 18,000 miles per hour. The target was launched from Kodiak, AK, and the interceptor was fired from Vandenberg Air Force Base, CA. In the first demonstration of GMD integrated performance, Raytheon's AN/TPY-2 X-band Radar acquired the target shortly after lift off. Operating in forward-based mode from Juneau, AK, the radar provided track updates to MDA's Ballistic Missile Defense system.

Raytheon's Upgraded Early Warning Radar, at Beale Air Force Base, CA, tracked the target during its flight downrange. Raytheon's X-band Radar, deployed aboard the sea-based X-band radar, actively participated by tracking, discriminating and assessing the target. "The UEWR, SBX and AN/TPY-2 performed as expected, demonstrating their missile defense capabilities," said Pete Franklin, vice president, National and Theater Security Programs for Raytheon Integrated Defense systems.

Lockheed Martin and ITT Team for US Navy Electronic Warfare Competition

Lockheed Martin has teamed with ITT Corp., Morgan Hill, CA, to compete for the US Navy's Surface Electronic Warfare Improvement Program Block 2 Upgrade (SEWIP BLK2). This program will lay the groundwork for the upcoming competition for the Navy's next-generation electronic warfare system. In at-sea demonstrations this summer, the Lockheed Martin/ITT team's Integrated Common Electronic Warfare System (ICEWS)—a single enterprise solution designed to scale across all ship classes in the US Navy's surface fleet—performed successfully. This ICEWS demonstration followed land-based testing and further validated the enterprise approach that the team has taken in developing sensor systems for US Navy vessels.

"The Lockheed Martin/ITT partnership brings more than 40 years of electronic warfare capabilities and experience together in a single team," observed Carl Bannar, vice president and general manager of Lockheed Martin's Radar Systems business. "We will provide a highly capable, modular solution that uses open systems architecture."

"We will leverage our existing relationship with Lockheed Martin supporting the AN/BLQ-10 submarine enterprise electronic warfare program to provide the Navy with a strong and experienced supplier," said Chris Bernhardt, president of ITT Electronic Systems.

Harris Corp. Urges Adoption of Multiband Radio Technology

Harris Corp., an international communications and information technology company, called for the adoption of software-defined, multiband, multimission radios as a principal solution for interoperable public safety communications among first responders.

During a presentation titled "Enabling First-Responder Interoperability through Multiband, Software Defined Radios," Kevin Kane, director of business development for Government and Public Safety, Harris RF Communications Division, said that multiband, multimode radios are a powerful tool that will enable state, federal, local and tribal agencies to operate more effectively. Kane made his remarks during the Second Annual Conference on National Preparedness, which took place at the Hilton Melbourne Beach Oceanfront Hotel in Melbourne, FL.

Hosted by the Florida Institute of Technology, the conference featured more than 25 distinguished speakers who are leaders in disaster preparedness and response, national and international security, and humanitarian and disaster relief logistics. The conference provided an in-depth look at technologies and integrated strategies on national preparedness. Sessions covered a wide range of topics, including national and international safety and security, command and control, global preparedness and cyber security. Kane told the conference that multiband radios will help first responders overcome barriers to more effective and efficient cooperation. "Overlapping jurisdictions and missions today create the need for communications that provide direct, full-spectrum interoperability," said Kane. "Multiband, software-defined radios have the power and flexibility to support these critical and fast-changing missions now and into the future."

"Multiband technologies address many communication challenges in homeland security that are driven by jurisdiction overlap, large areas of responsibility, joint missions, regional communications systems and the unpredictability of the unknown," said Kane. "Multiband is a superior solution to the current system of single-banded radios. Solutions that are capable of providing compatibility among today's communications systems are costly, provide limited capability or are unreliable," Kane said, citing ad-hoc interoperability tools, such as gateways, switches, patches and swaps as examples. "Multiband radio technology provides reduced cost of product development and communications upgrades, pathways to future technologies and improved battery life." ■


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European Space Centre at Harwell

The European Space Agency (ESA) and the UK government have signed an agreement in principle to develop an ESA research centre at the Harwell Science and Innovation Campus (HSIC) in Oxfordshire, UK. The aim is for the research centre to be up and running within a year.

Keith Mason, chief executive of the Science and Technology Facilities Council (STFC), one of the major partners in HSIC, said, "STFC welcome this significant announcement, as I'm sure the UK space community will. The development of an ESA centre at the Harwell Science Innovation Campus is a direct result of the UK's strong record in space, both within industry and in academia."

The proposed space centre will place an emphasis on exploiting the benefits of space to terrestrial users, and knowledge exchange and development to support the future ESA programme. It will take full advantage of the unique environment being created at the Harwell Science & Innovation Campus where state-of-the-art publicly funded scientific facilities will operate alongside industrial research and development.

Once established the new centre will expand ESA's existing pan European infrastructure facilities by enabling the agency to develop key technologies and capabilities, particularly new work on climate change modelling that uses space data and the development of technologies for a new era of planetary exploration, including robotics and novel power sources.

Cambridge Broadband Networks Joins NGMN Alliance

Cambridge Broadband Networks Ltd. is the first backhaul-focused technology vendor to join the Next Generation Mobile Network Alliance (NGMN). The NGMN is a group of world leading operators such as AT&T, China Mobile, Orange, T-Mobile and Vodafone as well as technology vendors, including Alcatel-Lucent, Cisco, Ericsson, Huawei and Nokia Siemens Networks.

Cambridge Broadband Networks supplies point-to-multipoint packet microwave backhaul network solutions, designed to provide flexible backhaul to mobile broadband network operators. These solutions enable mobile network operators to roll-out high performance mobile broadband networks quickly.

This new partnership combines the knowledge of NGMN's partners with Cambridge Broadband Network's expertise in traffic optimisation and PMP microwave backhaul architecture, thereby furthering the group's capabilities to work effectively towards providing better next generation mobile broadband services.

Peter Meissner, operating officer of NGMN, said, "To ensure that next generation networks deliver a quality experience to customers, backhaul networks need to be carefully designed to respond to traffic requirements while providing cost-efficient, flexible and easy-to-operate solutions for the operators. NGMN is glad to have Cambridge Broadband Networks on board to help us to achieve our challenging objectives and to make the vision of NGMN a reality."

ST Joins Microsystems Industrial Group at MTL

STMicroelectronics has become the first European company to join the Microsystems Industrial Group (MIG) industry consortium at the Microsystems Technology Laboratories (MTL), Massachusetts Institute of Technology. The Group is an exclusive industry consortium that was founded in the 1980s to support Microsystems Technology Laboratories infrastructure and provide direction to the MTL research and educational objectives in consultation with the faculty.

As one of the world's largest semiconductor companies and supplier of embedded System-on-Chip ICs for use in communications, automotive, consumer and computer peripheral markets, STMicroelectronics is engaged in a wide range of research programmes conducted with leading universities and research institutes around the world.

The significance of this latest collaboration was highlighted by Elio Guidetti, director for ultra low power platforms, advanced system technology at STMicroelectronics, who said, "By joining MTL, ST will be able to push its research efforts to fully exploit 'near-threshold' technology and reach far below the actual power consumption limits of energy-efficient System-on-Chip solutions. This technology can enable the development of an entirely new generation of microcontrollers for wireless sensors and portable medical devices."

Technology Strategy Board to Refocus KTNs

Following a major review the Technology Strategy Board—an executive non-departmental public body established by the UK Government in 2007—is to refocus the work of its Knowledge Transfer Networks (KTN). The aim of the networks is bring together interested parties from business, universities and research organisations to stimulate innovation through knowledge exchange.

KTNs engage with trade associations, technology providers, research councils, Regional Development Agencies and the Devolved Administrations to deliver benefits to businesses of all sizes.

The comprehensive review, which obtained views from 2,100 KTN users and R&D intensive businesses, strongly confirmed the value of the networks. Seventy-five percent of business respondents rated KTN services as effective or highly effective. Over 50 percent have developed, or are developing, new R&D or commercial relationships with people met through a KTN and 25 percent have made changes to their innovation activities as a result of their engagement.

The changes that have resulted from this consultation will see a revision of the coverage of business and technology sectors, creating a more targeted, comprehensive and accessible range of network resources to help accelerate innovation.

European Air Traffic Management Standard Adopted

A new page in the modern history of aeronautical standardization has been written by ETSI members and ETSI partner organization EUROCAE, with the adoption of a new European Standard on Advanced Surface Movement Guidance and Control Systems (A-SMGCS). It is seen as a significant step towards the completion of the first of many Community Specifications planned for ensuring an interoperable European Air Traffic Management Network.

The draft European Standard (draft EN 303 213-1 on A-SMGCS Level 1 systems) was produced by a team appointed by ETSI Aeronautical Standards Task Group TG25 in December 2007. The Task Group's parent Technical Committee (ETSI ERM) has now approved this draft for Public Enquiry, which is the next step in the process before formal European adoption of the standard.

The production of this draft European Standard builds on work by CEN, EUROCAE and ETSI members including EUROCONTROL to create a guidance document on the development of Community Specifications for application under the SES legislation. Community Specifications are European Standards that may be used to give presumption of conformity to the SES Interoperability Regulation. The document that has now been adopted is the first of the Community Specifications for SES produced by the European Standards organisations CEN, CENELEC and ETSI.

Gabrielle Owen, chairman, ETSI Technical Committee ERM, said, "With the achievement of this milestone, we have for the first time a draft of a European Standard for Air Navigation Service Equipment, which follows the requirements of the Single European Sky Legislation, adopted in 2004." ■

Economic Crisis Likely to Impact High-flying Cellphone Industry

While the cellphone industry has generally been unaffected by economic ups and downs, this recession may well be very different, reports In-Stat. The current economic slowdown is more widespread and deeper than ever experienced during the history of the cellphone, and has spread through Europe, Asia and North America, the high-tech market research firm says. The industry is currently strong, and this year is turning out to be a relatively good one, but the cellphone industry will likely have some bumps and turbulence over the next couple of years.

"The economic crisis is still playing out, but all indications are that it will have an effect on the cellphone business worldwide, but mostly on North America and Europe," says Allen Nogee, In-Stat analyst. "In-Stat believes that it will take until 2010 before cellphone sales return to their normal growth levels."

Recent research by In-Stat found the following:

- For the next five years, cellphone semiconductor revenue will only grow at a 3.3 percent compound annual growth rate (CAGR).
- Over 1.2 billion cellphones will be shipped this year, but the growth rate is rapidly slowing.
- The cellphone industry will be tested like never before in the next year, as it deals with the impact of a poor economy and a lack of new features to promote.

The research, "A Tarnish Silver Anniversary for Handsets—Worldwide Handset and Semiconductor Forecast," covers the worldwide market for cellular handsets and semiconductors. It provides forecasts for handset semiconductor shipments and revenue by region through 2012. Analysis of market conditions by regions is included.

High-power RFIC Markets Going from Strength to Strength

ABI Research's optimistic forecasts for the penetration of high-powered RF integrated circuits into the mobile wireless base station market have been borne out by the latest market developments. According to research director Lance Wilson, "Compared to the discrete devices they can replace, high-power RFICs take up less circuit board space; they are easier to use; and they cost the same or slightly less."

This new breed of high power RFICs is primarily intended for use in base stations for cellular and other wireless infrastructure. Although the conventional wisdom suggested relatively modest and stable growth for these chips, for several years they have been taking an increasingly significant share of this market. ABI Research expects that the pace of this market adoption will only increase over time.

The rate of growth in shipment numbers is expected to level out slightly in 2011, but overall, between 2008 and 2013, revenue growth from this market will show a compound annual growth rate of 6 percent, which may seem modest but should be viewed as strong in an overall declining RF power device market for wireless infrastructure. By far, the lion's share of these revenues will go to just three large vendors.

ABI Research's recent report, "High-power RFICs," identifies the factors driving the RFIC market, discusses the device technologies and the vendor landscape, explains this technology's disruptive potential, and contains new, accelerated forecasts. It forms part of two ABI Research services: RF Power Devices and Wireless Semiconductors.

Total Available Market for Microwave Tubes Approaching $1 B

While microwave and millimeter-wave high-power vacuum electron devices (VED) remain "below the radar" of many industry observers, the total available market (TAM) for this segment is nearly $1 B. Despite its size, and although these tubes (valves) remain essential elements in specialized military, scientific/medical and space communications applications, this market is generally under-reported and poorly understood by those not directly involved in it.

ABI Research director Lance Wilson says, "ABI Research's recent investigations of the high-power RF vacuum electron device market revealed a total market size that was surprising even to those who were familiar with the technology and its history. Because of this, I believe there is a latent thirst for knowledge in this area." Essentially, this is now a stable industry after several rounds of consolidation in recent years. Wilson says that there is potential for some further consolidation, but there are no signs of that happening yet. However, one new RF semiconductor technology—gallium nitride—may change the landscape. While it is not yet revolutionizing the microwave RF power industry, GaN is advancing steadily and is a technology that should be closely watched, as it will become a threat to some aspects of the microwave and millimeter-wave VED marketplace.

"Vacuum electron devices may at first seem anachronistic," Wilson adds. "But in some cases there is no other way to generate such high levels of RF power within an acceptably small space. Certain klystrons and gyrotrons can generate megawatts, and it would take tens of thousands of transistors to do that."

ABI Research's recent study, "Microwave and Millimeter-wave High-power Vacuum Devices and the Gallium Nitride Threat," examines the microwave and millimeter-wave high-power vacuum electron device market and assesses how emerging gallium nitride (GaN) devices could affect that business. It will be of interest to organizations involved in defense electronic, energy and scientific research and spacecraft electronics, as well as VED manufacturers, RF power semiconductor users and manufacturers, and government. It forms part of the firm's RF Power Devices Research Service, which also includes other Research Reports, ABI Insights and analyst inquiry support.

335,000 Cellular Base Stations to Include Solar Power by 2013

As mobile network expansion moves ostensibly to emerging markets where solar energy levels are more favorable, solar power appears ready to play an important role in reducing the costs of cellular service delivery and ensuring a more reliable power supply. The OEMs' drive toward reducing base station power consumption, along with improvements in photovoltaic cells, have meant that solar energy is now a very viable solution for powering cellular base stations.

ABI Research vice president Stuart Carlaw says, "Solar power will first be used in conjunction with other primary energy sources such as diesel or grid-based electricity, but will increasingly be seen as a primary source for autonomous cell sites." Carlaw adds that, "The market for autonomous solar powered cell sites looks set to grow from extremely modest levels to over 40,000 renewable energy sites by the end of 2013. A further 295,000 base stations are expected to supplement on-grid power usage with solar."

Solar power is at the leading edge of renewable energy's drive into the mobile network domain, but other interesting opportunities are on the horizon. Wind power has potential in areas that receive less solar energy, but is less predictable. Fuel cells and compressed air hold significant promise for the long term.

ABI Research's "Mobile Networks Go Green" research report examines the mechanisms being put into place by carriers and infrastructure vendors to reduce power consumption, ranging from network optimization to hardware integration, power amplifier efficiency and software-based dynamic asset dimensioning. It also considers the opportunity to integrate renewable energy sources into primary power sources for cell sites, focusing on solar, wind and hybrid solutions combining renewable cells, grid-based electricity, diesel generation and battery banks. The report forms part of ABI Research's Mobile Networks Research Service, which also include other Research Reports, Research Briefs, Market Data, Online Databases, ABI Insights, ABI Vendor Matrices and analyst inquiry support. ■

CELEBRATING 2009: THE YEAR OF MMIX

2009 translates in Roman numerals to "MMIX." It only happens once, so Mimix Broadband is celebrating by declaring 2009... **the Year of MMIX**. During the year, we'll highlight key advances in our product portfolio, as well as pay tribute to other engineering feats – specifically the Seven Wonders of the Modern World as chosen by the American Society of Civil Engineers.

Toronto's CN Tower is a communications and tourist tower standing 553.33 meters (1,815.39 feet) tall. It is the tallest freestanding structure in the Americas and, amazingly, varies from true vertical accuracy by only 29 millimeters (1.1 inches) over the entire height of the tower. The CN Tower is a powerful communications tower for numerous radio and cellular media.

Here at Mimix, we have engineered an impressive range of power amplifiers (PAs) that tower above industry averages! Our PAs offer high power, excellent performance and efficiency, and are available in a selection of bare die and packaged versions.

MIMIX POWER AMPLIFIERS... TOWERING ABOVE INDUSTRY AVERAGES!

	Description	Device	Frequency (GHz)	Gain (dB)	Gain Flatness (dB)	Output P1dB (dBm)	OIP3 (dBm)	Bias (mA @ V)	Package (mm)
In Production	Power Amplifier	XP9003	1.6	38.0	+/-0.5	+43.0	-	2900 @ 9.0	40x36
	Power Amplifier (QFN)	XP1035-QH	5.9-9.5	26.0	+/-1.0	+29.0	+39.0	500 @ 6.0	4x4
	Power Amplifier (QFN)	XP1050-QJ	7.1-8.5	14.5	+/-0.5	+34.5 Psat	+49.0	1200 @ 8.0	6x6
	Power Amplifier (QFN)	XP1042-QT	12.0-16.0	21.0	+/-1.0	+25.0	+38.0	500 @ 5.0	3x3
	Power Amplifier (QFN)	XP1043-QH	12.0-16.0	21.5	+/-1.0	+30.0	+41.0	700 @ 7.0	4x4
Coming Soon!	Power Amplifier	XP1057-BD	13.5-16.0	17.0	+/-1.0	+39.0	+48.0	4.0 A @ 7.5	DIE
	Power Amplifier	XP1058-BD	14.0-16.0	27.0	+/-1.0	+36.0	+45.0	2.1 A @ 8.0	DIE
	Power Amplifier	XP1072-BD	33.0-37.0	22.0	+/-1.0	+35.0 Psat	-	2.2 A @ 6.0	DIE
	Power Amplifier	XP1073-BD	33.0-37.0	21.0	+/-1.0	+37.0 Psat	-	4.4 A @ 6.0	DIE

Explore our wide range of power amplifiers and download complete datasheets for all products at www.mimixbroadband.com.

Celebrate the Year of MMIX with us by visiting www.mimixbroadband.com/year-of-MMIX

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INDUSTRY NEWS

■ **EMS Technologies Inc.** announced that it has signed a definitive agreement to acquire **Satamatics Global Ltd.**, a global provider of Inmarsat IsatM2M (machine-to-machine or "M2M") services, headquartered in Tewkesbury, UK. The acquisition complements the company's existing Iridium- and Inmarsat-based tracking solutions. EMS expects the acquisition to be accretive and to add EBITDA of $3 to $5 M in the first year post-acquisition.

■ **Herley Industries Inc.** announced that it has sold its **Innovative Concepts** (ICI) subsidiary located in McLean, VA to **Elbit Systems of America LLC**, which is a wholly owned subsidiary of Elbit Systems Ltd., of Haifa, Israel, in a $15 M all cash transaction.

■ **inTEST Corp.**, an independent designer, manufacturer and marketer of semiconductor automatic test equipment (ATE) interface solutions and temperature management products, announced its acquisition of privately-held **Sigma Systems Corp.** Sigma Systems, founded in 1956, is located in El Cajon, CA, and is a manufacturer of thermal platforms, custom configured environmental chambers and other environmental test solutions for a variety of industries, including automotive, medical/pharmaceutical, electronic, aerospace/defense and semiconductor.

■ **Milmega's** distributor, **Schmidt Equipment Asia Ltd.**, has successfully installed China's very first 6 GHz IEC 61000-4-3 capability at Beijing CQC Technical Services Ltd. Key to achieving this capability is the company's amplifiers that provide the necessary microwave power. This latest phase of work was an upgrade to the existing system utilizing a Milmega 2 to 6 GHz, 50 W amplifier, designed to bring the intrinsic benefits of Gallium Nitride transistor technology to the lab environment.

■ **AWR®**, a leader in high-frequency design software, and **Rohde & Schwarz Japan K.K.**, the Japanese subsidiary of Rohde & Schwarz, a leading test and measurement manufacturer, announced a partnership in Japan to deliver customized hardware/software solutions. AWR software and Rohde & Schwarz test equipment will be combined to produce solutions ranging from component characterization through sub-system and system verification. Under the terms of this partnership, the companies will provide customized platforms that combine Rohde & Schwarz test and measurement equipment with AWR's high-frequency design software to produce unique simulation and measurement solutions.

■ **Arrowhead Global Solutions**, the government services division of CapRock Communications, announced that it is launching the industry's first managed network services based on commercial X-band satellites. The announcement is part of a strategic initiative to provide the next generation of advanced satellite communications services for the military and intelligence community. Arrowhead is making significant investments in X-band teleport infrastructure and satellite capacity, including signing a multi-year, multi-transponder agreement with XTAR LLC, headquartered in Rockville, MD.

■ **ETS-Lindgren** announced the establishment of **ETS-Lindgren Engineering India Private Ltd.**, a new company to better serve its customers in India. With the January 2009 opening of an office in Bangalore, ETS-Lindgren Engineering India will have a full staff offering its customers local technical, project management, installation and system integration expertise, as well as access to the full resources of ETS-Lindgren's support centers worldwide.

■ **ROHM Co. Ltd.** recently announced its new corporate name and logo, effective immediately. ROHM Semiconductor (www.rohmsemiconductor.com), in business for over fifty years and with sales of nearly $4 B, has grown from its roots as a compact resistor manufacturer to become one of the world's largest, full-range suppliers of semiconductor products.

■ **Aeroflex** recently announced it has secured a series of sales for the recently launched TD-LTE version of its market-leading TM500 test mobile from various leading suppliers of cellular mobile infrastructure equipment in China. These orders for the new TM500 TD-LTE further strengthen Aeroflex's position as the leading provider of test mobiles for LTE, HSPA and WCDMA.

■ **Agilent Technologies Inc.** announced that the Telecommunications Technology Association (TTA)—Asia's leading test and certification institution and USB independent test lab—selected Agilent's USB testing solution for USB compliance testing. TTA will use Agilent's USB compliance testing solution, including the DSA91304A high-performance oscilloscope, N5416A USB compliance test software and 81134A pulse pattern generator, to provide compliance testing and certification services to the international community.

■ **Raytheon Space and Airborne Systems** recently honored suppliers who demonstrated exceptional performance in supporting SAS programs in the areas of quality, delivery and customer satisfaction in 2007. SV Microwave received a 3-star award by showing excellence for 12 consecutive months, which indicates the strong commitment to the Raytheon SAS team and to helping achieve results that contribute to a mutual growth.

■ **LPKF Laser & Electronics AG** has received the Cathay Pacific China Trader Award for Innovation & Technology. The award recognizes German corporations that demonstrate innovative technology and design as well as intercultural corporation of its German and Chinese employees. LPKF has been doing business in China, the world's fourth largest economy, for over 20 years and operates five successful offices with almost 60 employees. By selling laser systems for stencil production, LPKF has reduced market share of chemical etching from 100 percent to less than 30

percent. The installation of several hundred PCB prototyping systems has also made a considerable contribution for the reduction of environmental pollution by providing an alternative to the use of chemicals.

■ **The Phoenix Company of Chicago** announced the company's quality management system is certified compliant with the requirements of the AS9100:B quality standard for designers and manufacturers of aerospace products and services. The Phoenix Company of Chicago was also re-certified for the ISO 9001:2000 quality management standard. With this re-certification, Phoenix ensures quality management throughout all avenues of its business operations is met or exceeded. Both certifications signify the company's commitment to providing products and services with attention to quality, safety and customer satisfaction.

■ **Endicott Interconnect Technologies Inc.** (EI) has been awarded certification to the AS9100 Quality Management Standard for aerospace suppliers. This certification signifies that its Endicott, NY facility complies with all requirements of the AS9100 quality management system covering quality assurance in design, development, production, installation and servicing, as well as purchasing, validation and shipping. The standard includes all ISO 9001:2000 requirements and has been expanded to address needs specific to the international aerospace industry.

■ **Emerson Network Power**, a business of Emerson, has been issued US Patent No. 7,455,542 for a miniature BNC connector. Marketed by Emerson as the Trompeter 250 series, this innovation offers designers of high reliability network equipment and the end-users of this equipment the advantage of a 40 percent gain in connector density. The new carrier-class UPL250 series (M-BNC) was originally designed to address specific challenges evolving in telco central office space, where the telco-grade BNC is the well-established workhorse connector.

■ **Murata Electronics North America**, a world-leading innovator in electronics and the largest global supplier of ceramic passive components, announced that it has selected **Digi-Key** to receive the company's Corporate Award for 2007. Digi-Key was selected out of Murata's distributors worldwide for extraordinary sales expansion and its overall contribution to the company.

CONTRACTS

■ **Applied Radar Inc.** has been selected to receive an additional $6.4 M in new contracts from the Department of Defense (DoD), according to company CEO William H. Weedon. The new funding consists of $4 M in SBIR/STTR funding, through four separate contracts, from the US Missile Defense Agency (MDA) for Next-generation Radar and a $2.4 M congressional appropriation to develop a Wideband Digital Airborne Electronic Sensing Array for the US Air Force Research Laboratory (AFRL).

■ **OEwaves Inc.** has been selected as a subcontractor to support Lockheed Martin Maritime Systems & Sensors in support of a Science and Technology contract from the US Army Research Development and Development Command's (RDECOM) Aviation and Missile Research Development and Engineering Center (AMRDEC). The total value of the initial award to OEwaves is $1.5 M, with a potential total value of approximately $5 M. This activity is part of an RDECOM AMRDEC effort to develop and demonstrate critical technologies that bridge the gap between existing capabilities and the Army vision for future protection capabilities.

■ **MCL Inc.**, a **MITEQ** company, Bolingbrook, IL, a global supplier of satellite communications (SATCOM) and instrumentation equipment, has received a $1.4 M+ contract to design and develop an airborne Ka-band high power traveling wave tube amplifier (TWTA) for the United States Air Force. This contract has been sponsored by the Air Force Research Laboratory (AFRL) located in Rome, NY. The resultant product is expected to compliment and enhance present military airborne communication technology.

■ **RF Micro Devices Inc.** (RFMD), a leader in the design and manufacture of high performance semiconductor components, announced it has signed a 12-month contract with the United States Department of Defense (DoD) valued at $1.4 M for the development of Gallium Nitride (GaN) technology and high-power RF solutions. The contract award (#FA8650-05-C-5411) represents an extension to previous contracts with the DoD and is in support of RFMD's ongoing GaN RF power technology project.

■ **Jersey Microwave** has been awarded a $1.1 M dollar contract to supply high performance Ka-band block converters into a major military SATCOM program. The award is the third release of this magnitude awarded to Jersey Microwave in 2008. Jersey Microwave became the preferred source by providing superior performance over other suppliers and passing stringent military tests.

■ **Equipment Management Technology** (EMT), a leader in electronic test equipment asset management, has placed a $1 M purchase order with **Giga-tronics** for RF and microwave test solutions including Fast-switching Microwave Signal Generators, High-accuracy Power Meters and the newly introduced 2 to 20 GHz High Power Amplifier. The order allows the two companies to develop integrated promotion, advertising and sales. EMT will have enhanced access to the US market through the Giga-tronics sales channel, and Giga-tronics will be able to supply its products for rental, lease and distribution through EMT.

■ **Anaren Inc.** announced, in unison with **CSR**, it has achieved a design win on CSR's UniFi UF1050 b&g Wi-Fi chipset. Optimized for the CSR application, the matched-balun approach results in a solution boasting 65 percent fewer discrete components even as it saves additional board space. Anaren's "0404" balun was selected for its small form factor, easy implementation and significant performance improvement relative to ceramic-based solutions. With the new design, Anaren and CSR expect to seize opportunities in the global handset community where size is of paramount concern.

RFMD.®

SBB Gain Blocks

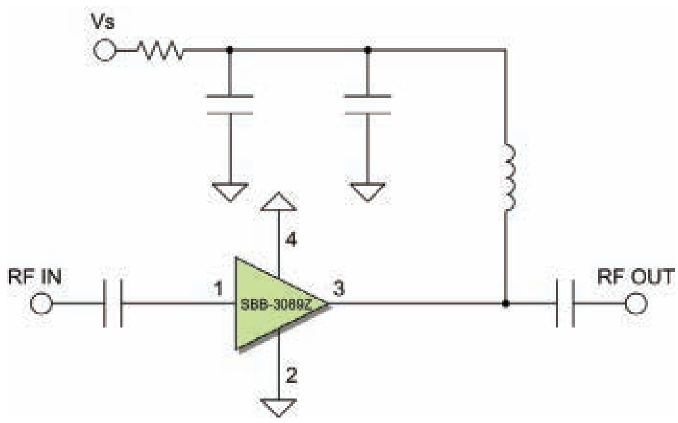
High-Linearity InGaP HBT Active Bias Gain Blocks

The SBB series is a high-performance family of InGaP HBT MMIC amplifiers utilizing a Darlington configuration with an active bias network. The active bias network provides stable current over temperature and process Beta variations. This product is designed for high-linearity 5 V gain block applications that require excellent gain flatness, small size, and minimal external components. Only two DC blocking capacitors, a bias resistor, and an RF choke are required for operation. The SBBs are internally matched to 50 ohms. Applications for the SBB series include IF/RF amplifiers for WCDMA and TD-SCDMA base stations, and driver amplifiers for cellular repeaters.

SBB SPECIFICATIONS

Part Number	*Frequency*	*Gain*	*Id*	*NF*	*Output IP3*	*P1dB*	*Vd*
SBB-1089Z	50-850 MHz	15 dB [1]	90 mA	3.1 dB	43 dBm [2]	19 dBm	5
SBB-2089Z	50-850 MHz	20 dB [1]	90 mA	2.6 dB	42 dBm [2]	20 dBm	5
SBB-3089Z	50-6000 MHz	16.5 dB	40 mA	3.8 dB [3]	28 dBm	15 dBm	5
SBB-4089Z	50-6000 MHz	15 dB [1]	80 mA	4.6 dB	35 dBm	19 dBm	5
SBB-5089Z	50-6000 MHz	20.5 dB [1]	75 mA	4.2 dB	35 dBm	20.5 dBm	5

1 - at 850 MHz; 2 - at 240 MHz; 3 - at 2200 MHz



FEATURES

- **Single fixed 5 V supply**
- **Patented self-bias circuit and thermal design**
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- **MSL 1 moisture rating**
- **High OIP3**
- **Excellent gain flatness**

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■ **HRL Laboratories LLC** announced it has demonstrated the world's first graphene radio frequency (RF) field effect transistors (FET) as part of the Carbon Electronics for RF Applications, or CERA program. The milestone is the first in the proposed 51-month, three-phase program to develop a new generation of carbon-based RF integrated circuits for ultra-high-speed, ultra-low-power applications.

■ **Keithley Instruments Inc.**, a leader in solutions for emerging measurement needs, announced that it is developing a WiMAX device production test solution for two 802.16e WiMAX devices from **Fujitsu Microelectronics Ltd.** This WiMAX RF SISO/MIMO manufacturing test configuration features Keithley's award-winning RF test solutions, the model 2820 RF Vector Signal Analyzer and Model 2920 RF Vector Signal Generator. The configuration will enable Fujitsu Microelectronics to perform a set of Tx and Rx test sequences quickly and efficiently. The system's easy expandability also will offer Fujitsu the unique ability to test its WiMAX devices in both SISO and MIMO mode.

FINANCIAL NEWS

■ **Provigent**, a provider of System-on-a-Chip (SoC) solutions for the Broadband Wireless Transmission market, announced that it has closed a fifth-round of financing in the amount of $10 M. Lightspeed Venture Partners led this round of funding with a $10 M investment, joining Provigent's existing technology investors: Sequoia Capital, Pitango Venture Capital, Globespan Capital Partners, Magma Venture Partners, Ascend Technology Ventures, Delta Ventures, Stata Venture Partners and Dr. Andrew Viterbi.

PERSONNEL

■ **TriQuint Semiconductor Inc.**, a leading RF front-end product manufacturer and foundry services provider, is pleased to announce **Ralph Quinsey**, its chief executive officer, has received the *Portland Business Journal*'s "CEO of the Year" award for technology companies in Oregon. The award was presented at the *Business Journal*'s Annual Most Admired Companies Award Luncheon attended by more than 800 executives of Oregon's top companies. Quinsey will be profiled in the "Most Admired Companies" special publication of the *Portland Business Journal*.

▲ Ralph Quinsey

■ TECOM Industries Inc., a Smiths Interconnect business, announced the appointment of **Arsen Melconian** as president. Melconian succeeds Ralph L. Philips who was recently appointed president of Smiths Interconnect. Melconian has served as TECOM's vice president of engineering and chief technology officer since March 2004. He joined the company in January 2002 as director of engineering with responsibility for design, modeling, simulation, testing and new product development. Under his guidance, TECOM's engineering department has more than doubled in size and several key commercial, military and satellite communications R&D programs have advanced from concepts to production.

▲ Arsen Melconian

■ **James Rowland** has been named director of MI Technologies' Customer Support business unit, the company announced. In this new assignment, Rowland is responsible for managing MI Technologies' entire global Field Service network, Software Maintenance, Training and Certification programs, Warranty and Post Warranty services, Calibration and Repair services, Equipment Refurbishment and Customer Range Verification services. He also oversees MI Technologies' in-house test and measurement services conducted in two anechoic chambers at its Suwanee, GA facility. Rowland joined the MI Technologies management team in June 2007. Prior to joining MI Technologies, he served as president of Ultra Electronics, EMS Development Corp., Yaphank, NY where he had overall responsibility for the company's strategy, operations and business growth.

▲ James Rowland

■ Crane Aerospace & Electronics, a segment of Crane Co., has announced the appointment of **Greg Masciana** as director of quality for the Electronics Group. Masciana will be located at the Electronics Group headquarters in Redmond, WA. In this role, Masciana will have overall responsibility for the Quality Management System at each of the Electronics Group sites. Before joining Crane Aerospace & Electronics, Masciana held Worldwide Lean Sigma Deployment, quality director and sr. quality engineer manager roles at Tektronix (a Danaher company), Tyco Electronics and Teledyne.

▲ Greg Masciana

■ Park Electrochemical Corp. announced the appointment of **David R. Dahlquist** as director of business development for the company. Dahlquist previously held the positions of product director and more recently director of marketing at Park Electrochemical Corp. He has previous experience with Photocircuits Corp. in the positions of director of technology – Corporate and director of Quality and Engineering – PC-Asia.

■ Renaissance Electronics Corp. recently announced the appointment of **Lynn Kibblehouse** as the newest edition to the company's sales team. She comes to Renaissance with over nine years experience in the sales and marketing industry. Kibblehouse will manage the company's North American sales development network and provide sales support across all product lines.

■ Strand Marketing Inc., a Newburyport, Massachusetts-based marketing and advertising agency specializing in the high tech industry, has announced the hire of two new full

RFMD®

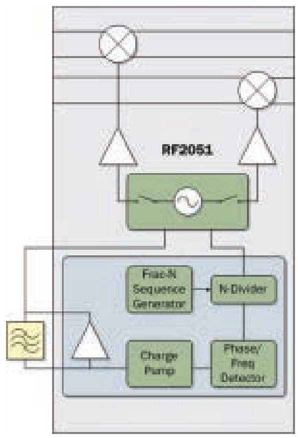
Integrated RF Synthesizer and VCO with Mixers

Family of Integrated Configurable Components for RF Front Ends

Designed to reduce development time, risk, and size of RF front end circuits in modern radios, the RF205x family of products from RFMD® provides engineers with a highly integrated, yet flexible solution. These devices use a unique system partitioning—a vertical slice through an RF section—that combines a high-performance fractional-N PLL, low phase noise VCOs, LO buffers, and high-linearity RF mixers. The components generate a low noise LO signal of between 300 MHz to 2400 MHz, and have built-in wideband RF mixers that operate from 50 MHz up to 2500 MHz. All RF205x devices are contained in a standard plastic 32 pin, 5 x 5 mm package.

RF205x SERIES SPECIFICATIONS

	Units	*RF2051*	*RF2052*	*RF2053*
Fractional-N PLL		Yes	Yes	Yes
On-chip VCOs		Yes	Yes	No
RF mixers		2	1	1
DC Parameters				
Supply voltage	V	3.0	3.0	3.0
Supply current (low-current setting)	mA	55	55	55
VCO and Synthesizer				
Input reference frequency	**MHz**		**10 to 104**	
LO frequency	MHz	300 to 2400	300 to 2400	-
Open loop VCO phase noise at 500 MHz LO frequency	dBc/Hz	-140	-140	-
RF Mixer				
RF and IF port frequency range	**MHz**		**50 to 2500**	
Noise figure (low-current setting)	dB	-	9.5	-
Input IP3 (high-linearity setting)	dBm	-	20	-



FEATURES

- **2.7 V to 3.6 V operation**
- **Fractional-N synthesizer—1.5 MHz resolution**
- **Integrated LO buffers, high-linearity RF mixers, and low phase noise VCOs**
- **Programmable linearity mixers for power-saving**
- **Two frequency registers for FSK modulation**
- **Three-wire serial control interface**

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For sales or technical support, contact RFMD at 336.678.5570 or sales-support@rfmd.com - For complete specifications and free evaluation samples, email RF205x@rfmd.com time employees, **Arianne Bedard** as project coordinator and **David Byers** as web developer. As project coordinator and media specialist, Bedard brings experience in high tech MARCOM administration from Hittite Microwave of Chelmsford, MA, a leading supplier of RF/microwave components to the wireless, telecom, military and homeland security markets. She also was previously a PR and copy writer at the Emily Post Institute, in Burlington, VT. Byers joins Strand Marketing's web group as lead developer, and brings his 15 years of experience working in the fast paced world of Las Vegas travel and entertainment to the position. He is experienced in dynamic web design, e-commerce, and search engine optimization, and is also well versed in FLASH programming, AJAX, CSS and JAVA scripting.

REP APPOINTMENTS

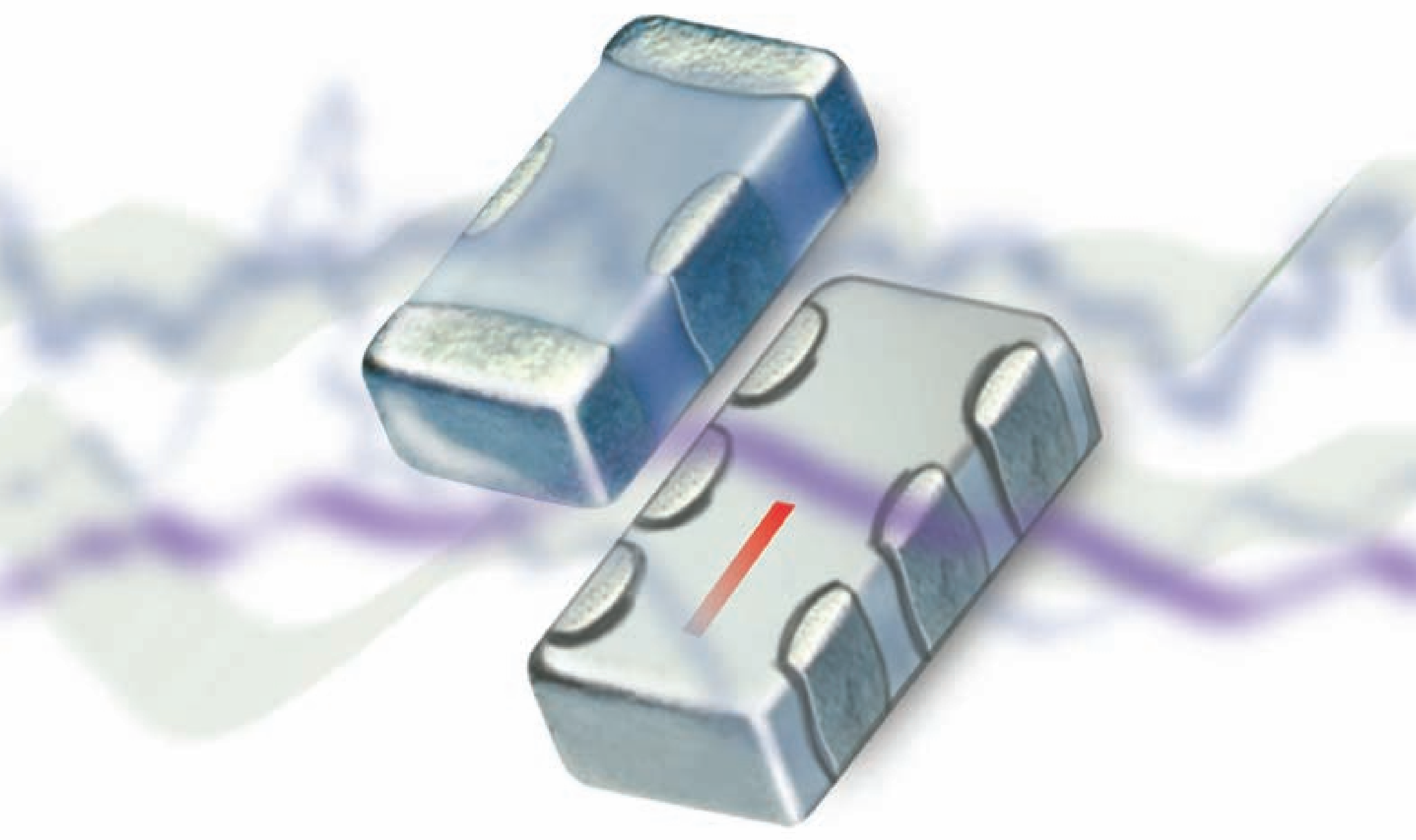
■ **Richardson Electronics Ltd.** announced that it has entered into an agreement with **RADIALL**, a global manufacturer of interconnect components, to promote and distribute "Service +", an innovative and automated program for ordering, manufacturing and delivering RF cable assemblies.

■ **Sprague-Goodman Electronics Inc.**, Westbury, NY, has expanded its agreement with the **Cain-Sweet Co.** to include all Canadian provinces. The Cain-Sweet Co., whose corporate office is in Bellevue, WA, has represented Sprague-Goodman's line of trimmer capacitors, transformers, fixed and variable inductors and tuning tools throughout the Pacific Northwest and British Columbia since 2007. The provinces of Ontario, Quebec, Alberta, Manitoba, New Brunswick, Newfoundland, Nova Scotia, Saskatchewan and Prince Edward Island have been added to the territory. Contact information for the Cain-Sweet Co. corporate office: 1409 140th Place, Suite 105, Bellevue, WA 98007 ph: (425) 562-6028; fax: (425) 562-2680.

■ **MI Technologies** has signed a distribution agreement with **Bluetest AB** of Gothenburg, Sweden, to distribute and support Bluetest's products in North America, Italy, the United Kingdom and India. This agreement broadens MI Technologies' test and measurement capabilities for the wireless marketplace and strengthens Bluetest's sales and support channels for its innovative line of reverberation technology-based products for characterizing communication devices with small antennas.

■ **W.L. Gore & Associates** has announced that its high-tech line of surface mountable EMI shielding materials will now be available through **Richardson Electronics Ltd.** Richardson, LaFox, IL, will now sell Gore's GORE-SHIELD® Supersoft SMT EMI Gaskets and Grounding Pads, and the GORE™ snapSHOT® Board-Level EMI Shield.

■ **Times Microwave Systems** is pleased to announce the appointment of **Connekt Electronics** as the company's distributor for the entire range of Times commercial products in India. Connekt will maintain inventories of



Times LMR® cables and connectors and provide technical support to customers in the wireless communications industry. LMR cable is a flexible low loss cable ideal for use in a broad range of antenna feeder and jumper applications in cellular, WiFi, WiMAX and other wireless systems.

■ **KOR Electronics**, a systems leader in exploiting the digital RF domain, announced it has signed a marketing partnership agreement with **LS Engineering** to enhance its coverage to valued customers in North California and Nevada. Headquartered in Fremont, CA, LS Engineering is the exclusive worldwide applications/representative for a wide range of manufacturers in the North California and Nevada regions, specializing in value added high-end RF/microwave components, subsystems and various supporting services. For further information, contact: LS Engineering, 4080 Carol Avenue, Fremont, CA 94538, ph: (510) 687-9415 or visit: www.lsengineer.com.

■ **Digi-Key Corp.** announced that it has recently expanded its current franchise agreement with **Tyco Electronics** to a global authorization.

■ **Florida RF Labs/EMC Technology** recently announced two new rep appointments. **D&L Technical Sales Inc.** is located in Tempe, AZ, and will cover the territory of Arizona and New Mexico. For more information, visit: www.dltechsales.com. D&L has been working in the industry for 30 years with over 50 years of combined experience in the electronics industry. **Elcotech Ltd.**, located in Moscow, Russia, will be responsible for the Russia territory. Elcotech Ltd. has 11 years experience in the industry with a total staff of 18 persons.

■ **Technical Communities**, a leading service provider for technical organizations that sell to US government agencies, military organizations and prime federal contractors, announced a new exclusive government services partnership agreement with **LadyBug Technologies**, a manufacturer of the PowerSensor+™ line of "no-cal, no-zero" USB power-measurement instruments. The agreement authorizes Technical Communities to provide government organizations with LadyBug Technologies' PowerSensor+ line of miniaturized USB power meter-sensors.

■ **Peregrine Semiconductor Corp.** has appointed **Clavis Co.**, a division company of Macnica Inc., to market and sell Peregrine's line of UltraCMOS™ RFICs throughout Japan. Clavis specializes in the supply of high-value-added electronic parts and equipment, particularly semiconductors, to the electronics, information and communications industries. Peregrine's UltraCMOS RFICs have gained popularity with Japan OEMs as complex designs for multi-mode, multi-band cellular and Digital Television (DTV) applications demand exceptional RF performance and higher levels of integration.

DEVELOPING HIGHLY RUGGEDIZED SILICON MOSFETs FOR RF AMPLIFIER APPLICATIONS

This article describes a new vertical silicon MOSFET that has been developed specifically for high power RF amplifier applications. The High Voltage Vertical Field Effect Transistor (HVVFET™) is engineered with unique structural features that produce high breakdown voltage, superior thermal management properties, minimized parasitic capacitance and extremely short gate length. This novel device structure results in a transistor that is inherently more rugged than competing RF power transistors while exhibiting superior RF power performance.

High power RF amplifiers are expected to provide high primary performance parameters such as output power, gain and efficiency, as well as operate reliably for more than 20 years in the field. Traditionally, designers have built these amplifiers using components fabricated in cost-effective silicon-based technologies such as bipolar or LDMOS. While these technologies can operate at high voltages, they suffer from low ruggedness ratings. For example, LDMOS has an inherent destructive mechanism (i.e., a parasitic bipolar transistor) built into the transistor structure that limits the ability of the device to work reliably at high operating voltage. In contrast, the HVVFET exhibits extreme ruggedness in high voltage, high power and high frequency wireless applications.

DEFINING RUGGEDNESS

Ruggedness refers to the ability of the RF power transistor to withstand load mismatch conditions under high output power conditions without experiencing device failure or measurable long-term degradation in device performance. Under mismatched load conditions a large amount of power can be fed back into the active device where it is dissipated in the semiconductor. The ability to handle the large power dissipation internally in the active area without altering the performance is indicative of a reliable device.

Although there are no standard metrics to uniquely define ruggedness, the ruggedness of a specific transistor will be a function of the magnitude and phase of the mismatch, the output power level conditions and the thermal dissipation properties of the amplifier. Similarly, no widely accepted standard exists to define

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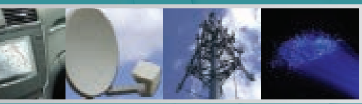

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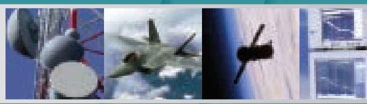

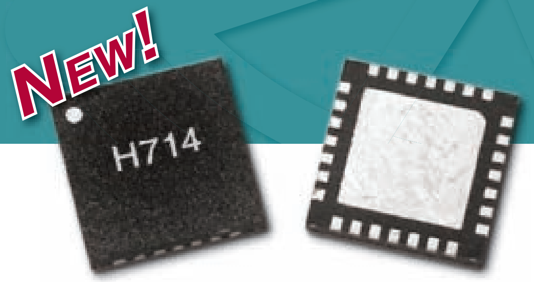

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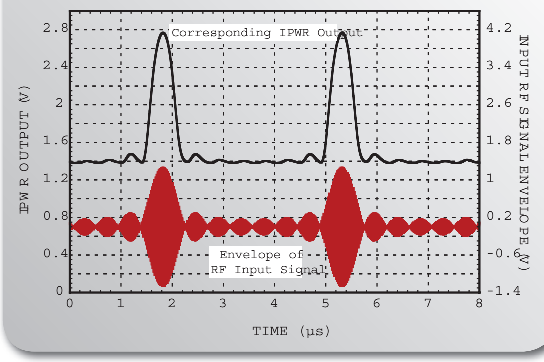
iPAR Output & Input RF Signal Envelope vs. Time for an Input Crest Factor of 12.04 dB @ 1900 MHz



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	0.001 - 8.0	Log Detector	70 ± 3	-25	-61	+5V @ 113mA	LP4	**HMC602LP4E**
	0.001 - 10.0	Log Detector	73 ± 3	-25	-65	+5V @ 103mA	Chip	**HMC611**
	0.001 - 10.0	Log Detector	70 ± 3	-25	-65	+5V @ 106mA	LP4	**HMC611LP4E**
	0.01 - 4.0	Log Detector	70 ± 3	19	-68	+3.3V @ 30mA	LP4	**HMC601LP4E**
	0.05 - 4.0	Log Detector	70 ± 3	19	-69	+3.3V @ 29mA	LP4	**HMC600LP4E**
	DC - 3.9	RMS Power Detector	69 ± 1	37	-60	+5V @ 65mA	LP4	**HMC610LP4E**
NEW!	0.1 - 3.9	Dual RMS / PAR Power Detector	70 ± 1	37	-55	+5V @ 138mA	LP5	**HMC714LP5E**
NEW!	0.1 - 3.9	RMS / PAR Power Detector	71 ±1	37	-58	+5V @ 75mA	LP4	**HMC614LP4E**
	0.1 - 20	SDLVA	62	14	-57	+3.3V @ 83mA	LC4B	**HMC613LC4B**
	Connectorized Power Detector Modules							
NEW!	0.01 - 2.0	RMS Power Detector	70 ±1	37	-58	+12V @ 95mA	C-6 / SMA	**HMC-C054**
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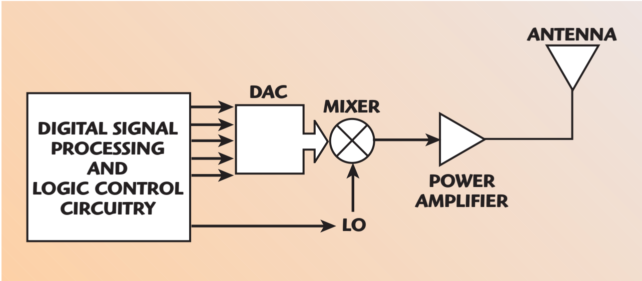


Fig. 1 *Transmitter diagram with antenna.*

the input conditions or the pass/fail criteria for ruggedness testing. However, catastrophic device failure is always a ruggedness failure.

Some semiconductor device manufacturers define the failure criteria for the ruggedness test as zero degradation in output power. This is not an adequate definition for failure, however, since some technologies, like bipolar, can deliver the full rated output power even when the ruggedness test damages some of the cells so that the remaining cells provide the full power at a higher temperature, which will result in a decrease in the MTBF of the device. Other power device manufacturers specify failure criteria as a more than 20 percent shift in one or more of the DC test parameters.[1] A few semiconductor power device vendors do not specify a ruggedness rating at all. Some LDMOS manufacturers measure ruggedness with what they call a 'burn-in' test. The 'burn-in' test acts as an accelerated life test, causing a large change in the DC parameters after a single trial that minimizes the performance drift over the operating lifetime of the active device in the field. The following discussion will describe a comprehensive ruggedness test. Using data collected in this test, this article will demonstrate that this new high voltage vertical technology does not exhibit any measurable performance difference before and after the test.

CRITICAL METRIC

Ruggedness is among the most important reliability metrics for high power amplifier designs. ***Figure 1*** shows the block diagram of an RF transmitter chain. In a communication system, the information to be transmitted is processed in the baseband using DSP and analog logic circuits. In order to transmit this information in an efficient manner the data is modulated with an RF carrier frequency. The local oscillator is used to mix the required information up to the RF frequency. The power amplifier (or power amplifier chain) transmits this signal into the air through the antenna with the output power of the final stage amplifier and the antenna gain determining the range that the information is broadcast. A power amplifier output matching circuit transforms the output impedance of the transistor to the antenna impedance in order to optimize the performance of the active device. The antenna component, however, is exposed to uncontrolled environmental conditions so that the antenna impedance will vary. Similar issues affect radar transmitter ruggedness.

Superior ruggedness can also reduce cycle time during the initial circuit design process. Once high power amplifier design moves from theory to the laboratory bench, much of the procedure involves measuring amplifier characteristics while modifying the matching circuit of the device. When a design involves a device with low ruggedness, engineers must use extreme care in these experimental matching circuit trials in order to avoid damaging the device. A highly rugged device, however, allows the designer to move more quickly to optimum conditions without fear of device damage or destruction.

MEASURING RUGGEDNESS

Figure 2 shows a standard RF bench and the equipment needed to measure the RF performance of a power amplifier. During device characterization an industry standard matched load of 50 ohms is presented to the output of the power amplifier. When performing the ruggedness test, the RF switch changes the load from the matched case to that of a shorted load connected to a line stretcher. The line stretcher component varies the phase of the shorted load over a full 360 degrees simulating the conditions that can occur in the real world application.

There are three controlling electrical factors presented to the power amplifier in a ruggedness test, which are the amount of input power, the DC bias supply voltage and the load presented to the device, as shown in ***Figure 3***. A fourth factor, temperature, also can affect ruggedness, but is first order independent of the three electrical factors, so is not considered in the following discussion. Any of the electrical factors can be varied, although many semiconductor vendors only vary the mismatch seen by the load and use the nominal value for RF power and bias voltage. The semiconductor may indeed prove rugged under these set conditions. However, a true test of ruggedness will vary all of these factors at the same time to accurately mimic real world conditions and see if the device still maintains performance after the

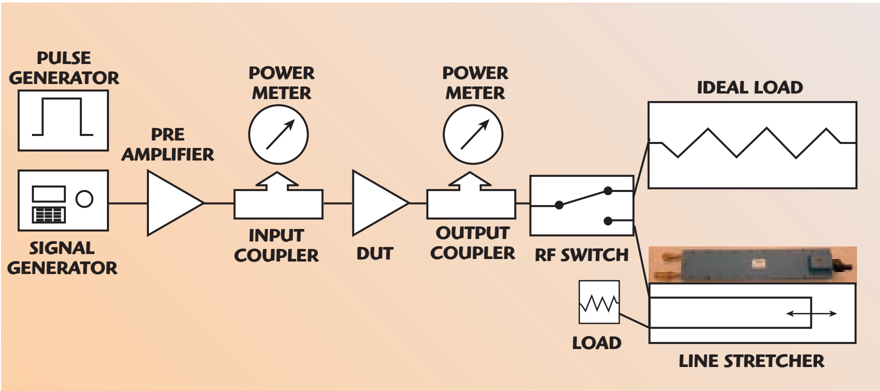


Fig. 2 *RF bench diagram with load and line stretcher.*

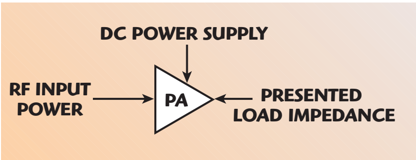


Fig. 3 *Parameters affecting power amplifier performance.*

ruggedness test. "A truly realistic possibility... is the condition whereby the RF power device 'sees' a worst case load mismatch (an open circuit, any phase angle) along with maximum Vcc and greater than normal input drive—all at the same time."[2]

The HVVFET technology exhibits the capability to survive a ruggedness test that presents 1) an input power level twice that needed to obtain rated output power; 2) a bias supply voltage that is 10 percent greater than rated power supply level; and 3) a mismatched load that is the highest in this industry. The device can survive this extreme condition and show no degradation in performance after the ruggedness test.

Under linear conditions, a perfectly matched load is able to convert the entire applied RF signal into trans-

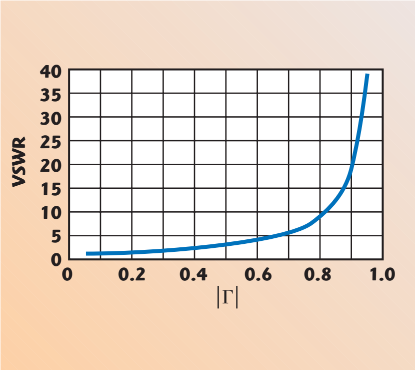


Fig. 4 VSWR vs. gamma.

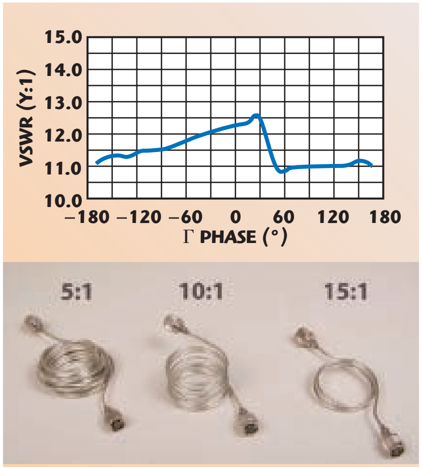
mitted RF energy. A mismatched load will transmit some of the RF signal, but will reflect the remaining power back into the device. This reflected power must be absorbed internally in the transistor. The amount of energy reflected is measured by the reflection coefficient, gamma, where the magnitude of gamma normalized to unity relates to the amount of reflected energy (i.e., gamma of zero implies no reflection and perfect transmission, while a gamma of one implies total reflection). Another parameter that expresses the amount of reflection and characterizes the type of mismatch is the voltage standing wave ratio (VSWR). It is directly related to the magnitude of the reflection coefficient as seen in Equation 1.

$$\text{VSWR} = \frac{1+|\Gamma|}{1-|\Gamma|} \tag{1}$$

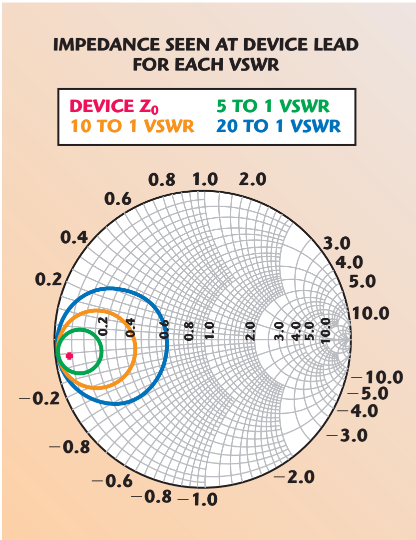
VSWR is the more common figure of merit when discussing ruggedness testing. The higher the VSWR, the more power that is reflected back to the load of the amplifier. That power must be absorbed by the active device without damage. As you can see in ***Figure 4***, a VSWR of 5:1 implies that nearly half of the desired output power is actually reflected back to the amplifier and a VSWR of 10:1 corresponds to more than 2/3 reflected energy. Most semiconductor companies specify the ruggedness of their devices with one of these two VSWR conditions. The measure of the robustness of the vertical device is its ability to pass a ruggedness test with a mismatch of 20:1 VSWR, which reflects more than 85 percent of the output power back into the device under test.

CREATING VSWR

During a ruggedness test a load with a certain VSWR is presented to the device and the phase of this load is varied over an entire period. The phase of the load is modified by a line stretcher (see Figure 2). Different values of VSWR are obtained by using a short circuit, having a magnitude of reflection of 1, and an attenuator. A lossy coaxial stretch of line acts as the attenuator. An infinite VSWR is achieved by terminating the load with a short and no attenuation. Note that the 20:1 VSWR is achieved by connecting the short directly to the line stretcher, which is effectively a zero line length. Real world losses in the output coupler, RF switch and line stretcher attenuate the magnitude of the reflection coefficient by a few percent generating a VSWR greater than 20:1, but less than the theoretical value of infinity. Varying the length of coaxial cable will vary the VSWR presented to the load. The shorter the coaxial cable length, the smaller the attenuation, producing higher VSWR. The length of the cable is determined by the properties of the cable, the desired VSWR and the frequency of interest. Three different VSWR values are achieved using different line lengths, as seen in ***Figure 5***. Theoretically, the VSWR will present a perfect circle on a Smith Chart as it is rotated through all 360 degrees of phase. In the real world, however, there are losses in the coaxial cable and therefore the VSWR is expected to change as the line stretcher varies the phase of the device through all 360 degrees. This effect is seen in Figure 5 as the 10:1



▲ *Fig. 5 VSWR vs. line length.*



▲ *Fig. 6 Impedance Smith Chart vs. VSWR (sweep min. 1060 MHz).*

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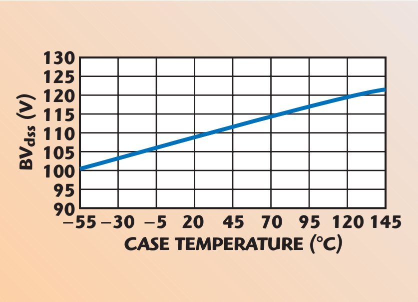
Figure 6 depicts the impedance presented at the leads of the device as the phase is swept from 0 to 360 degrees for each VSWR condition. As the phase is varied, the device sees the impedance indicated by the VSWR circle. Generally, when the impedance is less than the nominal impedance and under an ideal load, the device will operate in a low voltage/high current condition. If the high current generates enough heat, thermal failure can occur due to the silicon melting. If the impedance presented to the device is greater than the nominal impedance, the device will operate in a high voltage/low current situation. When the high voltage condition exceeds the breakdown voltage rating, the device goes into avalanche breakdown.

OPERATING VOLTAGE CONSIDERATIONS

The vertical MOSFET technology allows the epitaxial layer to standoff a large amount of voltage. The higher drain-source transistor breakdown voltage gives the transistor the ability to withstand high voltage spikes on the drain without damaging the device. Typically under normal operation, RF power transistors are exposed to twice the voltage swing of the operating voltage as the AC signal rides on top of the DC bias voltage. This condition is observed even under ideal conditions of nominal DC supply voltage, input power and a load matched to 50 ohms. There are instances in the normal operating life of the power transistor when all of these three factors change to a non-optimum condition. There are times when the load condition is mismatched from the ideal 50 ohms to an open load with any given phase angle. The general rule of thumb in the industry is that the mismatched load impedance condition will create voltage swings on the load of approximately 2.5 times the rated DC power supply voltage. Since the HVVFET breakdown voltage exceeds 115 V, it supports operating voltages of 48 V.

In addition, the HVVFET can handle a large avalanche current without overstress to the device. The limitation on the avalanche current in the HVVFET is that the avalanche power (the product of breakdown voltage and the avalanche current) be less than the maximum power dissipation rating of the device. In the case of this device, the maximum power dissipation calculated with the thermal resistance is 875 W. Therefore, with breakdown voltage equal to 115 V, the maximum allowable avalanche current is 7.6 A. This high avalanche current rating allows the HVVFET to survive severe over voltage ruggedness conditions with a low operating voltage to breakdown voltage ratio. ***Figure 7*** shows the behavior of the HVVFET breakdown voltage versus temperature. The positive temperature coefficient means that the high avalanche current condition will not result in destructive thermal run away. As the device temperature increases due to an avalanche condition, the breakdown voltage increases thus limiting the amount of avalanche current. This characteristic allows the transistor to withstand high currents and thus higher temperature even at high voltage without damaging the device. Although other silicon technologies



▲ *Fig. 7 Voltage walk-out.*

such as bipolar and LDMOS structures can operate at high voltages, they only provide ruggedness ratings of 10:1 VSWR or less.

There are many benefits to operating power amplifiers at high operating voltages. First, higher operating voltages lead to higher impedances of the device, which comes from Ohm's law. The higher device impedance is inherently easier to match than lower impedances and results in fewer matching components and a smaller PCB. This results in a more cost-effective solution.

At any given power level a high operating voltage requires a lower current level. From Watt's law, the higher power is achieved through either voltage or current.

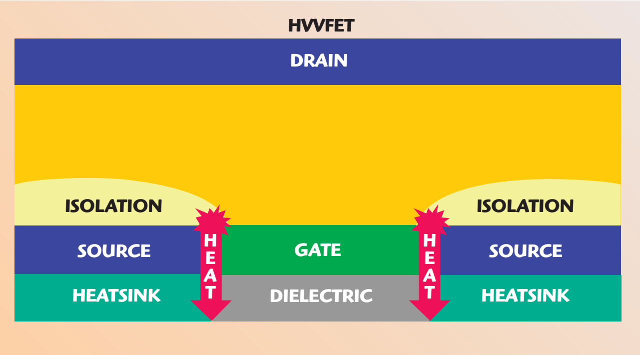
The advantage of obtaining higher power through voltage is the resultant lower current. Reduced current density reduces all energy-dependent aging mechanisms that lead to reliability issues. Lower current relates directly to higher reliability by preventing metal migration and achieving higher MTBF. Another advantage of the use of high voltage is the higher impedance required for the optimum load of the power transistor device. Higher impedance makes the device easier to match to the industry standard 50 ohm load. The higher impedance requires less current to achieve the same power levels and generates less heat during normal operation.

A third advantage of higher operating voltage and lower current is lower dissipated heat. RF performance parameters such as gain and efficiency decrease as temperature rises. Therefore, heat is the number one enemy of power transistor designers.

The HVVFET uses a 48 V supply, which is over 150 percent the level of typical high power amplifiers that utilize 28 V supplies. This translates into a nearly 3x improvement in the dissipated power consumption that the transistor has to withstand. An RF amplifier with 50 percent efficiency converts only half of the total power in watts consumed from the DC supply into usable transmitted RF power. The other half of the DC supply power is wasted energy that must be disposed of in some manner. The excess power that cannot be converted into usable RF energy is dissipated in the form of heat in the output resistance of the silicon device. The less heat the device generates, the more likely it operates at a safe level and avoids thermally-related failure conditions.

THERMAL CONSIDERATIONS

One of the big advantages of vertical technology is the ability to get the



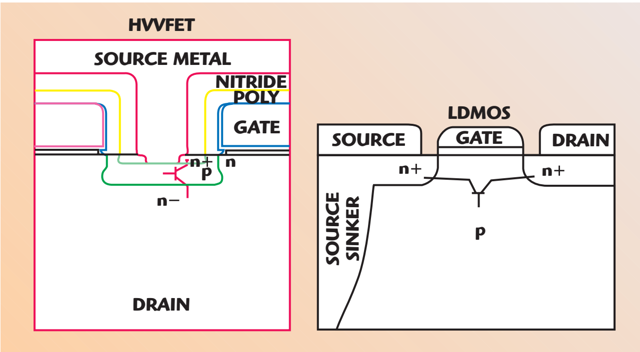
▲ *Fig. 8 Diagram of vertical structure (thermal path).*

adding resistors to the emitter area to effectively distribute the heat more evenly and prevent the onset of 'hotspots' that may go into thermal runaway. While the emitter resistors do tend to spread the heat, they also lower gain performance. All silicon MOSFET technologies exhibit a negative temperature coefficient. As temperatures increase, the amount of voltage required to bias the device to the same level also rises. If the same voltage is continually applied to the gate, the bias current is reduced, which produces less heat and reduces the temperature, thus stabilizing the device.

heat out of the device rapidly and efficiently. The vertical technology's improvement in the layout of the active area is designed and optimized for thermal performance. Maximum heat is generated in the drain of the device within a few microns of the gate-source junction and, given the vertical nature of the device structure, the heat travels less than 10 microns through silicon to reach the heat spreading capability of the metalized source contact. Therefore, the thermal path in a vertical device structure is an order of magnitude shorter than other silicon MOSFET technologies. ***Figure 8*** displays the thermal path of the device and demonstrates that the hottest spot in the silicon is, indeed, physically close to the heat sink. This design allows the device to more easily transfer heat to the heat spreading capability of the package.

In contrast, bipolar technology has a positive temperature coefficient where an increase in temperature leads to increased collector current. This leads to a feedback condition, thermal runaway, where the increased temperature increases the current, which creates more heat and thus more current. Bipolar technology attempts to avoid thermal runaway by

As the current state-of-the-art technology for RF power transistors, LDMOS devices can operate at high voltages and high frequencies; however, the technology has an inherent destructive mechanism that destroys the transistor in avalanche mode. ***Figure 9*** shows the simplified cross-section of a LDMOS structure with the intrinsic parasitic bipolar transistor. During the avalanche breakdown condition, this BJT turns on and saturates, resulting in a mode of operation called latch-up. During the latch-up condition the MOSFET creates an excessive amount of current, which generates high power dissipation resulting in thermal runaway and destroying the device in operation. Figure 9 also shows the HVVFET technology and the inherent parasitic bipolar transistor in the structure. Unlike LDMOS technology, the HVVFET structure has the base and emitter terminals of intrinsic bipolar transistor tied together at the MOSFET source terminal effectively creating a two-terminal device such as a diode. Thus, the vertical technology does not experience the failure condition of latch-up under avalanche breakdown.



▲ *Fig. 9 Diagram of vertical and lateral structures with parasitic BJT.*

TABLE I

RUGGEDNESS RESULTS SUMMARY AT RATED OUTPUT POWER

Supply	VSWR	VSWR	VSWR
Voltage	5:1	10:1	20:1
VDD	Pass	Pass	Pass
VDD +10%	Pass	Pass	Pass

TABLE II

RUGGEDNESS RESULTS SUMMARY AT 3 dB OVERDRIVE

Supply	VSWR	VSWR	VSWR
Voltage	5:1	10:1	20:1
VDD	Pass	Pass	Pass
VDD +10%	Pass	Pass	Pass

DC AND RF PERFORMANCE

The HVVFET device under test (DUT) is internally matched to bring the impedances up to a practical level to be matched to 50 ohms at the PCB board. All device performance data is generated in an evaluation circuit that is at the 50 ohm reference plane and includes all external matching circuitry losses, which closely resembles the actual losses experienced in a matched, real-world amplifier application.

The device was tested in a standard RF bench set-up, as described in Figure 2. The device was subjected to a ruggedness test where the input power was set to the amount required to achieve the rated output power, the bias was set at a nominal voltage of 48 V and the load was set to a mismatch with VSWR of 5:1 and swept through all phases. The RF power performance metrics before the ruggedness test were compared to the performance after the ruggedness test. The pass/fail criteria are specified as no measurable performance change in any of the DC or RF metrics. The load was changed to the 10:1 VSWR cable length and retested with the ideal load for the baseline data. ***Table 1*** summarizes that the device passed the ruggedness test with a mismatched load as great

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U2001H	10 MHz to 6 GHz	-50 dBm to +30 dBm	$458
U2002A	50 MHz to 24 GHz	-60 dBm to +20 dBm	$628
U2002H	50 MHz to 24 GHz	-50 dBm to +30 dBm	$696
U2004A	9 kHz to 6 GHz	-60 dBm to +20 dBm	$441

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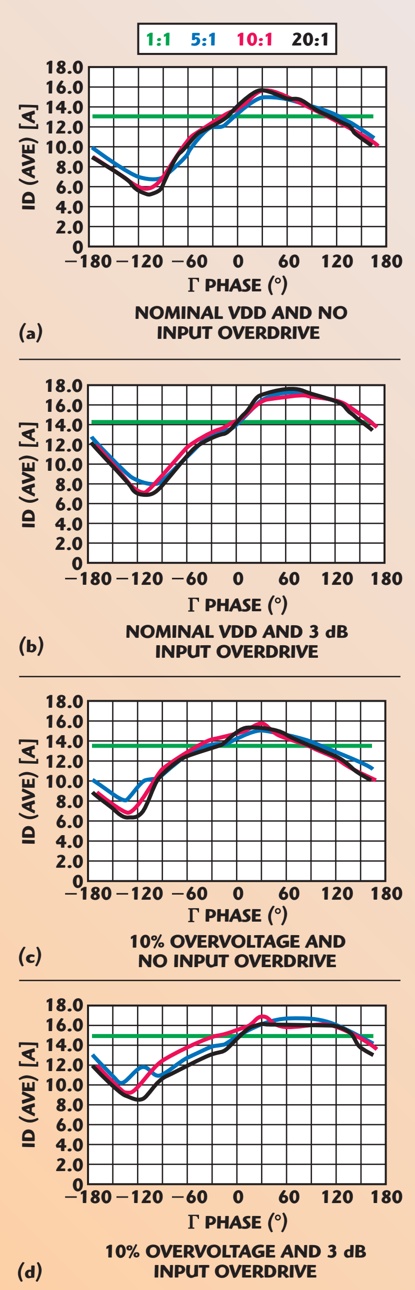
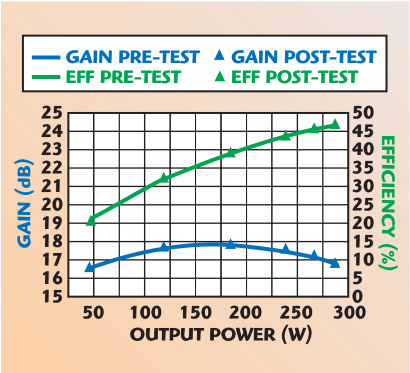


▲ *Fig. 10 Graph IDS vs. phase angle.*



▲ *Fig. 11 Pre/post ruggedness test RF data.*

as 20:1 VSWR. The device was then subjected to an over-voltage condition where the nominal bias supply voltage was increased by 10 percent to 53 V. It was subjected to nominal input power drive and re-tested with all three load VSWRs. Again the device passed the over-voltage condition and the high VSWR mismatch over all phase angles. Next, the device was subjected to twice the amount of input power needed to attain the rated output power, which is 3 dB worth of overdrive. ***Table 2*** shows the device passes this condition at both nominal power supply voltage bias and over-voltage power supply bias.

Figure 10 illustrates the amount of average drain current supplied to the test circuit versus the phase angle of the specified VSWR condition that the device is subjected to during the ruggedness test. If the output power of the device is calculated by Equation 2, it is easy to verify that the average current from the 1:1 VSWR case multiplied by the supply voltage does result in correct output power of the device. As would be expected from Figure 4, there is only an incremental increase in drain current variation as the VSWR is changed from 5:1 to 20:1, but a large increase in drain current variation as the VSWR is changed from 1:1 to 5:1. The effect of drain voltage variation for a fixed input power level shows almost no change in the maximum current. The reason for this is that the device has reached its drain saturation current. This is true for both values of the input drive level. The peak-to-peak variation in the average drain current is greater for the nominal input drive condition than the overdrive condition for the same reason. The device is able to survive the ruggedness tests with no performance changes since the device can handle the maximum current condition, drain saturation, and the maximum voltage condition, drain breakdown, without damage.

The DC and RF data was measured prior to testing as the baseline data for comparison after the ruggedness tests are performed. ***Table 3*** demonstrates that the value of the measured DC parameters of the device do not change by any significant quantity after all the ruggedness tests have been performed. If the ruggedness test was damaging the device, one would expect the DC parameters to shift. Typically ruggedness testing increases R_{ds}(on), decreases V_{gs}(th) and increases I_{dss}. Table 3 clearly demonstrates that the DC parameters are stable and unchanging before and after the ruggedness testing. ***Figure 11*** displays how the ruggedness testing had no effect on the RF performance of device. The measured RF parameters of gain, efficiency and output power are not affected by the testing procedure as the data after the ruggedness tests lie on top of the data prior to the testing.

TABLE III

DC PARAMETERS BEFORE AND AFTER RUGGEDNESS TEST

Condition	I_{dss} (μA)	BV_{dss} (Volts)	V_{th} (Volts)	R_{ds}(on) (mOhm)	G_m (s)
Pre-test	7.3	111.9	1.108	93.2	4.50
Post-test	7.3	112.6	1.113	93.3	4.56

CONCLUSION

The new high voltage RF power MOSFET described in this article demonstrates a high degree of ruggedness. This new device differs dramatically from traditional bipolar devices that are prone to thermal runaway or LDMOS devices that are susceptible to parasitic bipolar latchup. Moreover, this new silicon vertical technology was able to provide high performance output power, gain and efficiency even after the ruggedness test condition of 3 dB input overdrive and 10 percent over-voltage bias supply line and a 20:1 VSWR mismatched load. By combining this unique trait with better RF power performance, the HVVFET technology offers designers a new opportunity to dramatically improve ruggedness while increasing power density, lowering power consumption and shrinking system size in a wide range of radar and avionics applications. ■

THE VIRTUAL OUTER CONDUCTOR FOR LINEAR ANTENNAS

EXPERT ADVICE

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Linear antennas and their many variations have been essential to wireless communication and sensing for over a century. They have been widely deployed over the electromagnetic spectrum, especially at wavelengths ranging from VLF through microwaves. Even though they have been intensely studied throughout that time, there remain some fundamental questions that affect practical design and performance, and for which the answers are either unresolved, controversial, or mathematically very complicated. They include:

- Does a unique voltage exist along an antenna and, if so, between what easily determined and identifiable points?
- Is there an easy and convenient way to predict the current or voltage standing wave ratio along the antenna more accurately than the zeroth-order approximation of infinity?
- Is there an easy and convenient way to predict the input impedance for monopoles that are odd-integer multiples of a half wavelength (or dipoles that are odd-integer multiples of a full wavelength) more accurately than the zeroth-order approximation of infinity?

In this article, a novel and especially simple mathematical model will be described that provides elegant answers to the above questions and more. While previous investigations have resulted in lengthy and complicated mathematical expressions or computer code, this approach will give rise to remarkably simple formulas. They are also remarkably accurate, providing nearly perfect agreement with far more complicated theories and with measurements.

Perhaps most importantly, this perspective is intuitively appealing and provides a convenient way of thinking about how linear antennas operate as coaxial resonant cavities. This, in turn, should inspire new designs and applications.

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Raines Engineering, Rockville, MD

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AML218L0901	2.0 – 18.0	9	±1.0	2.2	+5	2.5:1	60
AML0518L1601-LN	0.5 – 18.0	16	±1.0	2.7	+8	2.2:1	100
AML0126L2202	0.1 – 26.5	22	±2.25	3.5*	+8	2.2:1	170
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AML28P3002-2W	2.0 – 8.0	30	±2.0	5.5	+33	2.0:1	2000
AML218P3203	2.0 – 18.0	32	±2.5	4	+25	2.0:1	450
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AML1718L2401	17.0 – 18.0	24	±0.75	1.6	+10	1.8:1	150

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L0208-41	2 - 8	41	12	40	40	17
L0218-32	2 - 18	32	1.4	31	35	5
L0408-43	4 - 8	43	20	41.5	45	17
L0618-43	6 - 18	43	20	41.5	45	22
L0812-46	8 - 12	46	40	45	45	28
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L1840-27	18 - 40	27	0.5	26	30	2
L2240-28	22 - 40	28.5	0.7	27	30	3
L2630-39	26 - 30	39	8.0	38	40	15
L2632-37	26 - 32	37	5.0	36	38	10
L2640-31	26 - 40	31	1.2	30	30	5
L3040-33	30 - 40	33	2.0	32	33	9
L3337-36	33 - 37	36	4.0	35	40	12
L3640-36	36 - 40	36	4.0	35	40	10

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C090105-50	9 - 10.5	50	100	49	1	8.75
C140145-50	14 - 14.5	50.5	110	49.5	2	10.25
C1416-46	14 - 16	46	40	45	0.35	5.25
C1820-43	18 - 20	43	20	41.5	0.25	5.25
C2326-40	23 - 26	40	10	39	0.25	5.25
C2630-45	26 - 30	45	30	44	0.45	5.25
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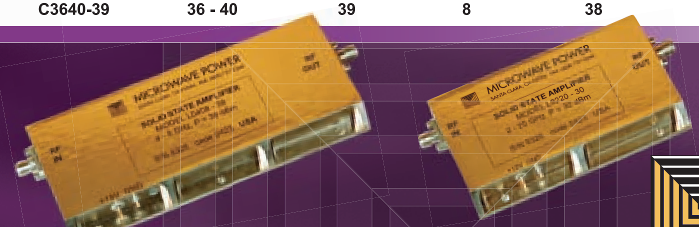

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RADIUS OF THE VIRTUAL OUTER CONDUCTOR

The investigation begins with the general linear antenna, as shown in ***Figure 1***, where the transverse dimensions are very small compared to a wavelength. The long dimension does not have to be straight and the wire may curve, twist and turn. Further, the transmitter or receiver may be located anywhere along the wire, not just at the center.

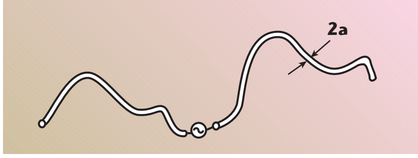


Fig. 1 The general linear antenna.

In a recent book,[1] the author derived a simple but rigorous formula for the characteristic impedance of such a wire that depends only upon its cross-section and the wavelength:

$$Z_0 = -\frac{\eta}{2\pi}\ln(k'a) \qquad (1)$$

In Equation 1, η is the impedance of free space (approximately 377 Ω) and k' is the quasi-static wave number:

$$k' = \frac{e^{\gamma}}{2}k = \frac{\pi e^{\gamma}}{\lambda} \qquad (2)$$

In Equation 2, $\gamma$is Euler's constant (577215...) and λ is the wavelength.

If Equation 1 is compared with the classic formula for the characteristic impedance of a coaxial transmission line with inner radius a and outer radius b,

$$Z_0 = \frac{\eta}{2\pi}\ln\left(\frac{b}{a}\right) \qquad (3)$$

Then it is readily found that some sort of equivalent outer radius b for the antenna is:

$$\boxed{b = \frac{1}{k'} = \frac{e^{-\gamma}}{\pi}\lambda \approx 0.179\lambda} \qquad (4)$$

One useful interpretation of Equation 4 is shown in ***Figure 2***. It is seen that the antenna may be conceptualized as a coaxial transmission line with an outer conductor of radius b. That is, b is the radius of a virtual outer conductor for the antenna. This interpretation will lead to many practical formulas and results for actual linear antennas.

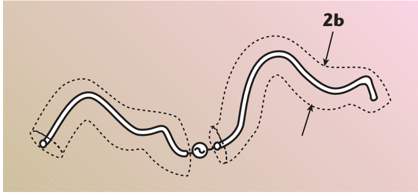


Fig. 2 The antenna considered as a virtual coaxial line.

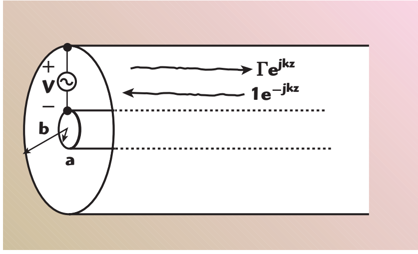


Fig. 3 The coaxial resonant cavity terminated by annular slot antenna.

An immediate benefit of this interpretation is the answer to the question: "Where and how is the voltage defined along a linear antenna?" With the antenna modeled as a coaxial cavity, the voltage is clearly the potential difference between the inner and outer conductors. That is, the antenna voltage is the potential difference between the actual wire and the virtual outer conductor.

REFLECTION COEFFICIENT AND STANDING WAVE RATIO

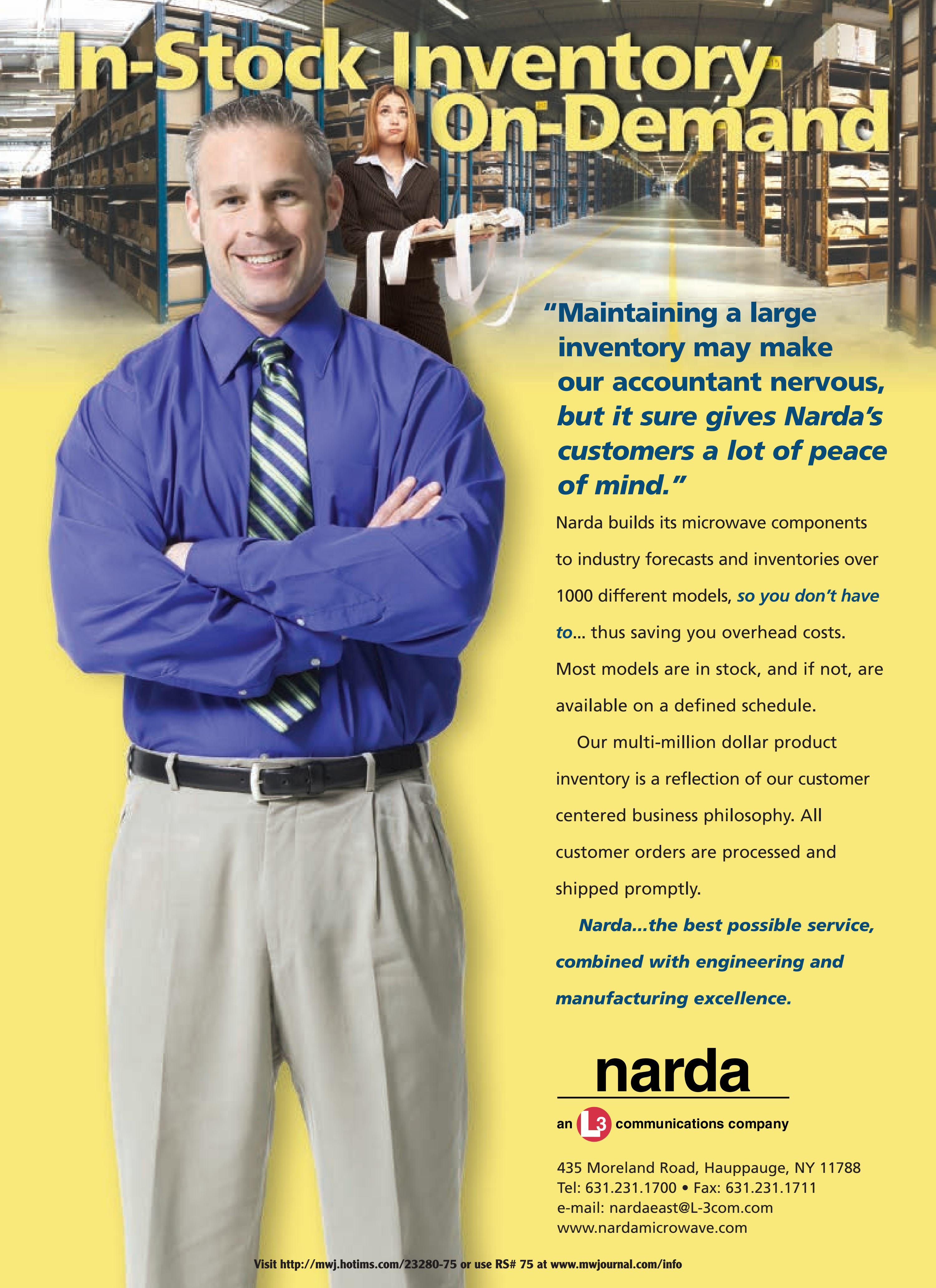
Together with its virtual outer conductor, the antenna may be regarded as a coaxial resonant cavity. Coupling into and out of the cavity occurs at its ends, which are annular slots. ***Figure 3*** shows the details at those ends. On the inner and outer conductors of the coaxial, the forward traveling current has a unity amplitude, and the reflected traveling current has an amplitude Γ. That is, Γ is the reflection coefficient for the current.

The circuit representation shown in ***Figure 4*** makes calculation of the reflection coefficient fairly straightforward. In that representation, R_s is the radiation resistance of the annular slot, and Z_0 is the characteristic impedance described by Equation 1.

The current in the equivalent circuit is:

$$I = \frac{V}{R_s + Z_0} \qquad (5)$$

When the annular antenna and the coaxial transmission line are matched, then the current is: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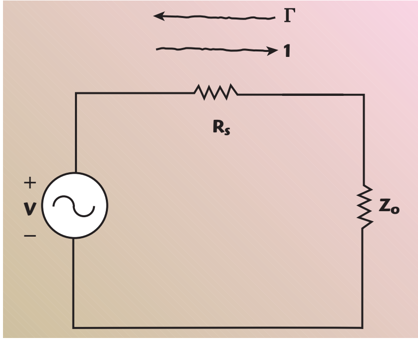


▲ *Fig. 4 A simple circuit representation to calculate the current reflection coefficient.*

$$I_{match} = \frac{V}{2R_s} \qquad (6)$$

The current I is the superposition of I_{match} and a reflected current:

$$I = (1 - \Gamma)I_{match} \qquad (7)$$

The reflection coefficient is readily found by substituting Equations 5 and 6 into Equation 7 and solving for Γ:

$$\Gamma = \frac{Z_0 - R_s}{Z_0 + R_s} \qquad (8)$$

Equation 8 is subtle in at least one way. Close examination shows that it is different from the reflection coefficient obtained using conventional transmission line analysis by a factor of –1. This difference is explained by the unique point of view. The coupling occurs from the annular slot into a coaxial resonant cavity, not the other way around. To transform the reflection coefficient from the plane of the annular slot to the more conventional plane at the input end of the coaxial line, then it must be rotated by a factor of exp (–j2kl), where l is the length of the line:

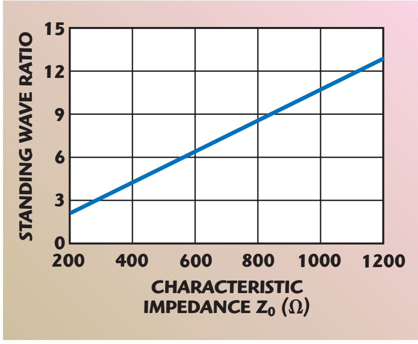
$$\boxed{\Gamma = e^{-j2kl}\frac{Z_0 - R_s}{Z_0 + R_s}} \qquad (9)$$

To evaluate Equation 9, the radiation resistance R_s of the annular slot must first be determined. Since the annular slot is the complement of a wire loop, Booker's theorem[2] can be used.

$$R_s R_{loop} = \frac{\eta^2}{4} \qquad (10)$$

The radiation resistance of a small loop antenna is:[3]

$$R_{loop} = 20\pi^2(kb)^4 \qquad (11)$$



▲ *Fig. 5 Voltage or current standing wave ratio along a monopole antenna as a function of its characteristic impedance.*

Combining Equations 10 and 11, the radiation resistance for the annular slot can be obtained:

$$R_s = \frac{\eta^2}{80\pi^2(kb)^4} \approx \frac{180}{(kb)^4} \qquad (12)$$

Using the value of b in Equation 4, Equation 12 tells that Rs is approximately 112.5 Ω. The current or voltage standing wave ratio is defined as:

$$SWR = \frac{1+|\Gamma|}{1-|\Gamma|} \qquad (13)$$

Applying Equation 9 to Equation 13, the surprisingly simple formula can be obtained:

$$\boxed{SWR = \frac{Z_0}{R_s} \approx \frac{Z_0}{112.5}} \qquad (14)$$

Figure 5 shows the standing wave ratio for a wide range of practical antenna characteristic impedances.

INPUT CURRENT AND INPUT REACTANCE

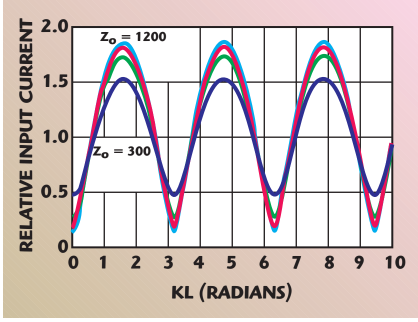
The current and voltage inside the coaxial resonant cavity can be easily written down using the reflection coefficient determined as in Equation 9. If z is the longitudinal coordinate along the cavity, then the current is described by the usual transmission line formula:

$$I(z) = I_0(e^{-jkz} - \Gamma e^{+jkz}) \qquad (15)$$

The choice of the minus sign with the reflection coefficient Γ is consistent with the discussion of the previous section, and with Figures 3 and 4 in particular.

The voltage, or potential difference between the inner and outer conductors, is:

$$V(z) = Z_0 I_0(e^{-jkz} + \Gamma e^{+jkz}) \qquad (16)$$



▲ *Fig. 6 Input current magnitude for monopole antennas of different lengths, and of different characteristic impedances.*

The impedance along the line is:

$$Z(z) = \frac{V(z)}{I(z)} = Z_0 \frac{1-\Gamma e^{+j2kz}}{1+\Gamma e^{+j2kz}} \qquad (17)$$

Equations 15 to 17 will provide convenient formulas for the input current and input reactance. The current is:

$$\boxed{I_{in} = I(0) = I_0(1-\Gamma)} \qquad (18)$$

Figure 6 shows the results of evaluating Equation 18 for antennas of varying lengths and characteristic impedances. It is seen that the current never quite vanishes, although its minima decrease monotonically with increasing characteristic impedance. This is in agreement with intuition. Further, the formula answers the question: "What is the value of the input current for monopoles (or dipoles) that are an odd-integer number of half-wavelengths (or full wavelengths for dipoles), more useful and with better accuracy than the zeroth-order approximation of zero?"

The input reactance is:

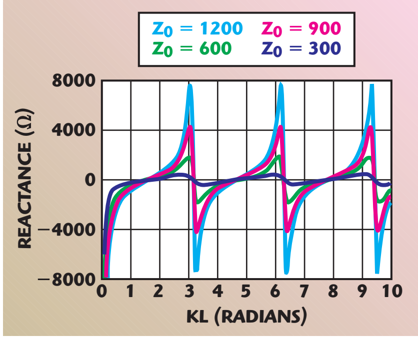
$$\boxed{X_{in} = \mathrm{Im}\left[Z(0)\right] = Z_0\, \mathrm{Im}\left(\frac{1-\Gamma}{1+\Gamma}\right), \quad kl \geq \pi/2} \qquad (19)$$

For short antennas, the classic open-circuited transmission line model is more convenient:

$$X_{in} = -jZ_0 \cot(kl), \quad kl \leq \pi/2 \qquad (20)$$

Equations 19 and 20 agree with each other exactly for $kl = \pi/2$.

Figure 7 shows the input reactance for antennas of varying length and for various characteristic impedances using Equations 19 and 20. It is seen that its magnitude is large for odd-integer half-wavelength monopoles, and zero for even-integer half-wavelengths. Again, the model answers the question: "What is the value of the input reactance for monopoles (or dipoles) that are odd-integer number of half-wavelengths (or full wavelengths for dipoles), more useful and with better accuracy than the zeroth-order approximation of infinity?"



▲ *Fig. 7 Input reactance for monopole antennas of different lengths, and of different characteristic impedances.*

RADIATED FIELD AND INPUT RADIATION RESISTANCE

The current distribution described by Equation 15 readily determines the radiated electric field:[4]

$$E_\theta = \frac{j\eta e^{-jkr} \sin\theta}{4\pi r} F(\theta) \qquad (21)$$

In Equation 21, the vertical radiation characteristic is:

$$F(\theta) = \int_{kl} I(z) e^{+jkz\cos\theta} d(kz) \qquad (22)$$

Equations 21 and 22 describe the contributions to the radiated electric field from z-directed currents. Similar formulas describe any contributions from wires bent in the x or y directions. For simplicity, here the examples will be limited to vertical, or z-directed antennas. For such geometries, Equation 22 can be evaluated exactly in terms of simple functions;[5] however, with modern desktop computers, it is quickly evaluated numerically as well.

From the radiated electric field, the radiated power density, or Poynting vector, is readily obtained:

$$S = \frac{\left|E_\theta\right|^2}{\eta} \qquad (23)$$

And also the total radiated power:

$$P = \int_0^{2\pi} d\varphi \int_0^{\pi} Sr^2 \sin\theta\, d\theta \qquad (24)$$

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151-11	dc-4.0	0-11/1	
152-90-3	dc-26.5	0-90/10	
150T-11	dc-18.0	0-11/1	◆
150T-15	dc-18.0	0-15/1	◆
150T-31	dc-18.0	0-31/1	◆
150T-62	dc-18.0	0-62/2	◆
150T-70	dc-18.0	0-70/10	◆
150T-75	dc-18.0	0-75/5	◆
150T-110	dc-18.0	0-110/10	◆
151T-110	dc-4.0	0-110/10	◆
152T-55	dc-26.5	0-55/5	◆
153-70	dc-40	0-70/10	New
153-110	dc-40	0-110/10	New

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

Notes: ◆ SmartStep® Control Circuitry, X = 75 Ohm Model
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For vertical or z-directed wires, using Equations 21 to 23, Equation 24 becomes:

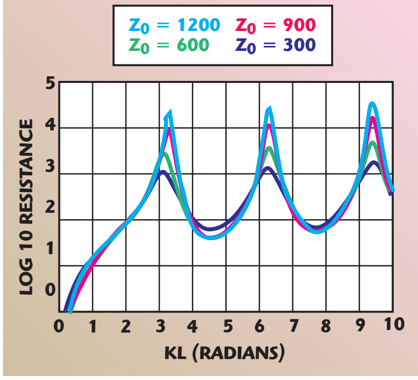
$$P = \frac{\eta}{2}\int_0^{\pi} d\theta \sin^2\theta \left|F(\theta)\right|^2 \qquad (25)$$

Finally, the input radiation resistance is:

$$\boxed{R_{in} = \frac{P}{\left|I_{in}\right|^2} = \frac{\eta}{2\left|I_{in}\right|^2}\int_0^{\pi} d\theta \sin^2\theta \left|F(\theta)\right|^2} \qquad (26)$$

Equation 18 is used to compute I_{in} in Equation 26.

Figure 8 shows the input radiation resistance for antennas of varying lengths and characteristic impedances, computed using Equation 26. It is seen that it is very large for monopoles that are an odd-integer number of half-wavelengths, and that value increases monotonically with increasing characteristic impedance. Again, the model answers the question: "What is the value of the input resistance for monopoles (or dipoles)

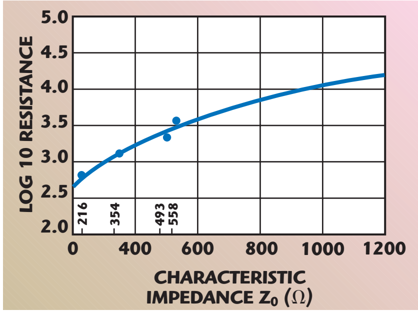


▲ *Fig. 8 Input resistance for monopole antennas of different lengths, and of different characteristic impedances.*

that are odd-integer number of half-wavelengths (or full wavelengths for dipoles), more useful and with better accuracy than the zeroth-order approximation of infinity?"

COMPARISON WITH MEASUREMENTS AND WITH OTHER THEORIES

The most sensitive (in the sense that they are highly variable) and historically controversial results are the ones described in the previous sec-



▲ *Fig. 9 The input resistance of a half-wave monopole as a function of characteristic impedance.*

tion, namely, the value of input resistance for monopoles that resonate at an odd-integer number of half-wavelengths. These values are typically orders of magnitude greater than the input resistance of antennas with non resonant lengths. Perhaps surprisingly, the results of the simple model agree almost exactly with both measured results and those of much more complicated theories.

Figure 9 shows the input resistance for half-wave monopoles as a function of characteristic impedance. A few data points from the classic reference by Sergei A. Schelkunoff[6] are plotted in the same figure. These data points represent both measurements and Schelkunoff's mathematical model. The latter is very complicated compared with the model proposed and involves lengthy expressions of higher transcendental functions such as sine integrals and cosine integrals. The agreement is close if not exact within the ability to precisely read data from the figure in Schelkunoff's book.

EFFECT OF END CAPACITANCE AND TOP LOADING

For many, if not most, practical antennas, the reflection coefficient described by Equation 9 is perfectly accurate. There are some exceptions, however, especially for antennas with actual radii that are significant fractions of a wavelength. For those antennas, the end termination is not only an annular slot but also a disk capacitor. The reactance of that capacitor is easily included in the model.

There is a classic formula for the capacitance of a single disk in free space:[7]

$$C = 8\varepsilon a \qquad (27)$$

where ε is the permittivity of free space, approximately 8.854 pF/meter.

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In the case of top loading, the capacitance is deliberately increased by modifying the end of the antenna, typically with guy wires or other improvised conducting surfaces.

Whether the capacitor is simply the intrinsic disk or a carefully designed enhancement, its reactance is:

$$X = -\frac{1}{2\pi fC} \quad (28)$$

To improve the accuracy of Equation 9 for the reflection coefficient, the reactance must be put in parallel with the slot radiation resistance. This creates a new, complex load impedance:

$$Z_s = R_s \,||\, (jX) = \frac{jXR_s}{jX + R_s} \quad (29)$$

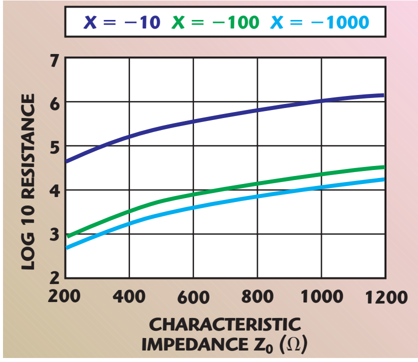
Using Equation 29, Equation 9 is replaced by:

$$\boxed{\Gamma = e^{-j2kl}\frac{Z_0 - Z_s}{Z_0 - Z_s}} \quad (30)$$

Figure 10 shows the effect of disk capacitance or top loading on the input resistance of resonant, half-wave monopoles for varying characteristic impedance. This figure is the same as the preceding one, with the results modified by using Equation 30 instead of Equation 9. Significant effects are seen for reactances X with magnitudes comparable to or smaller than the slot radiation resistance R_s. As X increases in magnitude, however, the effect vanishes, as expected.

CONCLUSION

A simple formula for the characteristic impedance of a single cylinder or wire has led to a comprehensive yet mathematically simple model for a vast family of antennas. That family includes all monopoles, dipoles and other linear antennas. It also includes multi-conductor antennas and antennas with non-circular cross-sections that can be reduced to a single wire with an equivalent radius.[8] The model provides simple formulas that answer practical, but difficult design questions concerning the standing wave ratios, input current and input impedance of antennas, especially at resonant wavelengths. Previously, long and complicated mathematical expressions were required to get at those answers. The answers given here agree almost exactly with those complicated expressions and with experimental measurements. The model also provides a novel and convenient point of view regarding linear antennas. That is, they are coaxial resonant cavities. Coupling into and out of the cavity occurs at the ends via an annular slot. For top loaded antennas and for antennas with radii not small compared with a wavelength, a capacitor is connected in parallel with the slot. ■



▲ *Fig. 10 The effect of end capacitance and top loading on the input resistance of a half-wave monopole.*

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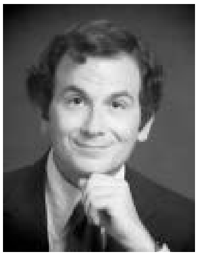

Jeremy Keith Raines *received his BS degree in electrical science and engineering from MIT, his MS degree in applied physics from Harvard University and his PhD degree in electromagnetics from MIT. He is a registered professional engineer in the state of Maryland. Since 1972, he has been a consulting engineer in electromagnetics. His antenna designs span the spectrum from ELF through SHF. He may be contacted at www.rainesengineering.com.*

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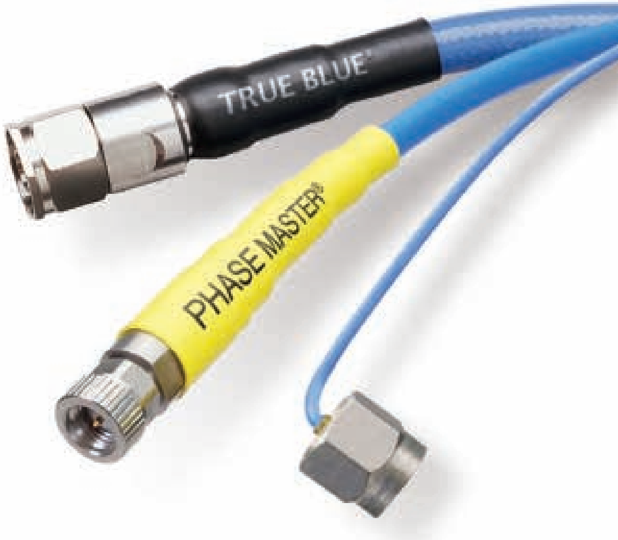

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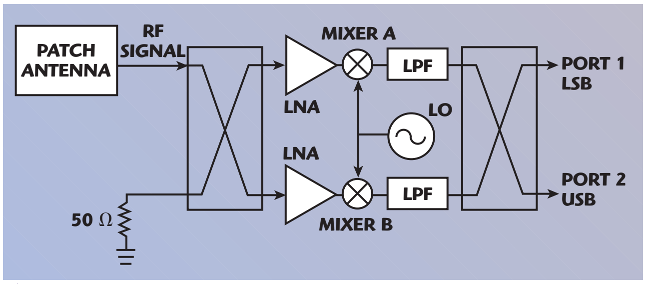
INTEGRATED POWER DIVIDING ANTENNA RECEIVERS

This article reviews four designs of highly integrated front-end receivers that use a power dividing antenna. Through this antenna, a discrete power divider function can be achieved by the antenna itself, yielding a compact receiver front-end.

Nowadays, microwave antennas are widely used, especially in achieving the objective of maximal integration for personal communication systems. These antennas can be mounted on the surface of high performance aircrafts, satellites, missiles, mobile phones and others. Integrated antennas are a combination of solid-state devices and circuits with printed antenna structures to form integrated radio system elements that are fabricated using inexpensive printed circuit techniques.[1] Integrated antennas have become an important area of research because they can give excellent results in term of efficiency, compactness, lightweight and low cost, compared to conventional systems. The main disadvantage of microstrip antennas is an intrinsic limitation in bandwidth, which is due to the resonant nature of the patch structure.[2] This problem gives a new motivation in research for solutions to overcome the bandwidth limitations of the microstrip antenna. Applications where an increase in bandwidth for operation at two separate sub-bands are found in dual-frequency microstrip antennas.[3,4] This kind of antenna can be more useful for a system that can receive and transmit at the same time.

This article discusses four different architectures of receivers that employ a power dividing patch antenna instead of a discrete power divider, which are applied to an image reject system, a dual-frequency system, a direct conversion receiver and a Butler matrix of smart antennas. These new system design approaches are useful for the RF designer, especially for compact system design requirement.



▲ *Fig. 1 Conventional approach for image reject system.*

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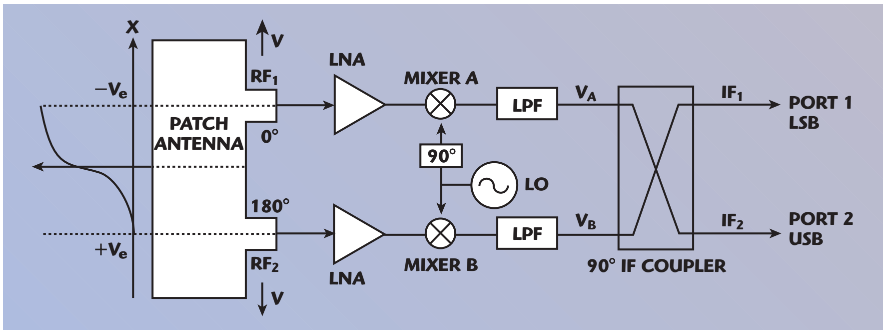
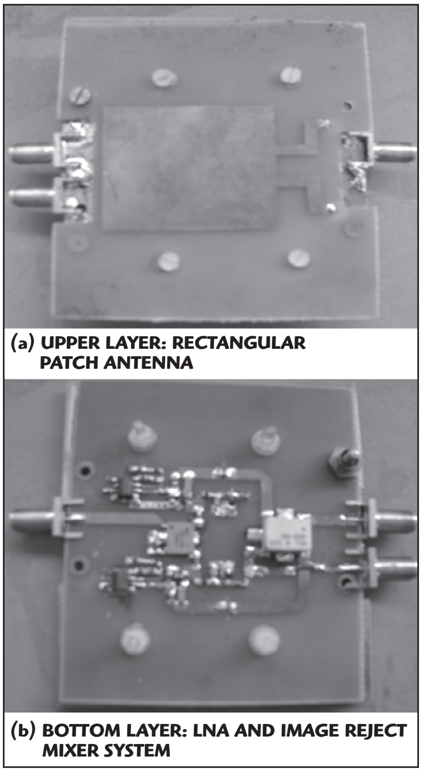
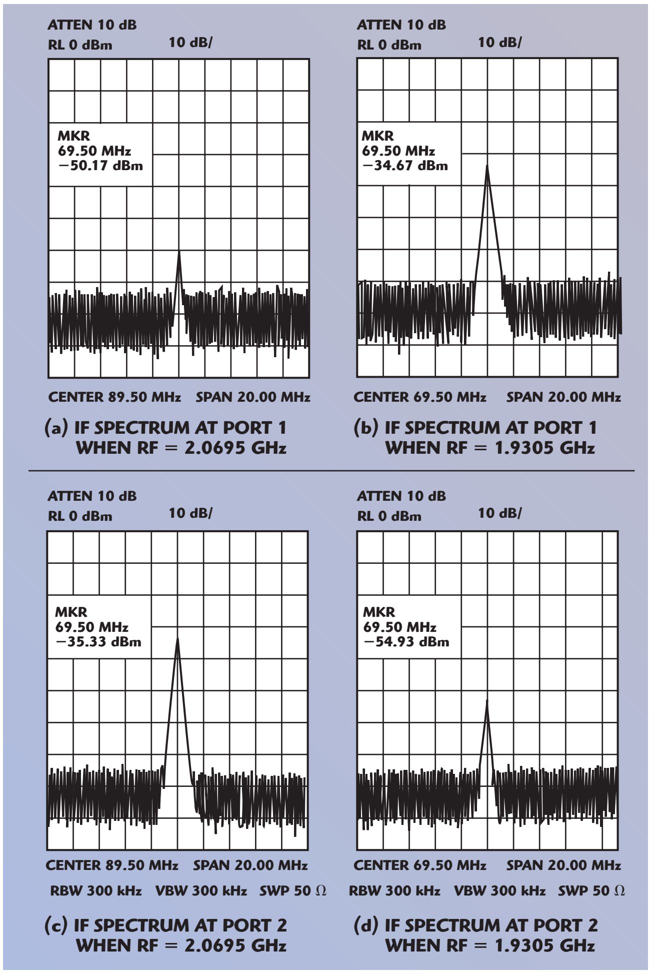


▲ *Fig. 2 Architecture of proposed image rejection mixer.*



▲ *Fig. 3 Fabricated layout of the proposed IRM.*



▲ *Fig. 4 Measured results of the IRM.*

INTEGRATED IMAGE REJECT MIXER (IRM) SYSTEM

Proposed IRM Receiver Architecture

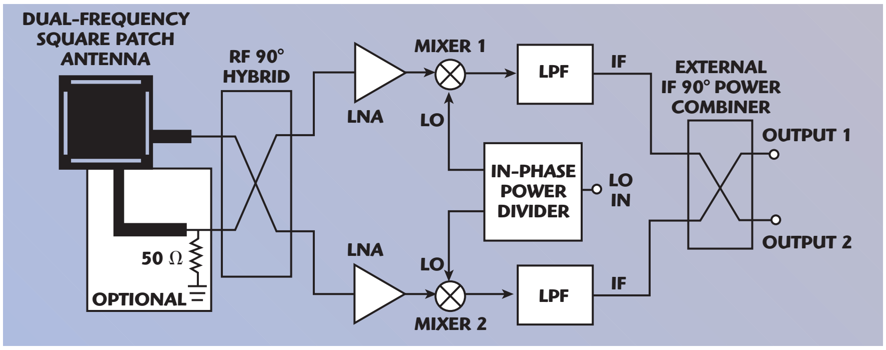
Different applications for active integrated antenna (AIA) have been rapidly developed, especially for wireless communications.[5] The AIA with image rejection, which was developed in this research, introduces a new application of an AIA system.

A basic and conventional IRM is comprised of a balanced mixer of any topology, driven in quadrature by the radio frequency (RF) signal (see ***Figure 1***). The local oscillator (LO) feeds an in-phase power divider that drives each mixer and the IF output is combined in quadrature.[6] The proposed IRM architecture that is developed uses a power dividing patch antenna, as shown in ***Figure 2***. The proposed configuration performs an operation similar to the conventional IRM, but with the phase shifts rearranged. At one of the radiating edges of the patch antenna, a positive maximum signal (+Ve) of a standing wave electric field distribution occurs. The field falls to zero in the center of the patch and a negative maximum (–Ve) occurs at the other radiating edge. Thus, the function f(x) that corresponds to the voltage distribution is odd about the centre of the patch (x=0) such that f(x)=–f(–x). Two microstrip lines are fed along one of the non-radiating edges of the patch, so that the antenna also achieves the function of a 180° hybrid coupler. Therefore, compared to the conventional IRM, the RF hybrid coupler is eliminated or effectively integrated with the operation of the rectangular patch antenna.[7] The RF signals are split into two signals, RF1 and RF2, which are 180° out of phase. The 90° difference of the LO signal is mixed to the received RF signals and the IF signals are combined using a 90° hybrid coupler. Therefore, the patch antenna used in the proposed system is closer to the LNA and image reject system and thus should have lower losses compared to the conventional approach.

IRM Prototype and Measurements

The IRM system has been fabricated on two layers of FR4 with ε_p=4.6. The layout is shown in ***Figure 3***. The upper layer is the patch antenna that is connected via through holes to the LNAs and resistive FET mixer system on the bottom layer. The ground plane is the middle layer. The two layers of FR4 are held together by a solder paste placed in the middle and heated so that the ground planes on both layers are joined. The integrated power dividing patch antenna with image rejection has been shown[8] to perform an image rejection of approximately 20 dB.

The AIA IRM system was characterized by transmitting a CW RF signal from a separate antenna. The output IF signals from both IF ports are illustrated in the spectrum analyzer



▲ *Fig. 5 Block diagram of the proposed DFIA.*

printouts in ***Figure 4***, clearly showing the degree of image rejection achieved. The integrated image reject mixer prototype system is shown to perform image rejection with the RF power divider function achieved within the receiving patch antenna. This system can obtain approximately 20 dB image rejection.

DUAL-FREQUENCY INTEGRATED ANTENNA (DFIA) WITH IMAGE REJECTION

Proposed DFIA Architecture

The first active integrated antenna (AIA) with image rejection has been introduced by Maci and Gentili.[2] The proposed configuration is similar to theirs, but with the phase shift rearranged and useful for dual-frequency operation. The image reject mixer (IRM) includes two balanced mixers of any topology driven in quadrature by the amplified radio frequency (RF) signal. The LO is applied to an in-phase power divider, which drives each mixer and the IF output power is combined in quadrature. ***Figure 5*** shows the block diagram of the proposed IRM system. In principle, the dual-frequency patch antenna should operate with similar features in terms of both radiation and impedance matching at two separate frequencies. There are many techniques to obtain a dual-frequency patch antenna, such as orthogonal-mode, multi-layer patch and reactively loaded. Maci and Gentili[2] introduced many of these techniques and one is used in the present system. A single layer slotted square patch antenna is used to provide the dual-frequency operation. Using two pairs of orthogonal slots, as shown, produces the dual-frequency antenna.

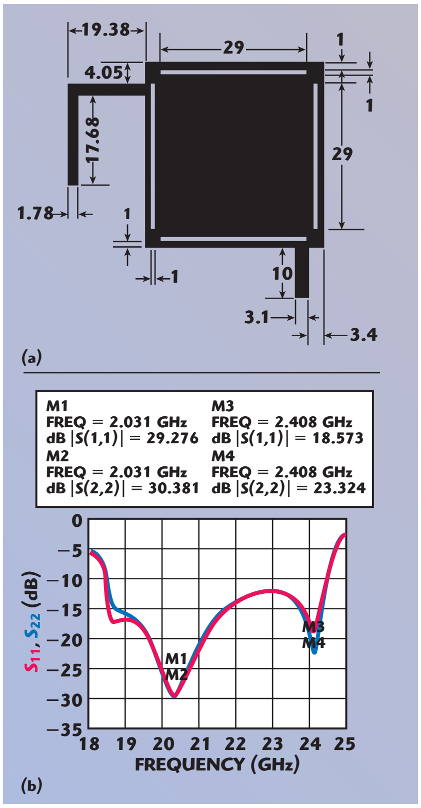
Design Procedure and Testing of DFIA

A square patch antenna of length and width of 35 mm is designed using FR4 with a dielectric constant of 4.5 and a height of 1.6 mm. The slots' length is 29 mm and the width is 1 mm. The slots are 1 mm away from the patch edges. The square patch antenna is simulated using Advanced Design System (ADS) Momentum analysis software from Agilent Technologies. The simulation result shows that the square patch antenna designed can perform at dual-band frequencies: at 2.031 GHz with a return

loss of approximately 29.28 dB and at 2.408 GHz with a return loss of approximately 23.32 dB, as shown in ***Figure 6***. A MGA-83563 low noise amplifier from Agilent Technologies is used to boost the received signal by approximately 22 dB (from 0.5 to 6 GHz). A balanced resistive FET mixer is designed using Agilent ATF-34143. The mixer operates at 0 V DC bias at the drain and only the gate needs to be biased, while the source is grounded. A 90° hybrid coupler is used to combine the two IF outputs at 70 MHz. The square patch antenna is connected to the LNA and IRM through via holes to complete the circuit of the DFIA with image rejection. The system is simulated using ADS Harmonic Balance circuit simulator.

Simulation and Measurement Results of DFIA

The simulation results show that image rejection is achieved as summarized in ***Table 1***. Image rejection results for both frequencies are acceptable. The prototype of the DFIA image reject system was fabricated on two layers of FR4. ***Figures 7*** and ***8*** show the layout of the system. The upper layer is the dual-frequency patch antenna, whereas the LNAs



▲ *Fig. 6 Patch dimensions (a) and antenna simulation results (b).*

TABLE I

DFIA SIMULATION RESULTS

Parameter	First Frequency Band	Second Frequency Band
RF frequency	1.961 to 2.101 GHz	2.338 to 2.478 GHz
LO frequency	2.031 GHz	2.408 GHz
LO power	10 dBm	10 dBm
Mixer gate voltage	-0.6 V	-0.6 V
LNA bias voltage	3.0 V	3.0 V
Conversion loss	<15 dB	< 15 dB
Image rejection at port 1	18.34 dB	19.15 dB
Image rejection at port 2	18.53 dB	16.81 dB

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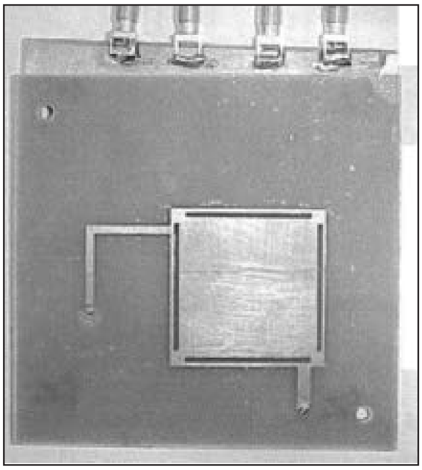
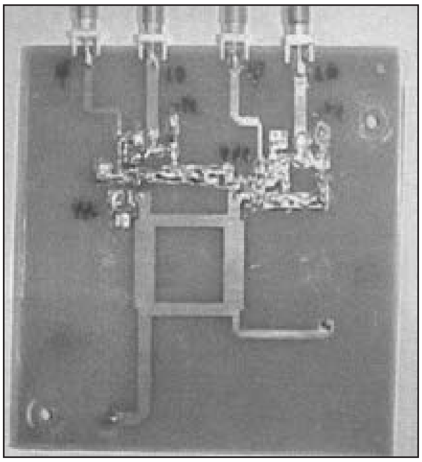
and the resistive FET mixer system are on the bottom layer. The two layers are connected via through holes.

The measured return loss of the dual-frequency patch antenna is shown in ***Figure 9***. Clearly, it has shown that the dual-frequency with acceptable return loss is achieved. The first resonant frequency is at 2.084 GHz with return loss around 26.25 dB, which can support the UMTS or CDMA wireless standards. The second frequency is at 2.49 GHz with a return loss of about 26.95 dB that can support Bluetooth, Wi-Fi or WiMAX wireless standards.

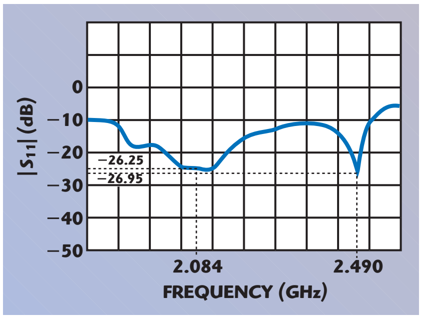
Two signal generators were used for transmitting the RF and LO signals. The signal generator for the LO is connected using an in-phase power divider to produce two LO signals that will be applied as the input to two mixers. Four power supplies were used to bias the two LNAs and two mixers. The measurement started by setting the LO frequency at 2.084 GHz and transmit the RF signal at 2.014 GHz using a dipole antenna. The output at port 1 from the external 90° IF power combiner is terminated in 50 Ω to obtain the wanted IF signal at the output in port 2 for LSB. The same method is used for the USB by transmitting the RF signal at 2.154 GHz and terminating port 2 with 50 Ω to obtain the wanted IF signal at port 1.



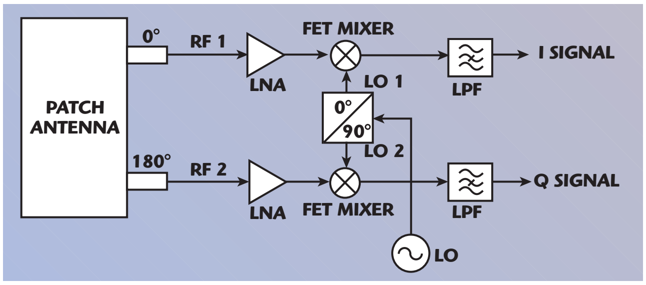
▲ *Fig. 7 Upper layer of the fabricated DFIA (patch antenna).*



▲ *Fig. 8 Bottom layer of the DFIA (image reject system).*



▲ *Fig. 9 Return loss of the dual-frequency square patch antenna.*



▲ *Fig. 10 Proposed architecture of DCR.*

Similarly, the same method is used by setting the LO frequency at 2.488 GHz and transmit the RF signal at 2.418 GHz; the wanted signal appears at port 1 for LSB. Then the RF signal at 2.558 GHz is transmitted to obtain the wanted signal at port 2 for USB. The system experimental setup and measurement results for the open-air measurement are summarized in **Table 2**. Clearly, it shows that the image rejection of approximately 10 dB has been produced, slightly less compared to the simulation results, due to open-air measurements.

It has been shown that the fabricated square patch antenna image reject system can reject the images to two different ports for two different operating frequencies using the same antenna. Phase cancellations are performed with image rejection of approximately 10 dB. Therefore, this architecture introduces a new technique in up-/down-conversion and modulation; thus, it is suitable as a transmitter and receiver at the same time that can support more than one wireless standard through the use of the dual-frequency operations.

INTEGRATED DIRECT CONVERSION RECEIVER (DCR) SYSTEM

Proposed DCR Receiver Architecture

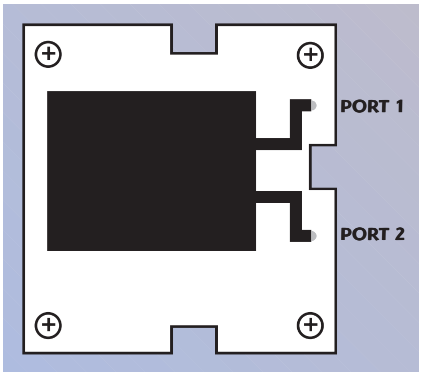
A new configuration of direct conversion receiver with integrated power dividing patch antenna is developed for wireless application. The schematic of the proposed DCR with AIA system for WCDMA applications is shown in **Figure 10**. In this receiver design, dual feed microstrip lines of a power dividing patch antenna are used to provide the odd-mode

TABLE II

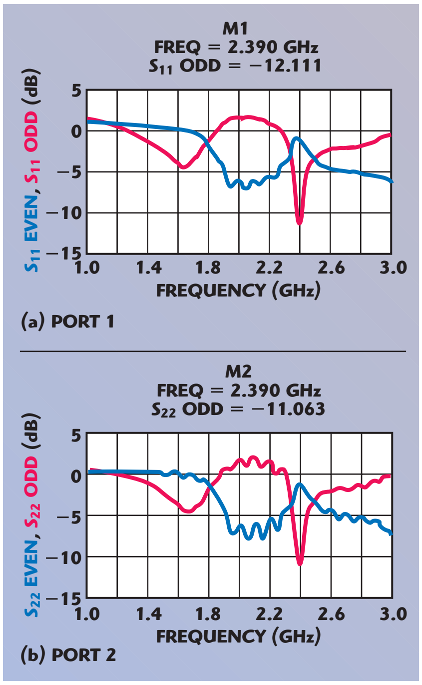
SUMMARY OF DFIA EXPERIMENTAL RESULTS

Parameter	First Frequency Band	Second Frequency Band
RF frequency	2.014 to 2.154 GHz	2.418 to 2.558 GHz
LO frequency	2.084 GHz	2.488 GHz
IF frequency	70 MHz	70 MHz
LO power	10 dBm	10 dBm
Mixer gate voltage	-0.6 V	-0.6 V
LNA bias voltage	3.0 V	3.0 V
Conversion loss	<15 dB	<15 dB
Image rejection at port 1	13.65 dB	9.85 dB
Image rejection at port 2	11.21 dB	9.23 dB

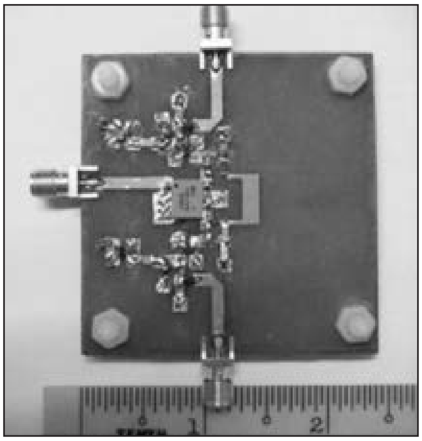
propagating characteristic that acts as a 180° hybrid coupler which is used in the conventional design. This eliminates the necessity of using an RF hybrid coupler to split the RF power and obtain the proper 180° phase shift difference into DCR system. Two low-noise amplifiers (LNA) are employed to improve the noise performance of the radio frequency (RF) signal, which are out-of-phase to each other. The local oscillator (LO) signal is applied to the gates of each mixer, with a 90° phase shift. The baseband signals are extracted from the drain of each mixer. The desired signals of I and Q components at the baseband frequency are extracted and then filtered using a low pass filter (LPF).



▲ *Fig. 11 Power dividing patch antenna prototype.*



▲ *Fig. 12 Odd- and even-mode excitation measurement results.*



▲ *Fig. 13 DCR circuit prototype.*

Design Procedure and Testing of the Proposed DCR

Power Dividing Antenna:

The concept of integrating a power-combining patch antenna has been described previously.[9,10] It is based on using the dual feeds to excite the proper mode profile in the antenna at the fundamental frequency and suppressing the radiation mode for the higher harmonics. A similar idea is applied in this proposed design in which a power dividing antenna is integrated, based on using a dual feed at one of the non-radiating edges of the patch antenna. This removes the necessity for a 180° RF power splitter. In the 3G WCDMA system, the RF receiving frequency band is from 2110 to 2170 MHz. Thus, the LO frequency is set to be at the center of the system bandwidth, which is 2140 MHz. The power dividing antenna layout, which was fabricated on a Duroid (ε_ρ=5.4) substrate, is shown in ***Figure 11***.

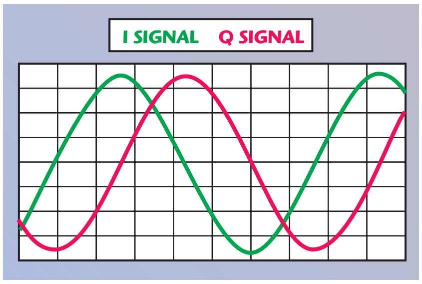
The two-port network of the patch antenna is decomposed into odd- and even-mode excitation. The patch antenna should work in the odd-mode in order to provide the power dividing function. The S_{11}odd (S_{11}–S_{12}) and S_{22}odd (S_{22}–S_{21}) in dB are defined as the ratio of the odd-reflected voltage to the odd-incident voltage wave at port 1 and port 2, respectively. The S_{11}even (S_{11}+ S_{12}) and S_{22}even (S_{22}+ S_{21}) in dB are characterized for the even-mode excitation for port 1 and port 2, respectively. The S-parameter's measurement is carried out using a network analyzer. The odd-mode and even-mode excitation results are shown in ***Figure 12***. The measured results of the odd-mode excitation (S_{11}odd and S_{22}odd) show that a return loss of –12.111 dB and –11.063 dB at the center frequency of 2.39 GHz, respectively, where the offset frequency is 0.25 GHz.

DCR System:

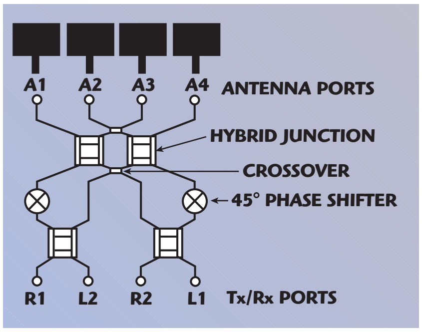
Figure 13 shows the fabricated prototype of the DCR system. The mixers in the DCR design are implemented using a FET resistive mixer and a single balanced mixer topology. The advantages of the FET balanced mixer are low levels of intermodulation distortion and spurious responses and high 1 dB compression point.[11] The ATF 34143 PHEMT mixer from Agilent is employed because it offers better conversion loss than MESFETs. In addition, it has low noise figure (0.5 dB), high 1 dB gain compression (20 dBm) and a high third-order intercept point (IIP3) of 31.5 dBm. The LO signal is divided into two 90° phase difference signals using a Mini-Circuits QBA-24W splitter. The low pass filter is formed by LC-lumped element component to extract the I and Q signals.

System Measurements:

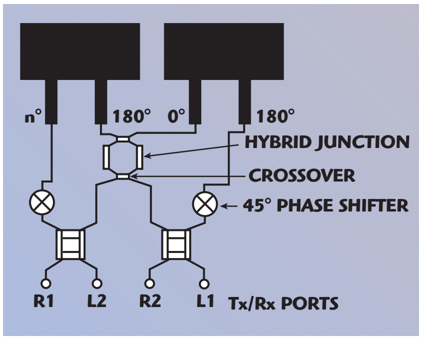
The RF signal of 2.15 GHz and the LO signal of 2.14 GHz are applied to the DCR system, so that the IF frequency is obtained at 10 MHz. The measured offset IF is 1.15 MHz. ***Figure 14*** shows that the I and Q components with 90° phase difference characteristics are achieved for the direct conversion purposes. This new direct conversion with active integrated antenna has been presented. The integrated power dividing antenna with DCR architecture yields a compact front-end receiver. The measurement results of the I and Q signals demonstrated that the down-converted QPSK signal has been successfully achieved.



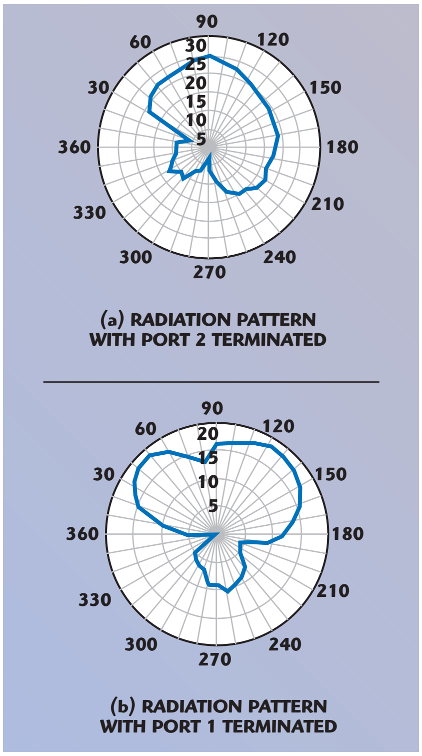
▲ *Fig. 14 Measured I and Q signals from an oscilloscope.*



▲ *Fig. 15 Conventional 4 × 4 Butler matrix.*



▲ *Fig. 16 Proposed 4 × 4 Butler matrix using power dividing patch antenna.*

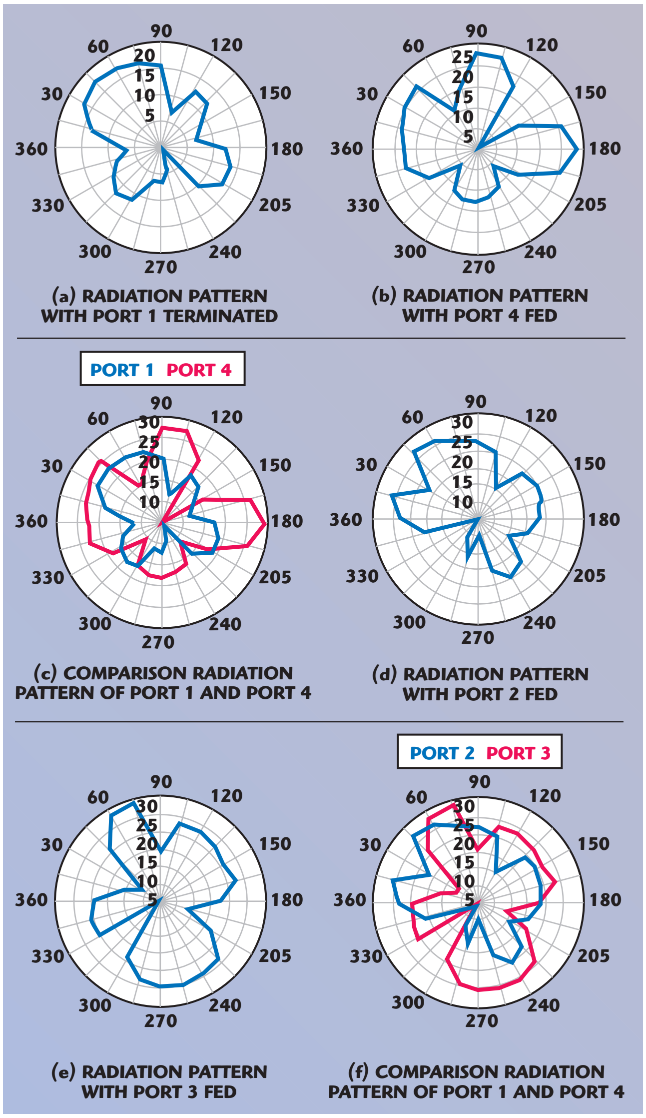


▲ *Fig. 17 Radiation pattern of the power dividing patch antenna.*

4 X 4 BUTLER MATRIX OF SMART ANTENNA

Proposed Smart Antenna

Smart antennas have recently received increasing interest for improving wireless systems.[12] The so-called 4 x 4 Butler matrix is a passive circuit, which gives the ability to get a main beam from an antenna array into one of the four beam directions, as shown in ***Figure 15***. The matrix is designed at 2 GHz and implemented on a microstrip structure using conventional manufacturing processes. The matrix consists of hybrid couplers, a crossover, phase shifters and power dividing patch antennas. The main purpose of this research is to reduce the number of couplers and antennas in the matrix from the original design. The matrix is designed and simulated, using ADS. The measurements that are of concern in this project are return losses, phase shifts, antenna gain and radiation patterns. The new design's results will be compared with the original and may prove that the new design operates in the same way. The new design's patch antenna shows a 180° phase shift at the edges. It may replace the hybrid couplers function in the original design's Butler matrix and the number of couplers may be reduced from four to two. Since there are two ports at each patch antenna, the number of antennas may be reduced from four to two also. The simulation results of the new design are being compared with the original design to prove the new design is workable. The physical implementation of the matrix consists of four hybrid couplers, two crossovers and two 45° phase shifters.[13] The matrix had been designed and simulated using ADS. The return loss and phase shift of each output were considered. However, the design was optimized to obtain better results. ***Figure 16*** shows the proposed block diagram of a 4 x 4 Butler matrix. By comparing with theoretical phase shift[14] (see ***Table 3***), the simulation results are similar



▲ *Fig. 18 Radiation patterns of the integrated Butler matrix.*

TABLE III

THEORETICAL INPUT-OUTPUT PHASE SHIFT OF A 4 X 4 BUTLER MATRIX

Ports	A1	A2	A3	A4
R1	135	90	45	0
L2	45	-180	-45	90
R2	90	-45	-180	45
L1	0	45	90	135

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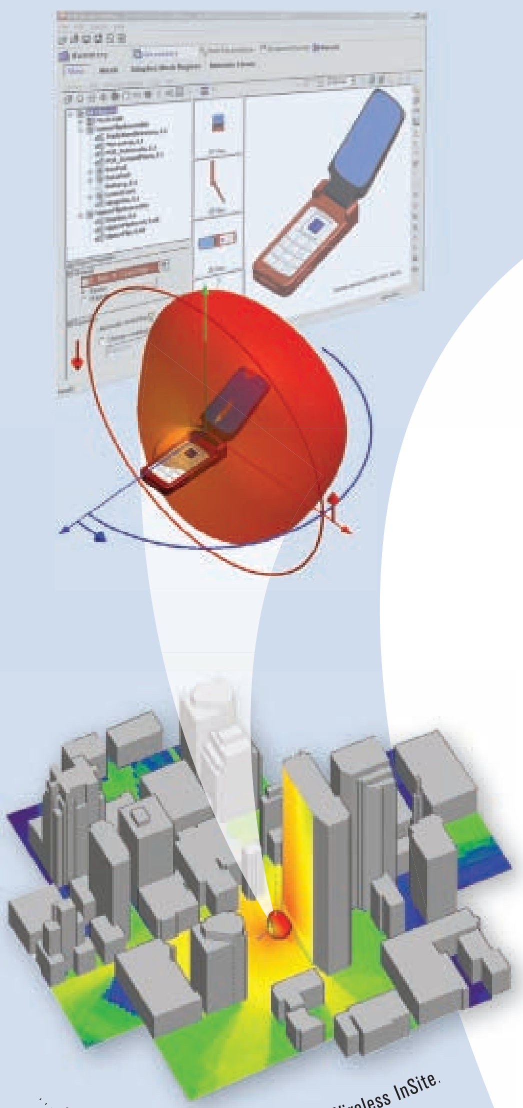

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AMERICA'S FASTEST-GROWING PRIVATE COMPANIES Inc. 5000 with only 15 percent phase difference, as shown in ***Table 4***.

The radiation pattern of the antenna used for the proposed integrated 4 x 4 Butler matrix is shown in ***Figure 17***. The radiation pattern is similar to the simulation results and is acceptable. The maximum pattern received by the patch antenna occurs when the transmitter and receiver are facing directly at 90°. Then a minimum happens when the antenna faces 270° from the dipole because the antenna ground plane prevents any signal from the transmitter to be received. The radiation pattern for the fabricated integrated Butler matrix is shown in ***Figure 18***. It shows that the pattern is similar for port 1 and port 4 when they are fed or when port 2 and port 3 are fed. From the pattern, it can be seen that there are four beams occur in the pattern. This is important evidence showing that the new design antenna is operating in a way similar to the original Butler matrix.

The objective of this project was to reduce the number of couplers and patch antennas. This has been proven by comparing the new design results with the original Butler matrix's results. This project has shown that it is possible to reduce the number of hybrid couplers and patch antennas in a 4 x 4 Butler matrix. The measured radiation patterns of the new design show that it is operating in a way similar to the original Butler matrix.

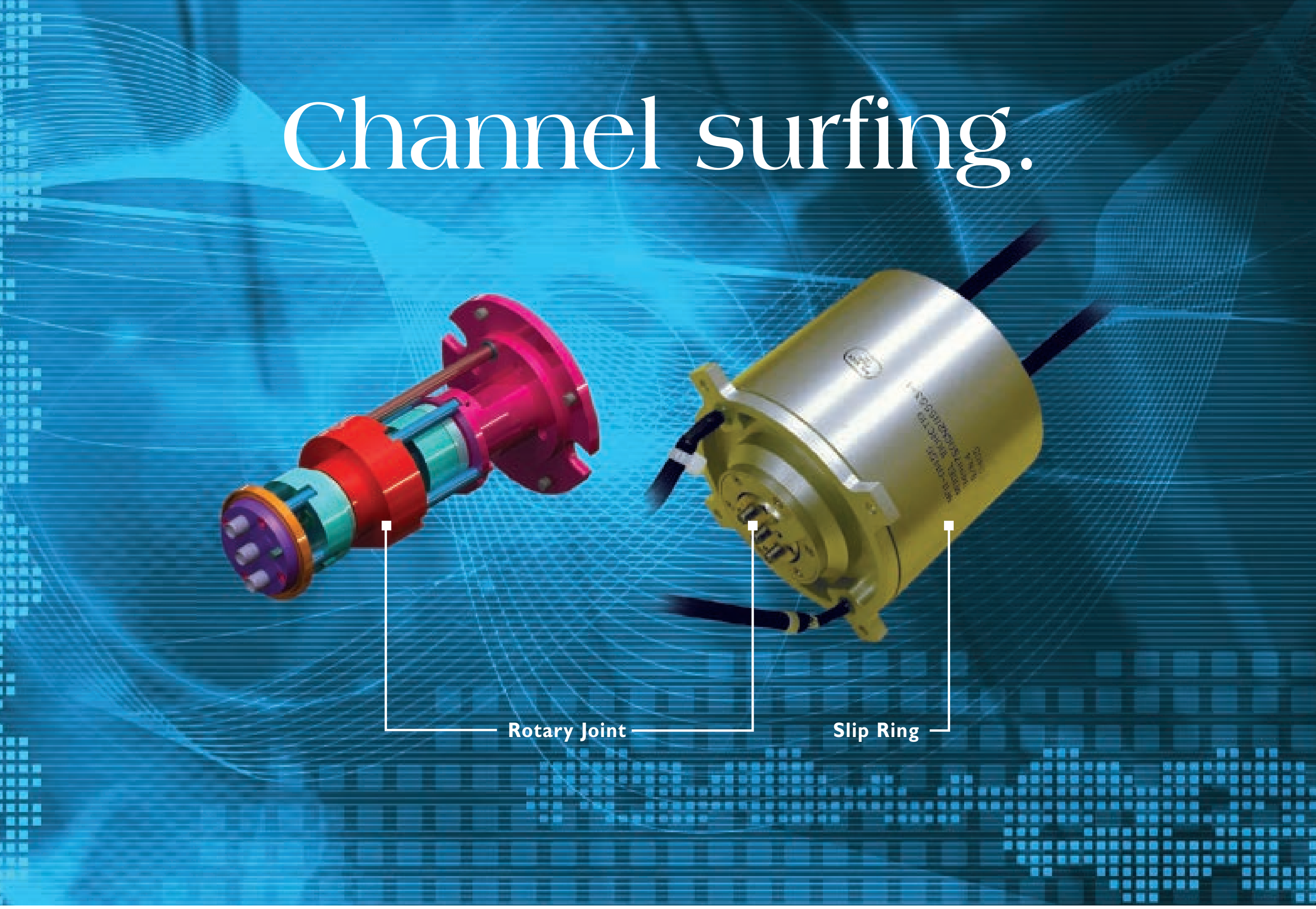
TABLE IV

INPUT-OUTPUT PHASE DIFFERENCE OF THE PROPOSED DESIGN

Ports	Comparison of simulation to theory	Antenna 1, port 1		Antenna 1, port 2		Antenna 2, port 1		Antenna 2, port 2	
		freq	phase	freq	phase	freq	phase	freq	phase
1	Simulation	1.93	131.77	2.19	88.69	2.05	50.62	2.10	2.52
	|% difference|	3.5	2.40	9.50	1.46	2.50	12.49	5.00	0.70
2	Simulation	1.91	43.71	1.86	-172.44	1.82	-43.09	2.03	92.92
	|% difference|	4.50	1.29	3.00	4.20	9.00	4.24	1.50	3.24
3	Simulation	2.03	102.88	1.82	-44.41	1.86	-171.40	1.91	41.64
	|% difference|	1.50	14.31	9.00	1.31	7.00	4.78	4.50	7.47
4	Simulation	2.10	11.03	2.05	54.40	2.19	90.27	1.93	130.74
	|% difference|	5.0	3.10	2.5	2.61	9.50	0.30	3.50	3.15

CONCLUSION

Four designs of integrated power dividing patch antennas have been discussed. The first architecture has shown to perform image rejection of approximately 20 dB, while the second one is similar but with the application for dual-band frequency. The third architecture has been shown to



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perform direct conversion with I and Q modulation. The fourth architecture is for a smart antenna system, using a 4 x 4 Butler matrix that reduces the number of antennas used from four to two, while maintaining the same performance. Therefore, all these four architectures eliminate the use of power dividers since their function is achieved by the antenna itself.

Four new approaches in front-end receiver design are presented. These four designs have shown to be compact and produced similar performance to the conventional design. Therefore, this system is useful for system designers if space is critical (in IC design, for example). It can also be used for other receiver applications by employing the power dividing antenna at the front-end. ■

ACKNOWLEDGMENT

The authors wish to acknowledge the support and contributions of all those who assisted in this research, and especially Universiti Sains Malaysia for sponsoring it.

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SiC High Power Transistors for Next Generation VHF/UHF Radar

Silicon RF and microwave power transistors have been supporting long-range surveillance radar systems since the early 1970s, starting at UHF with peak powers of 100 W at ~50 μs, 20 percent duty for the first UHF radar and L-band with peak powers of about 50 W at 100 μs, 10 percent duty and 20 W at 1 millisec, 20 percent duty cycle. The highest performance silicon products available today provide (see also ***Figure 1***):

- UHF (406 to 450 MHz) 1 kW in a push pull package 300 μs, 10 percent duty cycle
- L-band (1200 to 1400 MHz) 370 W at 300 μs, 10 percent, 150 W at 2 ms, 10 percent duty cycle
- S-band (2700 to 3100 MHz) 120 W at 200 μs, 10 percent duty cycle

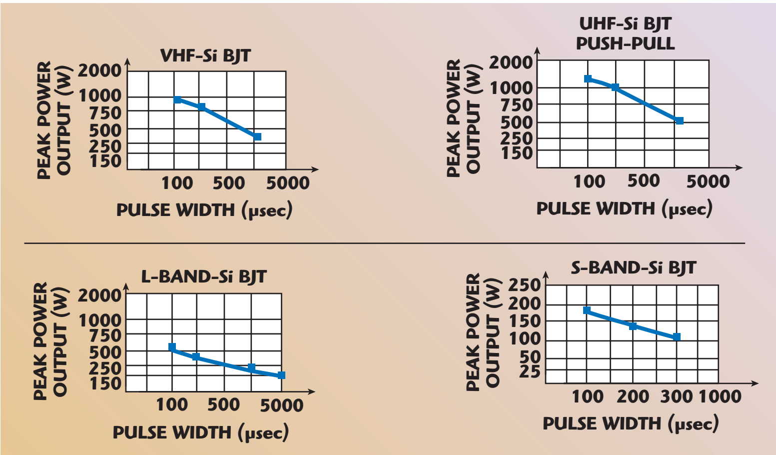

Fig. 1 Si transistor peak power performance at various frequency bands (10% duty cycle).

The historic silicon Class C amplifiers are limited by heat dissipation due to the potential for thermal runaway during long pulses (> 300 μs) and high peak powers. Silicon RF transistors—whether BJT, VDMOS or LDMOS—are not able to offer the combination of increased peak power performance and extended pulse (> 300 μs) characteristics for the next generation of radar systems.

NEXT GENERATION SYSTEMS SEEK OPERATIONAL IMPROVEMENTS

Long-range radar systems operating from VHF thru S-band are demanding increased performance from the RF power amplifier in order to support the improved ranging and sensitivity needed by today's defense and air transport customers. A key lesson learned from the crisis on 9/11 was the need to extend the pulse width to at least 300 μs for long-range radar as well as the ability to increase the operating dynamic range of the power amplifier. The capability of model 0150SC-1250M, SiC SIT peak power performance operating at the pulse width of 300 μs, 10 percent duty cycle, is shown in ***Figure 2***, direct from the Boonton Model 4500B peak power meter. The pulse droop is approximately 0.2 dB at power out of 1250 W peak.

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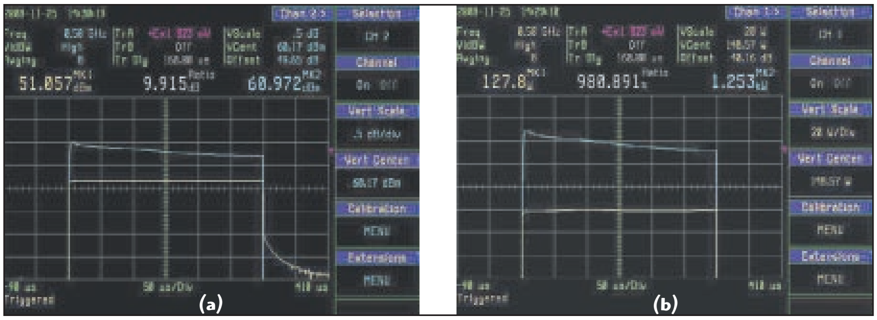


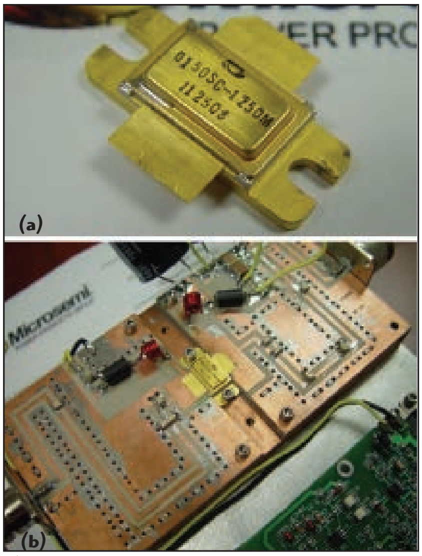
▲ *Fig. 2 Curve trace showing power droop of <0.2 dB (a) and output power of 1250 W (b) for SiC transistor.*

LONG-TERM RELIABILITY

The transistor design must meet the long-term reliability called for by the final customer. Since long-range radar systems have an expected life in excess of 30 years, equipment manufacturers need products designed and built with a high level of long-term reliability, as well as based on technologies that will be available to support the expected operating lifetime of the system. Microsemi Corp. offers a broad line of semiconductors used in legacy systems, including systems that have been in the field for more than 35 years. The use of all gold metallization and hermetic packages provides the transistor long-term reliability and the corporate commitment to the radar market ensures the source of supply for the long term. ***Figure 3*** shows the packaged transistor and test fixture.

MICROSEMI INVESTS IN RADAR POWER AMPLIFIER FUTURE

Microsemi's Power Products Group Microwave RF Power Division is a supplier of RF and microwave power semiconductors for radar systems. It understands the operational requirements for solid state radar power amplifiers and has recognized the need for moving to wide band gap (WBG) semiconductor technology in support of the new radar systems. Microsemi initiated a program to bring SiC technology from R&D into the factory-establishing products that will support radar systems from VHF thru S-band. Higher frequency products



▲ *Fig. 3 Packaged SiC transistor (a) and packaged SiC transistor in test fixture (b).*

will be designed and produced as WBG technology advances. At this time the WBG silicon carbide (SiC) material technology has progressed to the point were Microsemi can build high power devices with reasonable yields and consistent performance. The current focus is on developing an initial line of product to support new designs from VHF through S-band frequencies utilizing the proven SIT and MESFET technologies. ***Figure 4*** shows the SiC transistor performance at various frequency bands compared to Si transistors from Figure 1.

WBG MATERIAL FEATURES

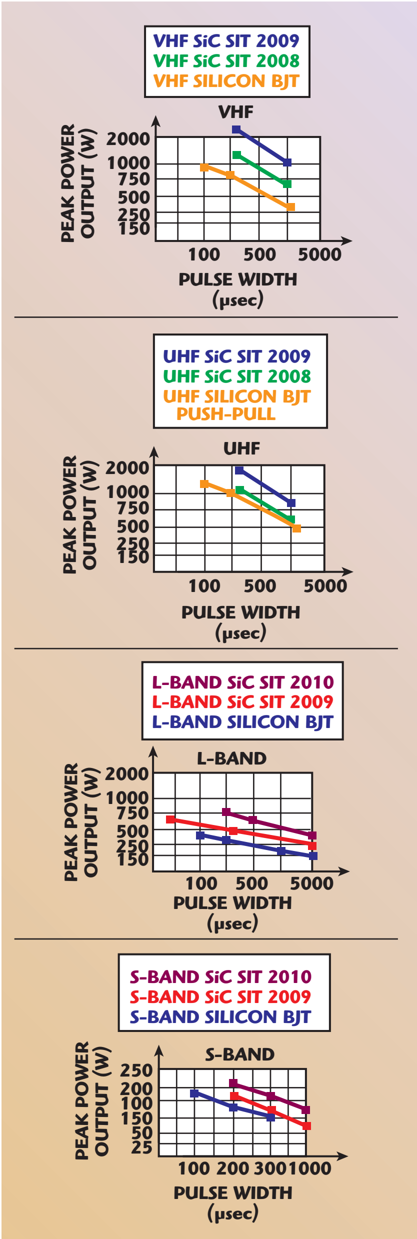
WBG semiconductors offer three key operating characteristics for high pulsed power:

- Higher Band Gap Energy (~ 3x that of silicon): The ability to operate at higher junction temperatures, and therefore longer life than silicon for reduced field costs.
- Higher Critical Field (~ 10x that of silicon): Allows for high voltage operation to increase the power output from the same current.
- Increased Thermal Conductivity (~ 3x of silicon): Provides higher power density for higher peak power in the same-sized package as with silicon.

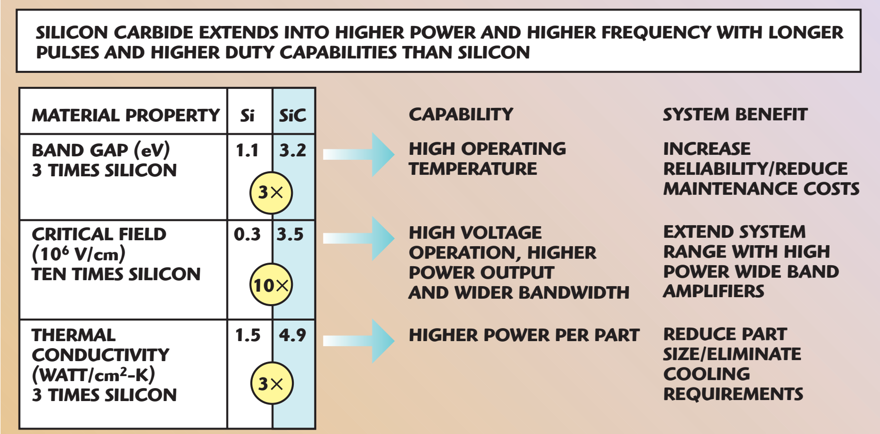
Figure 5 reviews the advantages of SiC over Si for transistor applications.

EXTREME ELECTRICAL RUGGEDNESS

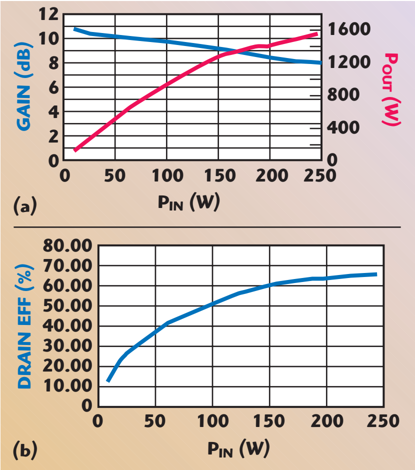
As the SiC device functions much as a junction FET, the device has neg-



▲ *Fig. 4 SiC transistor peak power performance at various frequency bands (10% duty cycle).*



▲ *Fig. 5 Advantages of SiC for pulsed RF power applications.*



▲ *Fig. 6 Gain and output power vs. input power (a) and efficiency vs. input power (b) for 0150SC-1250M (300 μs 10% duty, 125 V).*

TABLE I

KEY SPECIFICATIONS

Parameter	*0150SC-1250M*	*0405SC-1000M*
Frequency (MHz)	156	406 to 450
Power out (W)	1400 Typ.	1100 Typ.
Power gain (dB)	9	8
Pulse width (μs)	300	300
Duty cycle (%)	10	10
Bias (V)	125	125

ative temperature characteristics—the device power output will decrease with increasing junction temperature. It will not go into thermal runaway, much like a silicon BJT or LDMOS device. Microsemi has tested and verified that these transistors will withstand a full 10:1 load mismatch under full specified operating conditions.

HIGH VOLTAGE OPERATION SIMPLIFIES CIRCUITRY

The operation at a drain bias of 125 V reduces the complexity of the power supply and the peak current as well as offering higher terminal impedance, thereby reducing the complexity of the RF circuitry and making the device easier to match over extended bandwidths.

PRODUCT OFFERING

The first SiC products released include the VHF model 0150SC-1250M and UHF model 0405SC-1000M. These products are supplied in a commercially available hermetically sealed package. See ***Table 1*** for key specifications and ***Figure 6*** for power output and gain curves.

Microsemi has designed and characterized these SiC transistors using circuit materials and design criteria supporting next generation radar power amplifier equipment. The characterization of the product includes operational tests at various drive levels to verify the performance over the operational input power window and across the frequency band. Microsemi is developing SiC products to the full spectrum of next generation VHF thru S-band radar systems.

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FAST AND ACCURATE ANTENNA MEASUREMENT RECEIVER

When testing an antenna, the test engineer must typically measure a number of parameters such as the radiation pattern, gain, impedance, or polarization characteristics. One of the techniques used to measure antenna patterns is the far-field range where an antenna under test (AUT) is placed in the far-field of a transmit range antenna. A second technique is the near-field range where the AUT is placed in the near-field and then the data is mathematically transformed to the far-field. Radar Cross-Section (RCS) measurements are used to measure the angle-dependent echo characteristics of radar targets. Depending on the antenna and the application, a near-field, far-field or RCS range will be the preferred technique to properly determine the amplitude and/or phase characteristics of an AUT.

An instrument designed to address these techniques is the new PNA-X Measurement Receiver from Agilent Technologies, which offers the speed, accuracy, sensitivity and flexibility required for near-field, far-field or RCS antenna measurements. With a data acquisition speed of 400,000 data points per second simultaneously on each of five receiver channels, it sets the standard for antenna test applications.

ANTENNA-RANGE MEASUREMENT

A typical antenna-range measurement system can be divided into two separate parts: the transmit site and the receive site. The transmit site consists of the microwave transmit source, optional amplifiers, transmit antenna and communications link to the receive site. The receive site consists of the AUT, a reference antenna, receiver, LO source, RF downconverter, positioner and a PC controller.

On a traditional far-field antenna range, the transmit and receive antennas are typically separated by a distance sufficient to simulate the intended operating environment. The source antenna illuminates the AUT at a distance far enough away to create a near-planar phase front over the AUT's electrical aperture. Far-field measurements can be performed on indoor and outdoor ranges. Indoor measure-

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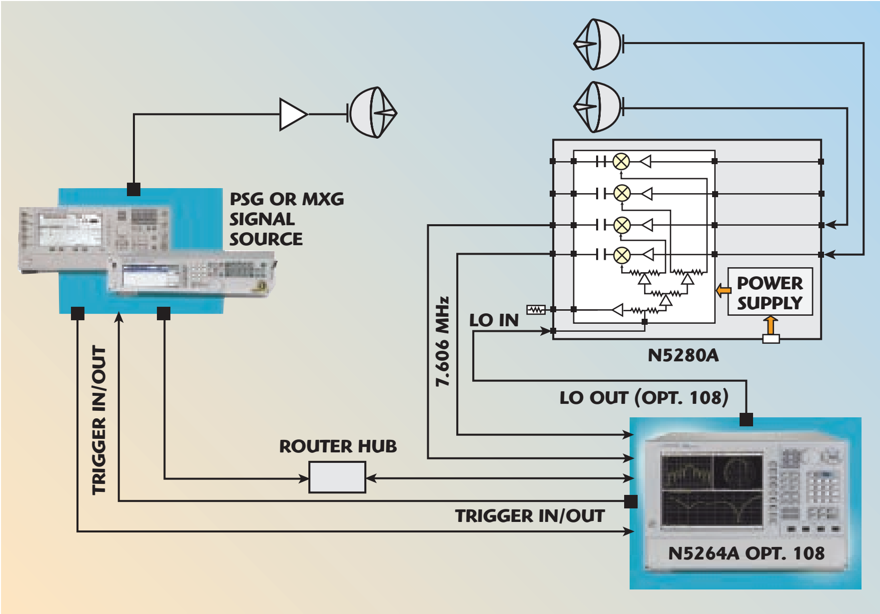

▲ *Fig. 1 Typical compact range configuration.*

ments are typically made in an anechoic chamber specifically designed to reduce reflections off the walls, floor and ceiling.

Measurement of an object's RCS is performed at a radar reflectivity range or scattering range. The first type of range is outdoors where the object is positioned on a specially shaped low-RCS pylon some distance down range from the transmitters. As with far-field antenna measurements, an anechoic chamber is also commonly used for indoor RCS measurements. Here the object is placed on a rotating pillar in the center of the chamber. The walls, floors and ceiling are covered by radar absorbing material to prevent corruption of the measurement due to reflections.

FAST, ACCURATE MEASUREMENT

The PNA-X Measurement Receiver has the features and performance to make such measurements accurately and efficiently. An optional Fast-CW mode enables a 500 million point data buffer, which allows users to stream almost infinite amounts of data directly to the network. It also provides dynamic range of 134 dB at 10 Hz IFBW, with up to five channels/unit.

The instrument includes an optional, built-in 26.5 GHz LO source with +10 dBm of output power, which can be used as a signal source for remote mixers or frequency converters. It is also compatible with the manufacturer's MXG/PSG signal sources, existing 85309A distributed

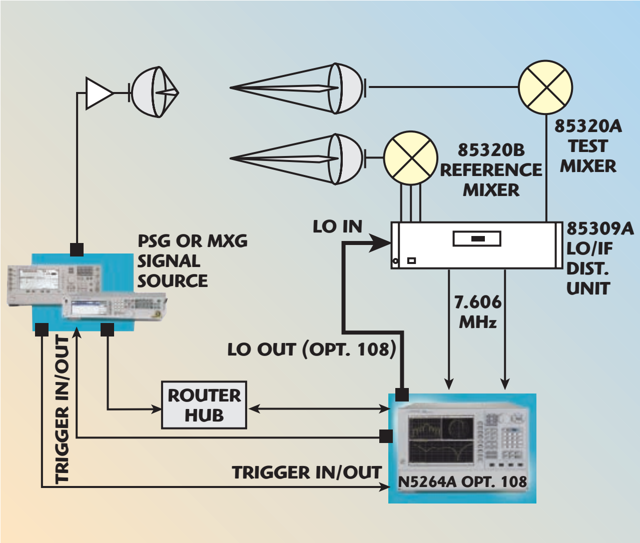

Fig. 2 Typical remote mixing configuration.

frequency converter and 85320A/B mixers. Combining the receiver with an MXG source typically results in a system speed improvement that is 10 times faster than existing systems.

The PNA-X Measurement Receiver is built on the Agilent PNA-X network analyzer technology platform and therefore provides a number of key benefits for antenna test applications, including:

High Sensitivity

The measurement receiver provides fast throughput and a low noise floor. Engineers can select from a minimum of 29 different IF bandwidths, optimizing sensitivity versus measurement speed to fit a particular measurement and application requirement.

Increased Speed

COM/DCOM features help the PNA-X realize extremely fast data transfer rates, while LAN connectivity through a built-in 10/100 Mbps LAN interface enables the PC to be located at a distance from the test equipment. These features enable remote testing as well as reduced test time.

Flexibility and Accuracy

For maximum flexibility, the instrument provides up to five simultaneous test receivers (A, B, C, D and R), with each receiver capable of measuring up to 400,000 points of data. It supports synchronization with external signal generators to further enhance performance and improve measurement accuracy.

Security

For secure environments, the PNA-X features a removable hard drive to completely ensure the security of the data it acquires.

Antenna Applications

With its array of features and benefits, the PNA-X can be easily integrated into near-field, far-field and RCS measurement systems, as is illustrated in ***Figures 1*** and **2**.

For far-field or large near-field antenna applications, the PNA-X Measurement Receiver-based system incorpo-

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CBL-2FT-SMSM+	SMA	2	1.1	27	69.95
CBL-3FT-SMSM+	SMA	3	1.5	27	72.95
CBL-4FT-SMSM+	SMA	4	1.6	27	75.95
CBL-5FT-SMSM+	SMA	5	2.5	27	77.95
CBL-6FT-SMSM+	SMA	6	3.0	27	79.95
CBL-10FT-SMSM+	SMA	10	4.8	27	87.95
CBL-12FT-SMSM+	SMA	12	5.9	27	91.95
CBL-15FT-SMSM+	SMA	15	7.3	27	100.95
CBL-25FT-SMSM+	SMA	25	11.7	27	139.95
CBL-2FT-SMNM+	SMA to N-Type	2	1.1	27	99.95
CBL-3FT-SMNM+	SMA to N-Type	3	1.5	27	104.95
CBL-4FT-SMNM+	SMA to N-Type	4	1.6	27	112.95
CBL-6FT-SMNM+	SMA to N-Type	6	3.0	27	114.95
CBL-15FT-SMNM+	SMA to N-Type	15	7.3	27	156.95
CBL-2FT-NMNM+	N-Type	2	1.1	27	102.95
CBL-3FT-NMNM+	N-Type	3	1.5	27	105.95
CBL-6FT-NMNM+	N-Type	6	3.0	27	112.95
CBL-10FT-NMNM+	N-Type	10	4.7	27	156.95
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CBL-20FT-NMNM+	N-Type	20	9.4	27	178.95
CBL-25FT-NMNM+	N-Type	25	11.7	27	199.95
		Female to Male			
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CBL-2FT-SFNM+	SMA-F to N-M	2	1.1	27	119.95
CBL-3FT-SFNM+	SMA-F to N-M	3	1.5	27	124.95
CBL-6FT-SFNM+	SMA-F to N-M	6	3.0	27	146.95
ARMORED CABLES		Male to Male			
APC-6FT-NM-NM+	N-Type	6	3.0	27	181.95
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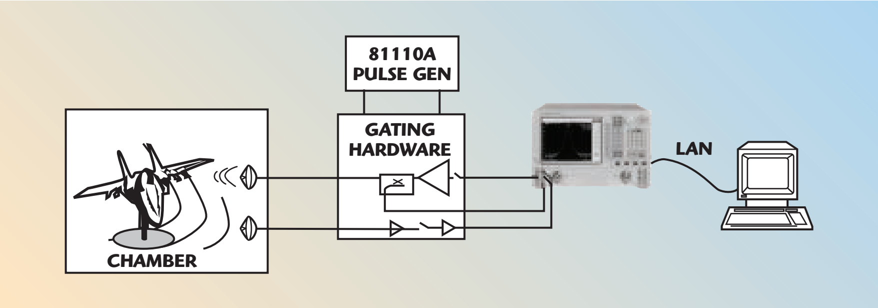

Fig. 3 Typical RCS measurement configuration.

rates the manufacturer's 85320A/B broadband external mixers and 85309A distributed frequency converter. Its optional, built-in 26.5 GHz synthesized source is used as the LO source for the 85309A LO/IF distribution unit.

The instrument's ability to obtain more than 400,000 points of data per second makes it ideal for far-field antenna range applications. Extremely fast data processing is particularly useful in applications where ranges include active array antennas and data acquisition is therefore quite intensive. With faster data acquisition speeds, the IF bandwidth can be narrowed, significantly improving measurement sensitivity without increasing total measurement times.

High-power pulses are often used in RCS measurements to overcome losses due to low device reflection and two-way transmission path loss. Receiver gating may therefore be required in a PNA-X RCS configuration to avoid overloading the receiver during the transmission of the pulsed-RF signal (see ***Figure 3***).

With the source and receiver integrated into the same instrument, with a choice of frequency ranges, a PNA-X RCS configuration is cost effective. Extremely long alias-free down-range resolution for RCS measurements is achievable through the 100,000 data points per measurement trace. In addition, the removable hard drive in the PNA-X complies with data security requirements.

CONCLUSION

Given today's increasingly complex antenna architectures and technologies, quickly and accurately characterizing an antenna and ensuring that it meets specification can be challenging. The PNA-X Measurement Receiver offers the speed, accuracy, measurement sensitivity and flexibility required to accomplish this task. All of these capabilities make the receiver well suited for near-field, far-field and RCS antenna measurement applications, making it an essential tool for today's antenna test engineer.

Agilent Technologies,
+31 (0) 20 547 2111,
contactcenter_benelux@agilent.com,
www.agilent.com.

RS No. 300

OPTIMIZING 4 GHZ MISSION CRITICAL NETWORKS

There are a number of applications and uses for the 4.4 to 4.99 GHz band. These include the 4.4 to 4.5 GHz band, which is designated in the US and NATO countries for military fixed and mobile communications. Typical uses include point-to-point microwave links and telemetry applications such as unmanned aerial vehicles (UAV). There are also peacetime training and test networks deployed in this frequency range. This band is also used widely by NATO countries in Europe for military communications networks. In the 4.635 to 4.685 GHz band, the United States Navy operates the Cooperative Engagement Capability network (CEC), which is a radar information distribution network. There is also a radio astronomy service (RAS) allocation globally on a secondary basis in the 4.8 to 4.94 GHz band. More recently, the FCC allocated 50 MHz in the 4.940 to 4.990 GHz band for public safety applications. Any state or local government agency including municipal utilities can utilize this "new" band on a shared basis. Communication networks deployed in the 4.940 to 4.990 GHz band must be related to the protection of life, health or property and cannot provide services commercially available to the public. Users include state and local governments, police, fire, and search and rescue organizations.

Fig. 1 4 GHz frequency allocation table.

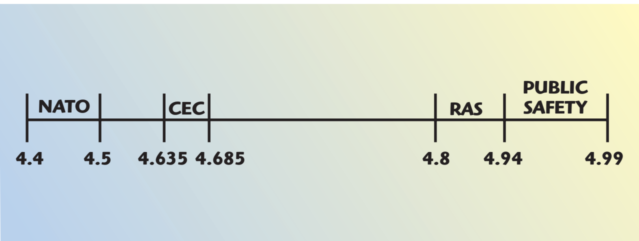

Figure 1 is a diagram showing these frequency allocations. The new FCC allocation of 4.940 to 4.990 GHz permits public safety agencies to implement on-scene wireless networks for video, Internet and database access, transfer of data and files such as maps, building layouts, medical files, police records and missing person images. This allocation also allows public safety agencies to establish temporary (up to one year) fixed microwave links to support sur-

RADIO WAVES
Billerica, MA

▲ *Fig. 2 Basic antenna types.*

▲ *Fig. 3 HPX-4.7 series antennas.*

veillance operations and emergency communications.

While there are a number of good radios available from companies for the 4.940 to 4.990 GHz public safety band, antenna selection is a critical decision relative to network performance. Because the antenna cost is a fraction of the radio cost, the antenna system offers perhaps the best return on investment (ROI) of any network component. Selecting and deploying the optimum antenna is critical to ensuring maximized network performance. In fact, choosing the right mix of antennas can lead to significant cost savings in a network. Designers can maximize the coverage for each antenna and minimize interference, thus minimizing the number of radio points required. Also, by planning in advance to minimize interference in the future, labor is reduced that might otherwise be required to solve interference issues down the road.

Radio Waves has a number of antenna families developed specifically for the 4.7 GHz band (see ***Figure 2***). The most recent addition is the HPX-4.7 series of high performance parabolic dish antennas, an example of which is seen in ***Figure 3***. The standard in point-to-point microwave antennas is the parabolic or "dish" antenna. The parabolic antenna consists of a parabolic shaped reflector, which focuses energy at the feed point of the antenna. They have a very narrow beamwidth that focuses energy at a specific point, making them ideal for point-to-point communications. Due to the narrow beam, they have a relatively high gain compared to other types of antennas. The high performance series of HPX-4.7 antennas utilize a shroud and absorber material to improve side lobe performance and the front-to-back ratio of the antenna. This family of antennas offers the ultimate in front-to-back and front-to-side ratios, which can be a tremendous advantage in minimizing interference during mission critical communications. As an example, a SP4-4.7 has a front-to-back ratio of 40 dB, while the high performance HP4-4.7 has a significantly better front-to-back ratio of 54 dB. Due to the crowded nature of spectrum these days, there are more and more users who utilize HP dishes on microwave links even in the 4.7 and 5.8 GHz bands. These HP dishes allow more links to coexist in the same geographic area.

Dual-polarized antennas may also be utilized to offer system capacity enhancement with a radio such as Motorola's Canopy Backhaul PTP400 and PTP600 series or polarization diversity to enhance the link performance. In the case of the radio produced by

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S3W2	S3W5	N3W5	3	±0.40
S4W2	S4W5	N4W5	4	±0.40
S5W2	S5W5	N5W5	5	±0.40
S6W2	S6W5	N6W5	6	±0.40
S7W2	S7W5	N7W5	7	-0.4, +0.9
S8W2	S8W5	N8W5	8	±0.60
S9W2	S9W5	N9W5	9	-0.4, +0.8
S10W2	S10W5	N10W5	10	±0.60
S12W2	S12W5	N12W5	12	±0.60
S15W2	S15W5	N15W5	15	±0.60
S20W2	S20W5	N20W5	20	-0.5, +0.8
S30W2	S30W5	N30W5	30	±0.85
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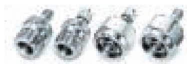
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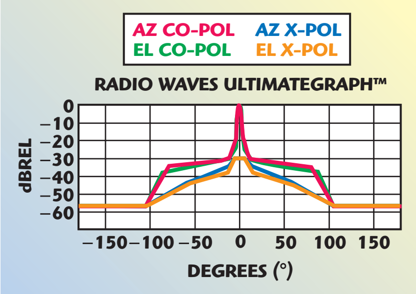
▲ *Fig. 4 HPD4-4.7 four foot dual-polarized parabolic antenna.*



▲ *Fig. 5 Model HPD6-4.7 radiation pattern envelope.*

Exalt Communications, the polarization can actually be switched remotely with a software controlled RF switch. Either of these radios would ideally be matched with an antenna such as the HPD4-4.7, which is a high-performance, four-foot dual-polarized parabolic dish pictured in ***Figure 4***. By utilizing the combination of one of these radios and a high-performance dual-polarized antenna, network performance is thus greatly enhanced and susceptibility to interference greatly reduced.

The HPX-4.7 series is available in a range of sizes, including the HP2-4.7, HP3-4.7, HP4-4.7, HP6-4.7 and the HP8-4.7 eight-foot dish for maximum possible gain in the 4.7 GHz band. The dual-polarized versions mentioned above are the HPD2-4.7, HPD3-4.7, HPD4-4.7, HPD6-4.7 and the HPD8-4.7. ***Figure 5*** is a radiation pattern envelope (RPE) of the HP6-4.7 that shows the superior side lobe performance of this high performance series of dishes. The HPX-4.7 series has a conservatively rated wind survival rating of 125 mph. By adding one extra side strut the wind survival rating is increased to 150 mph for challenging environments such as sea coast and mountain top installations. Each antenna in the series includes a molded plastic radome that is shaped for optimum side lobe performance.

The antenna can be the most cost-effective tool for system optimization. Choosing an antenna that focuses energy in the most useful area is key as well as assuring the antenna selected can minimize interference. Higher gain (larger diameter) antennas have narrower beamwidths that help to reduce interference from unwanted sources and maximize the desired signal. Choosing an antenna with good efficiency is also important for assuring optimized performance.

When selecting antennas, one should also be careful of "paper specs" in a catalog, as there is no agency or industry organization that assures data in a manufacturer's catalog is consistent with what one will realize in actual use. There are numerous antennas that have been measured that do not meet the gain specified by the manufacturer in actual use. It is best to visit a manufacturer's facility and actually witness the antenna gain being measured. Users should also carefully check the manufacturer's warranty and obtain warranties of at least five years.

As the most significant performance improvements are achieved by optimizing the performance of antenna systems, it is imperative that designers consider the choice of antennas carefully. Radio Waves provides an arsenal of antennas to solve complexities facing designers in optimizing their networks. In addition to the HPX-4.7 series of high performance parabolic dishes, Radio Waves offers standard performance parabolic dish antennas, grids, sectors, omnidirectionals and the Xcelarator™ series of flat panels for the 4.7 GHz band.

Radio Waves,
Billerica, MA (978) 459-8800,
www.radiowavesinc.com.

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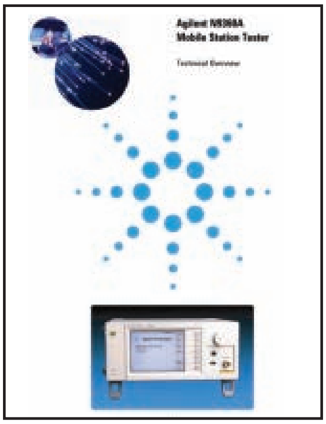

Technical Overview

This new technical overview explains the performance capabilities of the Agilent N9360A mobile station tester, which is a multi-format economy test platform with just enough go/no go test capabilities to meet the needs of the low cost mobile station test market. The free technical overview, "Agilent N9360A Mobile Station Tester," is available at: http://cp.literature.agilent.com/litweb/pdf/5989-9559EN.pdf.

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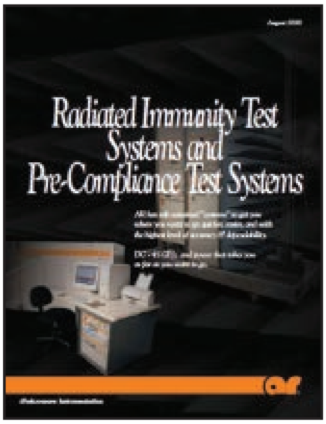

AR Systems Brochure

AR RF/Microwave Instrumentation's newest brochure highlights its systems' capabilities and ARCell Precompliance Test Systems. AR has the capabilities to customize systems to solve your RF and EMC test problems with the power and frequency its customers need – from 10 kHz to 45 GHz. The ARCell systems are out-of-the-box immunity and emissions test systems that perform precompliance testing to IEC 61000-4-3 requirements as well as other industry specific standards.

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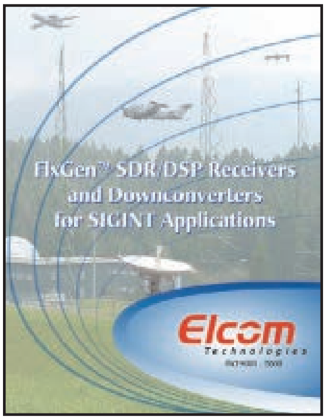

SIGINT Brochure

Elcom Technologies, a designer and manufacturer of synthesizers and receivers up to 40 GHz in the RF and microwave frequency spectrum for applications in the ATE, SIGINT, Custom Hi-Rel and SATCOM markets, has just released the new FlxGen™ family of HF-VHF/UHF-MW receivers and downconverters brochure.

Elcom Technologies,
Rockleigh, NJ (201) 767-8030, www.elcom-tech.com.

RS No. 312

Interactive Product Catalog

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

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

RS No. 313

Product Selection Guide

This product selection guide summarizes over 700 products including 34 new items. New for this publication is an expanded Frequency Generation section featuring Fractional-N and Integer-N PLL ICs. The guide also contains expanded Market and Application sections featuring Automotive, Broadband, Cellular Infrastructure, Fiber Optics and Microwave and Millimeter-wave Communications, and includes Competitor Cross Reference tables.

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

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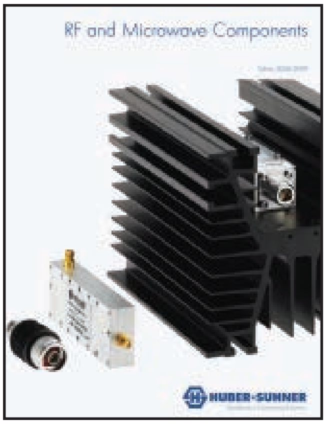

RF and Microwave Components

This short form catalog presents a snapshot of the company's extensive range of high-quality RF and microwave components that are also matched to the various needs in the field of test and measurement. All the products are distinguished by their high performance and stable characteristics, which are the result of years of experience in the development and production of radio frequency components. The order number of the catalog is: No. 84068558.

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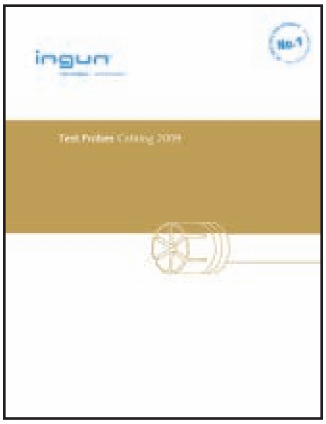

Three New Catalogs

Ingun presents three new catalogs with a completely new layout and numerous new products. The new *Test Probe Catalog 2009* contains over 50 pages featuring a substantial assortment of test probes for the Cable Harness Testing sector. In the new *RF-Catalog 2009*, new radio frequency probes have been included as well as numerous measurement diagrams with regards to return losses and insertion losses (matching and transfer characteristics) for the individual probes. The new *Fixture Catalog* now has over 40 pages and provides a clear structure for standard and special fixtures.

Ingun Prüfmittelbau GmbH, Konstanz, Switzerland, +49 (0) 753181050, www.ingun.com.

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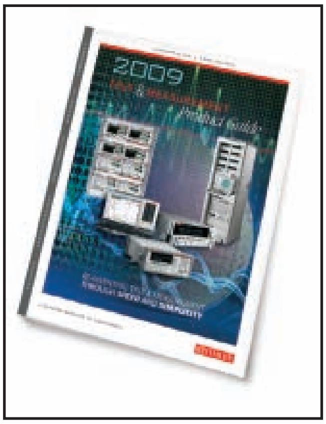

Test and Measurement Product Guide

Keithley's 2009 product guide includes information on the company's latest hardware and software innovations to address challenging test and measurement applications, as well as informative tutorials and selector guides. To request your free copy, visit www.keithley.com/at/556 or call (800) 588-9238.

Keithley Instruments Inc., Cleveland, OH (440) 498-2747, www.keithley.com.

RS No. 317

Microwave Components Catalog

This RF and microwave catalog is available online. It contains the complete technical specifications of more than 200 microwave components, including power amplifiers, low noise amplifiers, down converters, up converters, oscillators, frequency multipliers and high power signal generators. In addition, the catalog gives an overview of accessories like power supply units and heat sinks.

KUHNE electronic GmbH, Berg, Germany, +49 (0) 9293 800939, www.kuhne-electronic.de.

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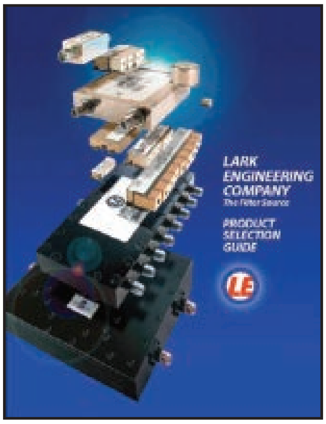


Short Form Catalog

The Lark Engineering eight-page short form catalog features a user friendly, quick reference to filter specifications and capabilities that guides users to the filter ideally suited for the application. Specifications and performance simulations are instantly available using the company's filter design tool located on its web site.

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

RS No. 319

Short Form Catalog

This web site and short form catalog highlights Mimix Asia's product offering, including high power amplifiers, attenuators, phase shifters and core chips. Comprehensive datasheets are available online at www.mimixasia.com with supporting application notes. The new products included in the catalog and web site represent the latest in a growing product line and include the XP1072-BD, a four-stage 33 to 37 GHz GaAs MMIC power amplifier with a small-signal gain of 22 dB and 4 W pulsed saturated output power, as well as the XZ1002-BD, a highly integrated dual path transmit/receive three-port core chip operating from 8.5 to 11 GHz.

Mimix Asia, Hsinchu, Taiwan +49 2102706155, www.mimixasia.com.

RS No. 320

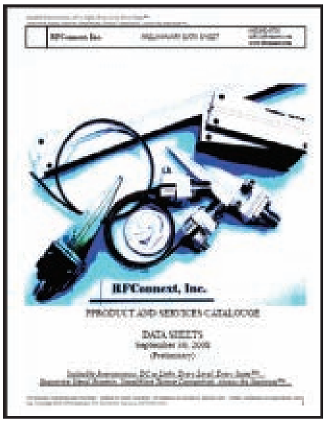
Amplifier Products Catalog

MITEQ's new 72-page JS Amplifier Products catalog provides a comprehensive listing of standard designs for its octave band, multi-octave band, ultra-wideband, moderate band, low-noise waveguide, and fiber optic amplifiers as well as the company's capabilities to customize in accordance with customer specifications. Technical specifications, typical test data and outline drawings have also been included on some of the company's custom products.

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

RS No. 321

Catalog Update



Product Catalog

This product and services catalog features the company's newly developed PMTL™, a new patent pending, transmission line technology, for high speed interconnect and packaging of devices and systems. The initial PMTL uflex cables provide stable phase, group delay, and impedance, with low insertion loss and extremely low cross talk, under bending, twisting, and mechanical distress, from DC to 50 GHz, and scalable to work to 220 GHz and beyond. This catalog provides data sheets for a family of products, based on the patent pending PMTL such as single and differential impedance flex/rigid jumper/connectors, wafer and PCB probes, and test fixtures and sockets.

RFConnext Inc.,
San Jose, CA (408) 981-3700, www.rfconnext.com.

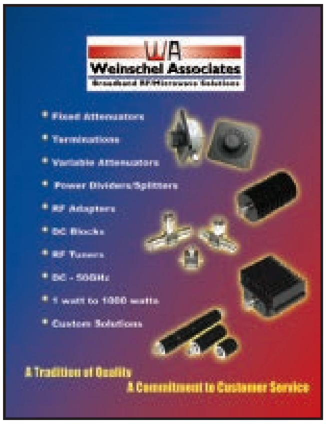
RS No. 322

Product Brochure

This brochure provides a brief, descriptive overview of the LMR® family of cables and connectors, including the acclaimed Advantage™ series. The brochure also includes T-RAD® leaky feeder cable for interior coverage solutions, SilverLine™ test cables including SilverLine QMA and SilverLine TuffGrip™ and also TCOM® flexible low-PIM cables. LMR cables are flexible, non-kinking low loss RF transmission line cables that utilize easy-to-install connectors.

Times Microwave Systems,
Wallingford, CT (203) 949-8400, www.timesmicrowave.com.

RS No. 323



Product Catalog

Weinschel Associates, a manufacturer of high-quality broadband RF and microwave products for commercial and military markets both domestic and international, recently released the 2009 edition of its full-line catalog. The company's goal is to serve its customers with an ever increasing usefulness of product line.

Weinschel Associates,
Gaithersburg, MD (301) 963-4630, www.weinschelassociates.com.

RS No. 324

Surface-mount Antenna

The Mixtus A10194 has been added to the gigaNOVA® range of surface-mount antennas. It is a dual-band 2.4 GHz and 5 GHz SMD antenna that operates over the full 2.4 to 2.5 GHz and 4.9 to 5.9 GHz bands and is designed for use in all Wi-Fi applications, including 802.11n. In addition, good isolation can be achieved between two closely spaced Mixtus antennas on the same platform making it suitable for MIMO applications. Mixtus A10194 is a compact 10 x 10 x 0.9 mm^3 size antenna intended for surface mounting and requires minimal ground plane.

Antenova Ltd., Stow-cum-Quy, Cambridge, UK +44 (0) 1223 810600, www.antenova.com.

RS No. 216

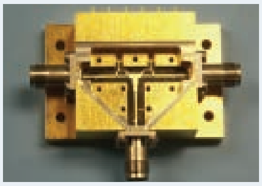
Cavity Backed Spiral Antennas

Cobham SASL's ASO-2045 six-inch diameter spiral antennas provide superior performance for use in applications requiring circular polarization. With excellent input VSWR, these antennas provide smooth broadband gain, low axial ratios and consistent pattern performance over 500 MHz to 4 GHz. This model was designed and developed for applications requiring unit-to-unit amplitude and phase matching, and is an excellent choice for airborne interferometry and direction finding systems. The six-inch diameter by three-inch depth spiral allows close element spacing in arrays to satisfy geometry for upper frequency ambiguity resolution. The ASO-2045 uses a SMA Female connector and has mounting edge for ground plane installation to allow for "clocking" of the elements.

Cobham SASL, Lansdale, PA (215) 996-2416, www.cobhamdes.com.

RS No. 217

SPDT Switch



The CCS33160 is a high power, broadband single pole double throw (SPDT) switch that operates from 6 to 18 GHz. The power handling is rated at 2 kW peak and 100 W CW, while the switching speed is rated at 500 nSec typical. The insertion loss is 1.8 dB maximum and the isolation is 40 dB minimum. The connectors are TNC, and this device utilizes single line TTL control. Bias requirements are +40 V, 20 mA; +5 V, 20 mA; -5 V, 150 mA.

Cobham Defense Electronic Systems, REMEC Defense and Space East, (603) 518-2700, www.cobhamdes.com.

RS No. 225

Frequency Synthesizer

The LX-4300 is a frequency synthesizer designed into an adaptive phased-array antenna system for co-channel interference cancellation. The LX unit operates from 4000 to 4200 MHz with 1 MHz step size and comes in a small surface-mount package of 0.75" x 0.75" x 0.15". The LX units offer a cost-effective design with excellent performance featuring low phase noise, <-80 dBc/Hz at 10 kHz, +7 dBm output power, and a supply of +5 VDC at 75 mA. Custom LX units are available for high volume, tape-and-reel packaging, and feature bandwidths > 50 percent. The LX series is ideal for use in ISM band and other commercial applications requiring small, cost-effective frequency synthesizers, with excellent performance.

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

RS No. 219

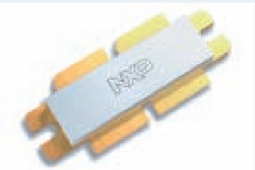
Low Pass Filter

The model 0868LP15A020 is a low pass filter designed for the popular European 868 MHz short-range device (SRD) band, ETSI EN 300 220. This ceramic chip low pass filter provides a cost-effective and compact solution (2.0 x 1.25 x 0.95 mm) and offers excellent performance for applications requiring harmonic filtering to meet the latest emissions regulations. Insertion loss is 0.5 dB maximum with second harmonic rejection of 30 dB minimum and third harmonic rejection of 40 dB minimum. Detailed specification and samples are available on request. This device is fully pin compatible with the popular 0915LP15B026, a similar solution for the US 915 MHz ISM band. Also available for sub 1 GHz ISM bands are the ceramic antenna solutions 0868AT43A0026 and 0915AT43A0026 for size constrained applications.

Johanson Technology, Camarillo, CA (805) 389-1166, www.johansontechnology.com.

RS No. 220

LDMOS Transistor

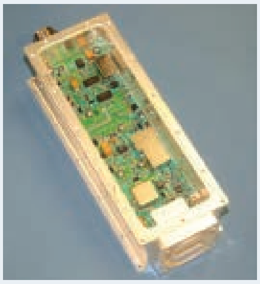


The BLL6H1214-500 Laterally Diffused Metal Oxide Semiconductor (LDMOS) transistor for L-band radar applications delivers RF output power of 500 W at frequencies between 1.2 and 1.4 GHz. It combines the power density of bipolar with the advantages of LDMOS technology for L-band radar design. The RF power transistor operates at a supply voltage of 50 V, exhibits a 17 dB gain and 50 percent drain efficiency. It is rugged, has an improved pulse droop of 0.2 dB, has non-toxic packaging and is RoHS compliant.

NXP Semiconductors, Eindhoven, Holland +31 40 27 29960, www.nxp.com.

RS No. 222

Ku-band LNB



This Ku-band LNB is designed for military and satellite customers. The LNB includes an LNA, RF filters, mixer, phase-locked LO, IF amp and filters. The unit has a low noise figure of 2 dB maximum and a conversion gain of 55 dB minimum. Input voltage is +15 to +24 VDC with less than 400 mA power consumption. Input is via a WR-62 waveguide, and the IF output is type N at 950 to 1700 MHz. The operating temperature range is -40° to +60°C. Rodelco can design customized units covering C- to Ka-band.

Rodelco Electronics Corp., Ronkonkoma, NY (631) 981-0900, www.rodelcocorp.com.

RS No. 223

In-phase Splitter

The model SPD-90-210 is a new L-band, four-way in-phase splitter for SATCOM applications. This low loss splitter spans the frequency band of 900 to 2100 MHz maintaining tight phase and amplitude tracking, typically within 3 degrees and 0.2 dB of signal unbalances respectively within specified frequency band. The splitter is well matched for applications in 50 ohms systems. This product replaces stripline splitters and saves critical board space when splitting local oscillator signals and when used as receiver antenna combiners. The splitter model SPD-90-210 is packaged in a small surface-mount RoHS compliant package, measuring 0.8" x 0.4" x 0.2". Prices start at $20.00 for low quantities, with deliveries ranging from stock to six weeks.

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

RS No. 224

Wideband RF Transistors

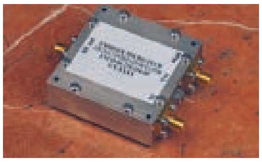
This wideband, high power discrete RF transistor family is designed for broadband applications including radar, signal jammers and wireless communications. TriQuint's new PowerBand™ device family delivers high power performance across an exceptionally wide bandwidth while maintaining very high efficiency. PowerBand offers the RF designer unequalled performance without all the traditional sacrifices.

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

RS No. 230

Active Components

Voltage-controlled Oscillators



The EVCO series of voltage-controlled oscillators (VCO) is designed to meet rigorous performance standards required for military, industrial and satellite applications. This VCO series features stable linear frequency and power output. The EVCO VCO series is hermetically sealed with operating frequency ranges covering 100 MHz to 5 GHz and an operating temperature range of -40° to +85°C. Typical phase noise is -100 dBc/Hz at 10 kHz.

Emhiser Micro-Tech,
Verdi, NV (775) 345-0461,
www.emhiser.com.

RS No. 218

Multi-position Switch

The MM Series coaxial multi-switch contains 4P3T electro-mechanical switches designed for cell sites with three antennas each receiving or transmitting over 120 degrees of one-third of the coverage area for cellular telephone carrier or wireless applications. The MM4 switch can replace three SDPT and SP3T switches or three transfer switches, creating space and cost savings. This series provides a VSWR of 1.20:1 maximum, insertion loss of 0.20 dB maximum, isolation of 80 dB minimum and operates in a frequency range from DC to 18 GHz.

Ducommun Technologies,
Carson, CA (310) 513-7214,
www.dt-usa.com.

RS No. 226

Ultra-wideband Block Downconverters

The DC Series, models DC-20/26.5G and DC-20/40G are high performance inverting ultra-wideband block downconverter systems. Model DC-20/26.5G converts an input signal in the 20 to 26.5 GHz band to an output of 10.3 to 16.8 GHz. This model is designed to be used with MITEQ's model DC-8/20G and DC-0.5G/20G ultra-broadband 2 Hz step agile downconverters to extend input receive bands to 26.5 GHz. Model DC-20/40G converts an input signal in the 20 to 40 GHz band to an output of 3.2 to 16.8 GHz. This model is designed to be used with MITEQ's Model DC-0.5/20G ultra-broadband 2 Hz step agile downconverter to extend the input receive band to 40 GHz.

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

RS No. 227

8 Bit Digital-controlled Phase Shifter

PMI model PS-360-DC-3 Option 618 is a 6 to 18 GHz, 0° to 360°, 8 Bit digitally-controlled phase shifter with a switching speed of less than 50 nS, rise and fall time of less than 20 nS. Insertion loss of 10 dB typical, 12 dB maximum, VSWR of 2.0:1 and with a phase accuracy of ±12° p-p maximum from 8 to 18 GHz and ±15° p-p maximum from 6 to 18 GHz. Size: 1.75" x 1.60" x 0.5". Unit can be hermetically sealed.

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

RS No. 228

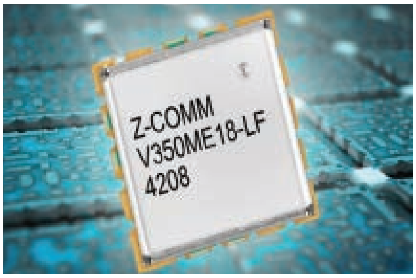
RF Coaxial Switch

The RMT series RF coaxial switch is a multi-position switch with type 'SMA' connectors in a 'Break before Make' contact configuration. This manually operated device provides crisp detent switching and is equipped with positive internal position stops. Standard package measures 1.19" square x 1.25" high and can be flange or bulkhead mounted (bulkhead hardware included). Available with performance rated up to 18 GHz with a maximum VSWR of 1.50:1, insertion loss of 0.50 and 60 dB isolation. The switch is available in 1P3T and 1P6T configurations.

RelComm Technologies Inc.,
Salisbury, MD (410) 749-4488,
www.relcommtech.com.

RS No. 229

Voltage-controlled Oscillator



The model V350ME18-LF is a new RoHS compliant voltage-controlled oscillator (VCO) in VHF-band. The V350ME18-LF operates in a frequency range from 205 to 350 MHz with a tuning voltage range of 0.5 to 11.5 VDC. This VCO features a typical phase noise of -109 dBc/Hz at 10 kHz offset and a typical tuning sensitivity of 14 MHz/V. The V350ME18-LF is designed to deliver a typical output power of 0 dBm at 3.3 VDC supply while drawing 10 mA (typical) over the temperature range of -40° to 85°C. This VCO features typical second harmonic suppression of -13 dBc and comes in Z-Comm's industry standard MINI package with shield measuring 0.50" x 0.50" x 0.22". It is available in tape and reel packaging for production requirements.

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

RS No. 231

Amplifiers

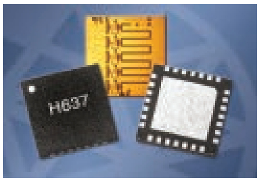
Magnetic Immunity Amplifier

AR RF/Microwave Instrumentation has unveiled a new magnetic immunity amplifier for susceptibility testing. Model 350AH1 (350 W, 10 Hz to 1 MHz) automatically accepts voltages from 90 to 260 VAC in the 47 to 63 Hz frequency range. The new amplifier, which has very low output impedance, will be used primarily for susceptibility testing for magnetic and audio frequency tests in MIL-STD-461D/E, DO160D/E, and a variety of automotive test standards. It can also be used as an AC voltage source, for watt-meter calibration, and as a driver for higher-power amplifiers.

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

RS No. 232

1 W Power Amplifier

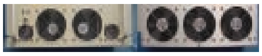


These new chip and SMT GaAs PHEMT MMIC power amplifiers are ideal for military EW, test & measurement, and telecom applications from DC to 6 GHz. The HMC637 is a GaAs PHEMT MMIC power amplifier chip that is rated from DC to 6 GHz, and delivers 14 dB gain, +30 dBm saturated output power and +41 dBm output IP3. The HMC637 also delivers consistent output IP3 and excellent gain flatness of ±0.6 dB across its rated bandwidth. This versatile power amplifier chip requires no external matching components, occupies an area of 7.3 mm², and consumes only 400 mA from a +12 V supply. For applications where an SMT compatible solution is preferred, the HMC637LP5 offers similar performance to the HMC637, and is housed in a RoHS compliant 5x5 mm leadless QFN SMT package.

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

RS No. 233

High Power Amplifier



MPI announces the availability of an updated 100 W model C090105-50 chassis type X-band unit with improved cooling and mechanical design. With this new design MPI can also provide in excess of 200 W in the 8.5 to 9.6, 9 to 10.5, 10.7 to 11.7 GHz, etc., frequency spectrum with model C090105-53.

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

RS No. 234

Broadcast Amplifier

The RES-INGENIUM FM550-108 is a new high performance pallet amplifier designed for FM and HDFM radio broadcast. This Class B amplifier will deliver 500 to 600 W CW output power, up to 82 percent collector efficiency, and very good harmonic suppression (-30 dBc). Rugged and reliable, featuring the MRF6V2300NBR1 LDMOS transistor from Freescale™ Semiconductor, it operates from -10° to +60°C. The typical gain (21 dB) allows the system designer to supply only 4.5 W input power (at 550 W P_{out}), eliminating one or more gain stages to save cost. The FM550-108 is ideal for FM transmitter, transposer and broadcast exciter designs. Connectorized versions are available upon request.

Richardson Electronics,
(800) 737-6937,
www.rfwireless.rell.com/amplifiers.asp.

RS No. 236

Passive Components

Triple Band Bandpass Filter

The model SPCL-00192 is a Joint Tactical Information Distribution System (JTIDS)/Multi-fuctional Information Distribution System (MIDS) Triple Band Bandpass Filter designed with in-house software CKTTOOL by dividing the 962 to 1215 MHz passband into three independent bands. For high Q (low loss) and high power handling, the solution of choice is TEM (combline) resonators. The result is a temperature-stable array of magnetically-coupled resonators in a relatively small package, measuring only 1.5" x 1.75" x 6.1" (excluding connectors).

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

RS No. 237

GPS L2 Ceramic Filter

LCW offers DR-1227/50, a ceramic filter that covers the GPS L2 frequency of 1227.6 MHz. The filter exhibits less than 3.5 dB of insertion loss across the passband of 1202 to 1252 MHz, while providing greater than 50 dB of rejection at 1127 and 1327 MHz. The unit measures approximately 1.00" x 0.45" x 0.25" and is available from stock.

Lorch Commercial and Wireless,
Salisbury, MD (410) 860-5100,
www.lorch.com.

RS No. 238

Wideband Bandpass Filter

The 11AS-2/6.16G-11 is a wideband bandpass filter that offers a passband of 2 to 6.16 GHz. Featuring loss of 1 dB and rejection in excess of 60 dB, this tiny unit is perfect for portable or "hi-rel" applications. Reactel manufactures many different varieties of filters; please contact them with your specific need.

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

RS No. 239

Two-way Power Divider

Model D5674 is a high power combiner/divider designed specifically for multi-octave, commercial and military solid-state amplifier applications. This model is available with full 0.01 to 250 MHz bandwidth, at a power level of 100 W CW. The model D5674 measures 7.38" x 6" x 3.17", with an insertion loss of 1.5 dB, VSWR of 1.4:1 and isolation of 18 dB.

Werlatone Inc.,
Brewster, NY (845) 279-6187,
www.werlatone.com.

RS No. 241

Low Pass Filters

RLC Electronics now offers 4th order tubular Bessel low pass filters with 3 dB cutoffs from 1 to 22

GHz. Computer design and tubular construction allow RLC to maintain excellent group delay characteristics with reasonable rejection while extending a 3 dB cutoff approaching 30 giga bits. These filters should be regarded as compromise designs for pulsed systems where truthful reproduction of the pulse shape is important. Primarily used on lightwave receivers to reduce the impact of higher order distortion and noise. These high frequency filters are essential for today's high bit rate applications.
RLC Electronics Inc.,
Mount Kisco, NY (914) 241-1334,
www.rlcelectronics.com.

RS No. 240

Systems

Military Communications Terminal

The MTT2450 terminal supports satellite communications at C-band, X-band, Ku-band and Ka-band frequencies, as well as troposcatter Beyond-Line-of-Site link communications in the 4.4 to 5 GHz and 14.9 to 15.4 GHz bands. Terminals may be configured with common SCPC-type modems or with SkyWAN® full-mesh capability. This full-featured, trailer-mounted, military tactical terminal is HMMWV-towable. It combines a 2.4 m antenna with an on-board diesel generator, unique power distribution/protection system and environmentally protected electronics. A supervisory monitor and control system provides simplified deployment and link acquisition as well as holistic terminal control and health monitoring via remote access.
ND SatCom GmbH,
Immenstaad, Germany +49 75459390,
www.ndsatcom.com.

RS No. 221

Global Positioning Systems

The model 092-00750 is a Global Positioning System (GPS) that employs a single feed input SMA or female connector. The antenna provides hemispherical coverage at the L1/L2 bands. Model 092-00750 has a VSWR of 2.0:1, gain of 5 dBi and impedance of 50 Ohms. The 3-inch in diameter by 0.575-inch thick compact design and rugged construction make model 092-00750 extremely reliable for harsh military shipboard environments.
Cobham Defense Electronic Systems-Nurad Division,
Baltimore, MD (410) 542-1700,
www.cobhamdes.com.

RS No. 242

Test Equipment

DIN Type Calibration Kit

Manufactured using precision machining and RF characterization technologies this DIN type calibration kit contains male calibration devices (Open, Short and Load). It can be used to calibrate all kinds of commercial VNA systems from DC to 4 GHz, and offers good load characteristics, including a return loss of <- 40 dB. This high quality, high frequency component is also RoHS compliant.

GigaLane Co. Ltd.,
Gyeonggi-do, Korea +82-31-233-7325,
www.gigalane.com.

RS No. 243

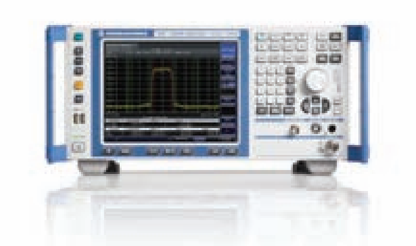
High Power Signal Generator

The KU SG 2325 100 is a high power signal generator for the frequency range of 2300 to 2500 MHz with a maximum output power of 100 W (optional 200 W). The unit provides power level adjustment in 1 W steps and can be remote controlled via an RS 232 or USB. Typical applications are electromagnetic wave propagation tests, microwave heating and electromagnetic compatibility tests.
Kuhne Electronic GmbH,
Berg, Germany 00 49 (0) 92 93-800 939,
www.kuhne-electronic.de.

RS No. 244

NEW PRODUCTS

13 and 30 GHz Instruments



The R&S FSV13 (up to 13 GHz) and the R&S FSV30 (up to 30 GHz) have been added to the R&S FSV family of combined signal and spectrum analyzers. Both models feature a convenient operating concept that includes a touch screen, an on-screen keyboard and an expanded control panel. The instruments exhibit a displayed average noise level of less than –148 dBm (1 Hz) at 13 GHz and less than –144 dBm (1 Hz) at 30 GHz as well as a third-order intercept of 15 dBm. They support all current mobile radio and wireless standards by means of software applications and an analysis bandwidth of 40 MHz makes even WLAN 802.11n achievable. For aerospace and defense sector users, the new models offer a removable hard drive and USB interfaces that can be deactivated to ensure that sensitive data from high-security areas is protected.

Rohde & Schwarz,
Munich, Germany +49 89 4129 13774,
www.rohde-schwarz.com.

RS No. 245

Transmission Line Components

Bias Tee/Diplexer

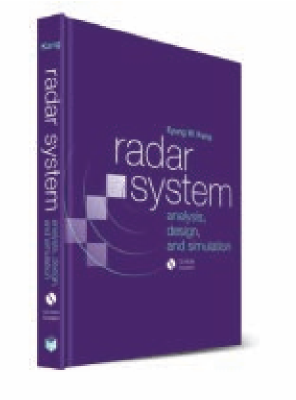
The ZABT-2R15G+ is a new bias tee/diplexer that is well suited for satellite/VSAT, LNB, BUC and modems. The ZABT-2R15G+ can be used as a bias tee or diplexer that can inject 10 MHz and DC on a L-band signal. It can also be used in the reverse direction that can strip off the DC and/or 10 MHz signal. A prime application for this model is in a satellite system where the basic architecture consists of a modem usually in the base or hub. This modem will convert IF signals to L-band (950 to 2150 MHz).

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

RS No. 235

Radar System Analysis, Design and Simulation

Eyung W. Kang



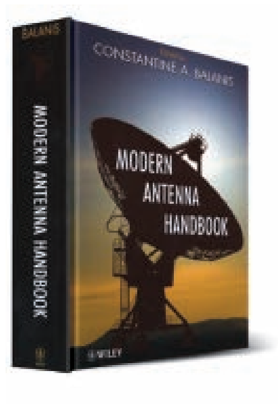
Whether you are an experienced radar engineer striving to optimize system performance or a graduate student looking to gain a practical understanding of radar system design, this authoritative volume is a smart choice. The book helps you master critical system analysis and design skills, and shows you how to use digital computer simulation to verify that an analysis is correct and that a design is optimal. This comprehensive resource covers a wide range of essential topics, from matrix, vector and linear equations, noise and clutter generation, filters (FIR and IIR), and fast Fourier transforms to ambiguity functions, antennas, target detection, and the Kalman filter to the Monte Carlo method, constant false alarm rate (CFAR) processing, and moving target indicators (MTI). Striking the right balance between depth and breadth, the book offers you a solid foundation in all the key topics covered, supporting discussions with detailed examples.

To order this book, contact:

Artech House · 685 Canton St. · Norwood, MA 02062 · (781) 769-9750 ext. 4030; or
16 Sussex St. · London SW1V 4RW, UK · +44 (0) 207-8750
280 pages; $139, £75 · ISBN: 978-1-59693-347-7

Modern Antenna Handbook

Constantine A. Balanis



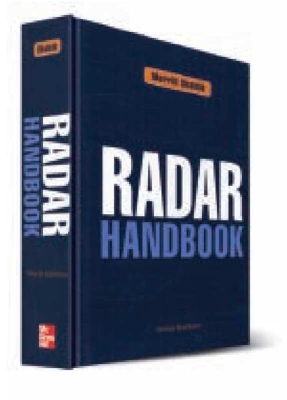
Find the most up-to-date and comprehensive treatment of classical and modern antennas and their related technologies in *Modern Antenna Handbook*. Have access to current theories and practices in the field of antennas, with topics like metamaterials, microelectromechanical systems (MEMS), frequency selective surfaces (FSS), radar cross-sections (RCS), and advanced numerical and computational methods targeted primarily for the analysis and design of antennas. Written by leading international experts, this book will help you understand recent developments in antenna-related technology and the future direction of this fast-paced field.

To order this book, contact:

John Wiley & Sons Inc. · 111 River St. · Hoboken, NJ 07030 · (201) 748-6395
1680 pages; $195 · ISBN: 978-0-470-03634-1

Radar Handbook

Merrill Skolnik



Turn to the third edition of *Radar Handbook* for state-of-the-art coverage of the entire field of radar technology from fundamentals to the newest applications. With contributions by 30 world experts, this resource examines methods for predicting radar range and explores radar subsystems such as receivers, transmitters, antennas, data processing, ECCM and pulse compression. This radar handbook also explains the target cross-section radar echoes from ground and sea, and all radar systems, including MTI, AMTI, pulse doppler and others.

To order this book, contact:

McGraw Hill · P.O. Box 182604 · Columbus, OH 43272 · (614) 759-3749
1328 pages; $165 · ISBN: 978-0-148547-0

PIN DIODE SWITCHES

FEATURES:

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

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

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Career Corner

RF Engineers: Looking Forward to 2009

Project Managers Should Be Planning Ahead Their 2009 Hiring Needs: According to a number of HR executives, typical search time for an RF engineer extends from three and up to six months in the tougher cases. Considering the diversity of related fields of expertise, we can expect to see different lead times locating qualified candidates according to the skill-sets they possess. In any case, none of them are easy or quick to find... Examples: High-power (such as HIRF) and low frequency are among examples of scarce fields of expertise, while Wi-Fi and RFID are examples of large and booming sectors pacing faster than the supply of skilled professionals.

Looking forward to 2009, although demand for RF engineers might possibly decrease somewhat, the shortage is here to stay for a while longer. Planning ahead therefore means overlaying the realistic, skill-dependent average time-to-hire over the projected needs of your project or firm. If planning on advertising, considering long-term job posting plans will be the right move.

A Note to Fellow RF Engineers: The employed engineer should also be watching the industry in his/her marketplace and location. Although somewhat reassured with the stable demand for RF engineering skills, one should consider that industry trends in his/her sector can sometimes reach very close.

Numerous applications and markets have been evolving in recent years. Combined with economical uncertainty of late 2008 it might be a good idea to consider career path: “Am I in the right industry? What will be the demand for my skills 10 years from now, and where?”

2008 Retrospective: During the year 2008 I have gained (and hopefully earned) the privilege writing this Career Column for *Microwave Journal*. The challenge in voicing out the relations and observations linking employment issues with microwave engineering technologies and skills has been an elaborating experience. Every month I found myself very keen to publish the Career Corner column.

Looking back at the headline of the first Career Column (March 2008), it stated that “employment topics should be part of the professional engineering media.” Doesn’t it seem to be even more relevant these days? In a rapidly diversifying technology, while all industries undergo extreme changes, the subtleties of engineering skill-sets and experience is what counts for one’s feasible career path and yes, his/her “market value”.

The decade-long and ongoing shortage in RF engineers (among other analog engineering sciences) at times where the country is losing jobs to offshoring is truly a sad reality. Researching before every month’s Career Corner column during 2008 I ran across numerous articles addressing this issue since the late 1990s. Unfortunately, the industry and education system have been ignoring these desperate calls throughout all those years. I am hopeful that recent realization from imaginary economies will steer back economical progress to leverage on creativity, science and technology.

It is my hope for the New Year to see the government, industry and academia jointly facing this challenge before the technological edge we have is lost as well.

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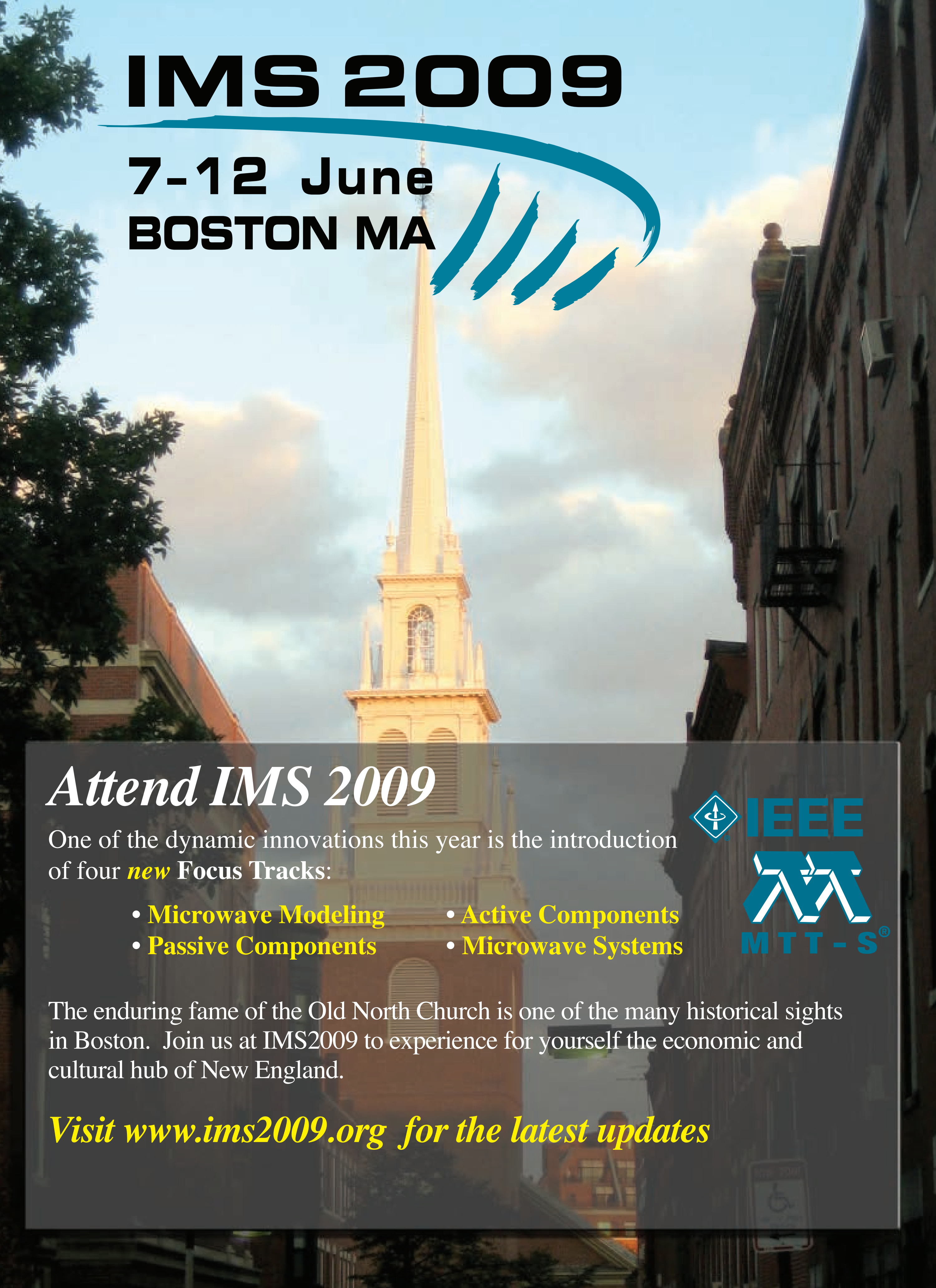
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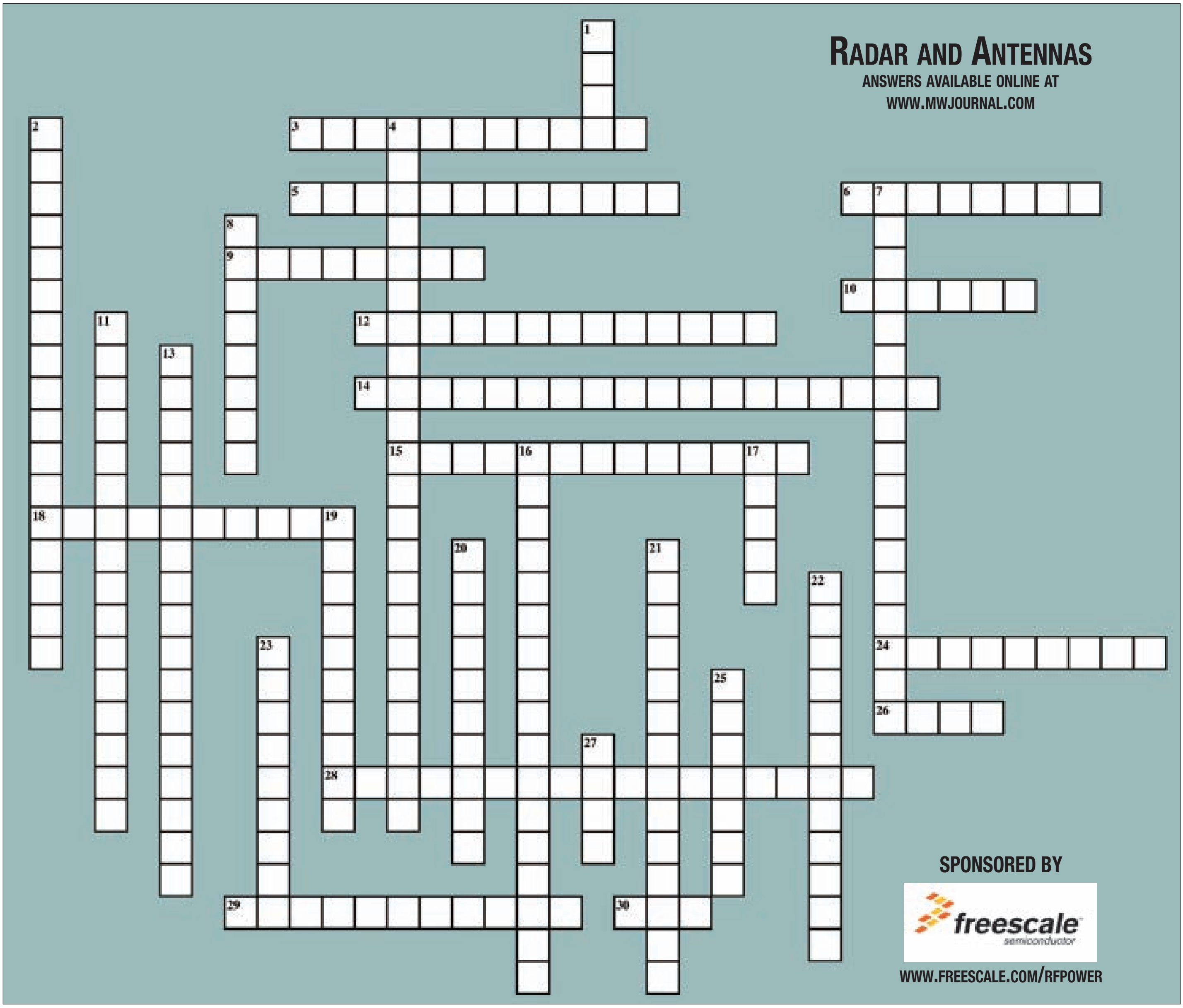

ACROSS

3 The degree to which an input signal is reduced in amplitude at the output of a circuit or device

5 A circuit that splits the power of an input signal into two or more locations without producing impedance mismatch (2 words)

6 A circuit or system that allows the ability to transmit and receive two distinct signals simultaneously

9 A three-port circulator with one of its ports terminated with its characteristic impedance

10 The frequency interval from 12.4 to 18 GHz

12 The apparent shift in frequency of an incident wave that is the result of relative velocity between the emitter of the wave and the receiver of the wave (2 words)

14 The ratio of the magnitude of a desired signal to that of noise (4 words)

15 The ratio between the amplitude of the output signal of a device or circuit compared to the amplitude of its input signal (2 words)

18 At a given point in a transmission system, the difference between the incident and reflected power (2 words)

24 The vector ratio of voltage to current, the reciprocal of admittance

26 Ratio between the amplitude of the output signal of a device or circuit compared to the amplitude of the input signal

28 A circuit or device that prevents incident high power, potentially-damaging signals from propagating to sensitive receiver components (2 words)

29 A signal processing technique used in sensor arrays for directional signal transmission or reception

30 Quadrature amplitude modulation

DOWN

1 Multiple input, multiple output

2 The ratio of the maximum magnitude of a standing wave to the minimum magnitude (3 words)

4 ELINT (2 words)

7 Magnetic linkage between physically unconnected signal paths or devices (2 words)

8 The degree to which the impedance of a component differs from the transmission line or component to which it is connected

11 The bandwidth divided by the center frequency of the band, expressed as a percentage (2 words)

13 The use of electronic signals and systems to disrupt the function of an opponent's surveillance, defense or communications systems (2 words)

16 The frequency at which the inductive and capacitive reactances of a circuit are equal in magnitude (2 words)

17 The frequency interval from 2 to 4 GHz

19 A mapping of the complex impedance plane onto a polar plot (2 words)

20 The process by which some characteristic of a carrier wave is modified in accordance with an intelligence signal

21 The state of operation in which there is no interruption of the presence of a signal (2 words)

22 The ratio of the number of bits in a data transmission that are incorrectly received to the number of bits received (3 words)

23 A system of material boundaries that direct electromagnetic energy waves

25 A structure that is intended to radiate electromagnetic waves into or collect electromagnetic energy from space

27 Quadrature phase shift key modulation