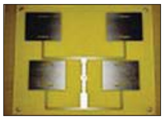
INSIDE TRACK with Dr. James Truchard, Living Legend | **32**

Enhanced Probe Stations Boost Productivity | **46**

Energy-Harvesting Antenna | **49**



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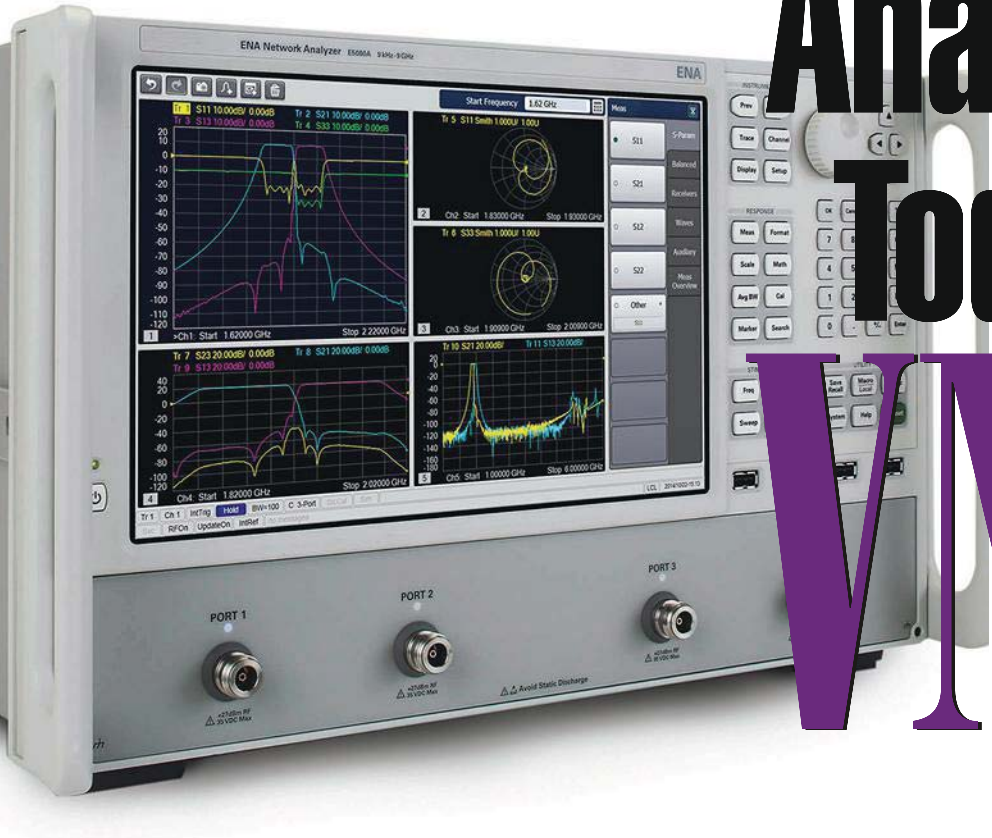
TEST & MEASUREMENT ISSUE

Analyzing Today's VNAs

p|38



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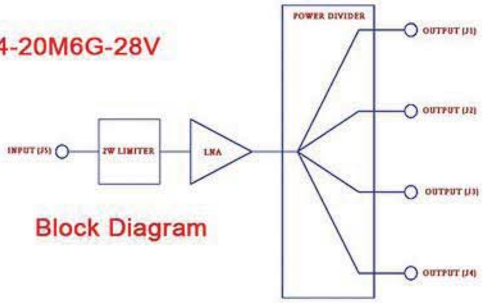

Block Diagram

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Quadport Device Balances Bandwidth, Low Noise, 3.5 dB Gain & 10 dBm Output Power

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• Output P1dB:	10 dBm (20 to 3000 MHz) typ. 9 dBm (3.0 to 6.0 GHz) typ.
• Input Power:	33 dBm max (survival)
• Power Supply:	+28V @ +75 mA typ.
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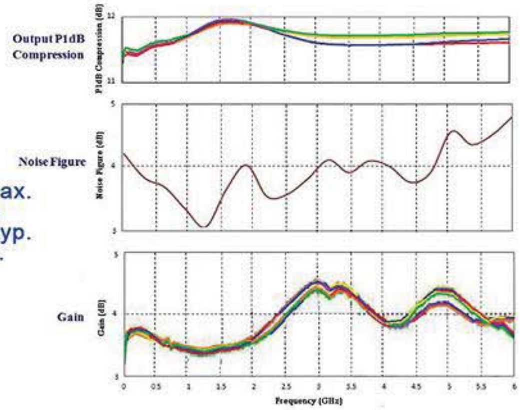

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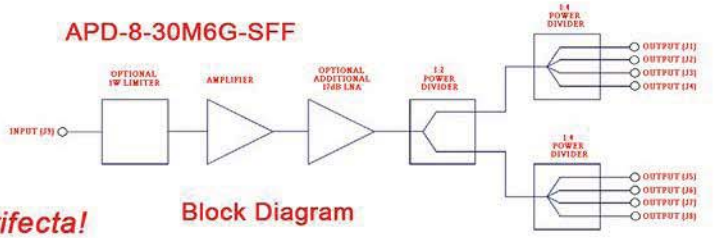

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Block Diagram

Octaport Device Balances Low Loss, Flat Frequency Response & High Reverse Isolation

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• Insertion Loss:	4 dB min. 6 dB nominal 8 dB max.
• Loss Flatness:	±1.0 dB typ.
• Noise Figure:	6.5 dB typ.
• VSWR (In/Out):	2.0:1 max.
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• Input Power:	+10 dBm (+30 dBm Optional)
• Connectors In/Out:	SMA(F)
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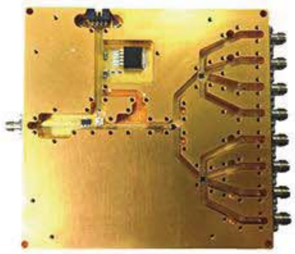

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VOLUME 54, ISSUE 7

In This Issue

FEATURES

38 **COVER STORY:**
NETWORK ANALYZERS TARGET PRODUCTION TESTING
Network analyzers are reaching new performance levels, enabling greater throughput for high-volume manufacturing.

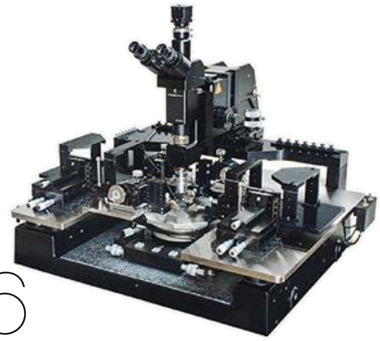
46 PROBING SOLUTIONS ENHANCE PRODUCTIVITY
Probe stations and their software applications must satisfy demanding test requirements. Performance enhancements provide a multitude of benefits.

49 ENERGY-HARVESTING ANTENNA AIDS WIRELESS SENSORS
A compact antenna with an integrated rectifying circuit was simulated and fabricated for converting RF energy to dc voltage at ISM band frequencies.

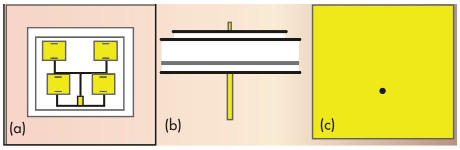
56 MAKING THE MOST OF ULTRANARROWBAND MODULATION
Ultranarrowband modulation provides the promise of effective communications—with the proper filtering.

60 SCRUTINIZE THE SPECS TO IDENTIFY THE RIGHT SWITCH
Selecting an RF/microwave switch requires understanding an application's needs and sorting through different switch types with different performance levels.

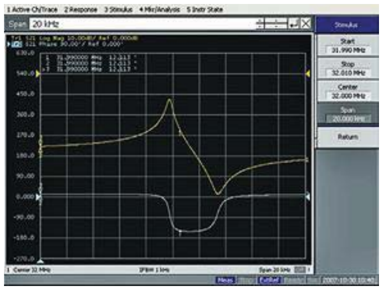
38



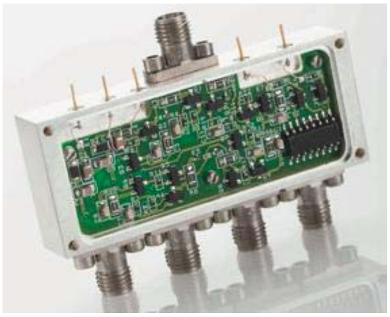
46



49



56



60

68

INDUSTRY TRENDS & ANALYSIS

42 **RF ESSENTIALS**
Mixers

68 **IMS SHOW WRAP-UP**
Product Trends

PRODUCT TECHNOLOGY

64 **PRODUCT FEATURE**
Channel Power Monitor

70 **PRODUCT FEATURE**
Synthesizer Modules

72 **PRODUCT FEATURE**
USB Sensors

74 **PRODUCT BRIEFS**

NEWS & COLUMNS

11 ONLINE CONTENTS
13 EDITORIAL
18 FEEDBACK
20 NEWS
28 COMPANY NEWS
32 INSIDE TRACK
with Dr. James Truchard, winner ofMicrowave & RF's Living Legend award

34 R&D ROUNDUP
62 APPLICATION NOTES
76 ADVERTISER'S INDEX
78 NEW PRODUCTS

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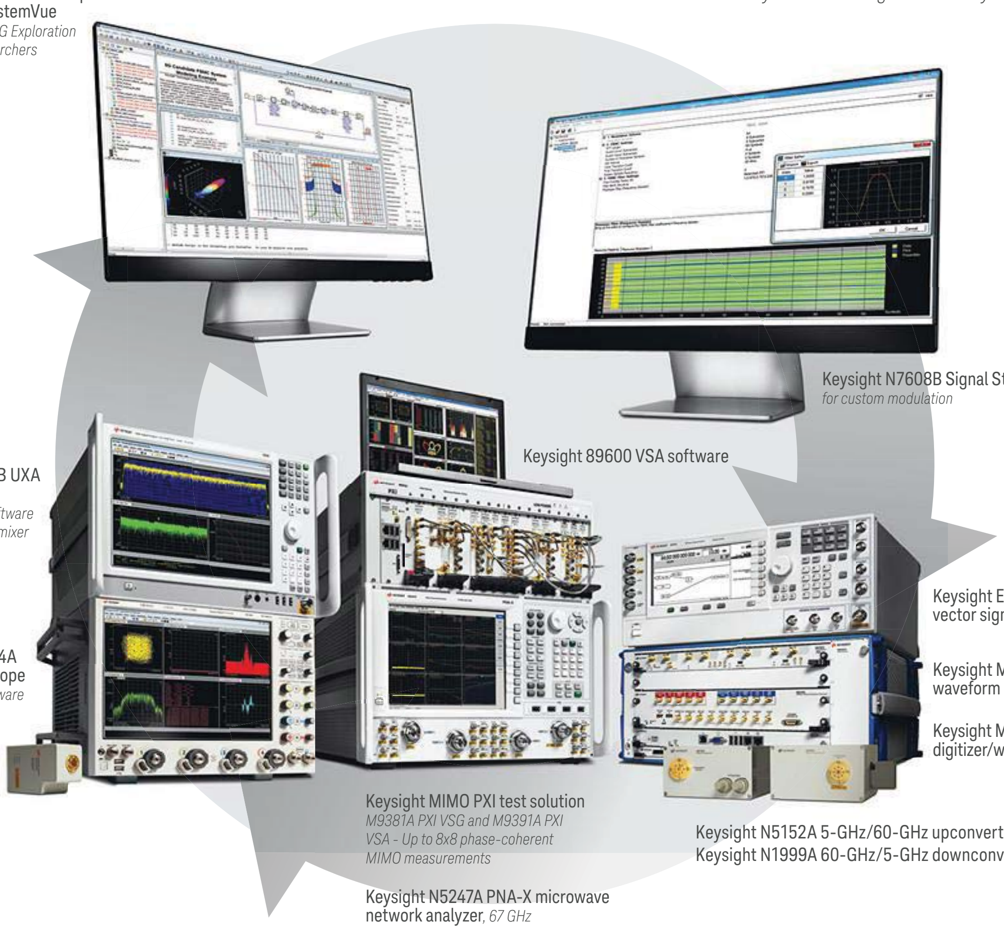

Unlocking Measurement Insights

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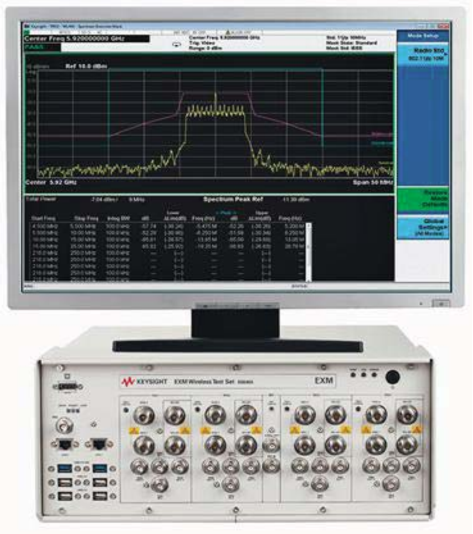
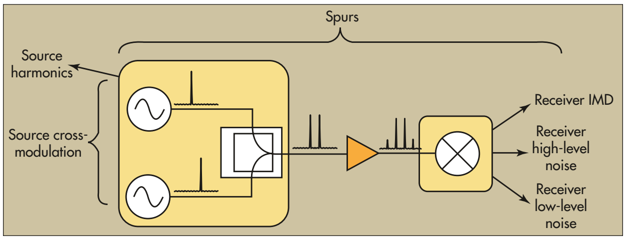


IoT WIRELESS CONVERGENCE SPARKS TESTING CHALLENGES

http://mwrf.com/systems/iot-wireless-convergence-sparks-testing-challenges

The wireless technologies enabling the Internet of Things (IoT) and machine-to-machine (M2M) devices have customized requirements and performance criteria for each application. In turn, devices based on these wireless technologies must be characterized, compliance-tested, and checked for quality before reaching an end user. This level of testing requires highly flexible and customizable test systems that can facilitate automation and cost-effective upgrades.



STRATEGIES FOR MEASURING COMMON SIGNAL-CORRUPTING DISTORTIONS

http://mwrf.com/test-measurement-analyzers/top-methods-measuring-5-common-signal-corrupting-distortions

The intrinsic imperfections of devices and the materials that comprise them lead to non-ideal electrical relationships. Nonlinear relationships among power, current, voltage, and phase cause complex responses, which are generally difficult to model. Anything from poorly connected metal structures to internal material properties can induce such relationships. Ultimately, these nonlinear effects limit component/device performance.

ANTENNAS GET NO RESPECT

http://mwrf.com/blog/antennas-get-no-respect

You can't have a successful wireless product without a good antenna. Of course, you already know that: You must have that small bent piece of metal to connect your radio to the ether or nothing will happen. And yet, in spite of its importance, it seems like the antenna always is regarded as the stepchild of any wireless system.

6 TRENDS DRIVING TRANSCEIVER DESIGN AND DEVELOPMENT

http://mwrf.com/components/6-trends-driving-transceiver-design-and-development

When it comes to transceivers, the RF communications landscape is always changing, ranging from the seemingly constant turmoil in the commercial cellular market to the somewhat more sedate—yet accelerating—rate of change in the military world. Here are six trends, in no particular order, that are projected to drive changes in transceiver design and development over the next five years.

REFERENCES & TOOLS

http://mwrf.com/references-tools

Visit our online References & Tools section to quickly and easily download tables covering topics such as Connector Frequency, which include Coaxial and Waveguide; Frequency Nomenclature: Kilohertz to Terahertz; Frequency Spectrum & Allocations; and Wireless Coexistence: From 300 MHz to 6 GHz.

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Editorial

CHRIS DeMARTINO
Technical Editor
chris.demartino@penton.com

Looking Ahead to 5G

As interest in 5G wireless technology continues to increase, the International Telecommunication Union (ITU) has chosen a formal name for the upcoming next-generation cellular system. IMT-2020 is now the official name for the 5G standard, following in the footsteps of IMT-2000 (3G) and IMT-Advanced (4G). The ITU also established a timeline for the development of 5G for the next five years, expecting it to be completed in 2020.

The news from the ITU proves that the plan for 5G to become a reality by 2020 is coming together. However, many of the remaining details in regards to 5G are still open to speculation. Technical performance requirements still need to be established.

Although the details of 5G haven't been decided, speculation is growing that data speeds will be as fast as 20 Gb/s. With the significantly faster data speeds provided by 5G, people will be able to download a full-length HD movie in a matter of seconds. In addition to data speed, 5G provides other benefits. It will offer significantly lower latency than 4G networks. And with the emergence of the Internet of Things (IoT), a network will be needed that can accommodate billions of connected devices. 5G aims to deliver that capacity as well as the capability to assign bandwidth depending on user and application needs.

With all of this being said, there are numerous reasons to be eager for 5G. Many of the possibilities with 5G don't even seem believable now. At this year's Mobile World Congress (MWC), it was demonstrated how 5G could be used to control heavy machinery from a remote location—just one of potential possibilities afforded by 5G. A demonstration of 5G technology is expected to take place at the 2018 Winter Olympics in PyeongChang, South Korea.

With the anticipation surrounding 5G, many efforts focusing on 5G technology are already underway. National Instruments, for example, is collaborating with top researchers to focus on 5G. Because massive multiple-input multiple-output (MIMO) is a candidate for 5G technology, National Instruments and researchers from Lund University have developed a massive MIMO system in an effort to further 5G research. Keysight Technologies also introduced a flexible testbed for 5G waveform generation and analysis.

These are just some examples of the current activity that will bring 5G from theory to reality. It will be extremely interesting to watch the latest 5G developments unfold before us. Although it may seem far away, the next generation will be here sooner than we all think. mw

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IMS OMISSIONS

Your June 3 article reviewing the CAE software available at the IMS 2015 in Phoenix ("Sorting Through Computer Engineering Software" on mwrf.com) was informative, but sadly incomplete. You neglected to mention newFASANT in Booth 108, Aurora Software in Booth 1039, Altair Engineering in Booth 1729, and others. It is important to not neglect any companies when writing a review article, since you are not providing your readers with an unbiased and impartial overview of CEM software products and their capabilities to solve engineering problems. I would strongly urge you to rectify this omission in the next few weeks to keep your readers informed of every software product, and not a select few.

Dr. Scott Best
Chief Technology Officer
SiberSci, LLC

EDITOR'S NOTE

Thank you for your note. For the very reasons you state, that articles tend to be short and limited to how much information they can contain. We have compiled an IMS wrap-up article featuring more information about the products that were displayed at the show. It can be found on p. 68.

IMS RECOGNITION

I just wanted to drop a line over to you and let you know I enjoyed reading your comments on the IMS show in the May issue of *Microwaves & RF*. I thoroughly enjoy the show each year and have been in attendance for the last five years, now. It is great to get another perspective on the show. Thanks for the interesting write-up. You have a lot of good points.

Jonathan Harris
Product Applications Engineer
Analog Devices

EDITOR'S NOTE

Thanks for taking the time to write and share your thoughts. I try to give opinions and ideas that I think might help someone, and not just write an opinion in those editorials. I am just glad that there are folks out there like yourself who can get something out of it and the magazine. Your reading it makes all the work I do worthwhile, and I thank you.

Jack Browne
Technical Contributor

Microwaves & RF welcomes mail from its readers. The magazine reserves the right to edit letters appearing in "Feedback." Address letters to:

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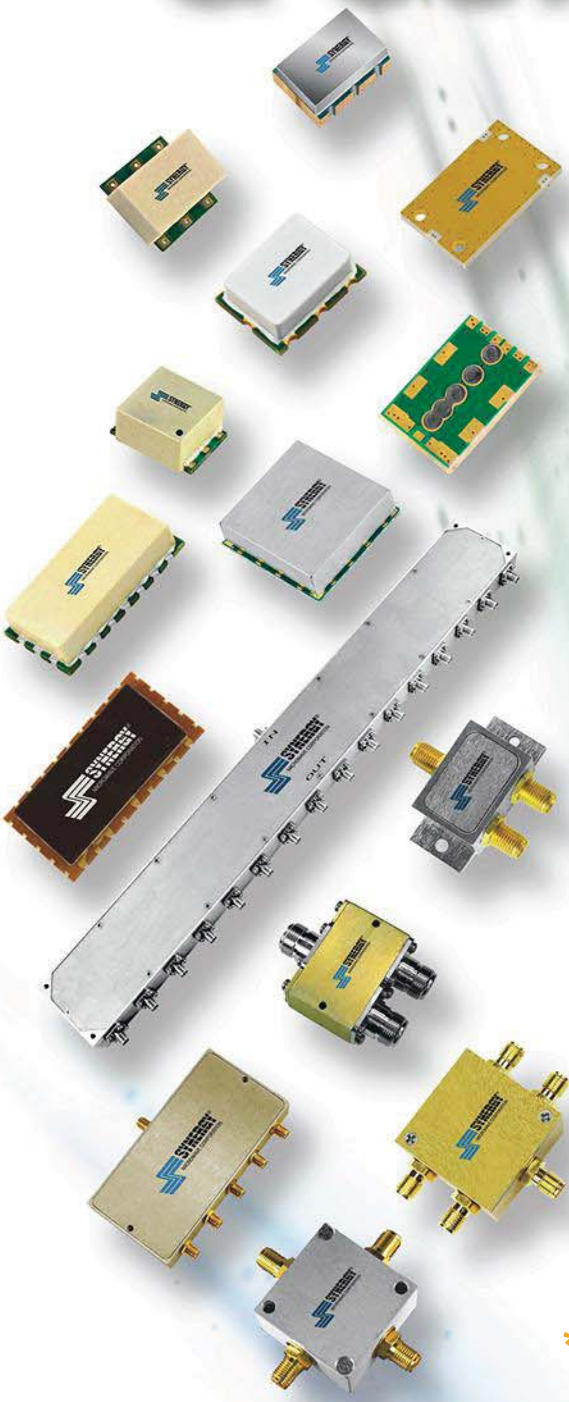


News

MUOS-3 SATELLITE
Approved for Operation in Military Communication Network

The third satellite in the Mobile User Objective System (MUOS) has been approved for operation by the U.S. Navy after a series of in-orbit tests were completed on June 1. Manufactured by Lockheed Martin and launched on Jan. 20, the MUOS-3 satellite is currently being relocated to its operational orbit slot.

This satellite is the latest addition to a network of orbiting satellites and relay ground stations that is expected to provide near global coverage by the end of the year. The MUOS network is a narrowband tactical satellite communications system designed to improve operational availability for highly mobile military users on the ground. Operational MUOS terminals will have communications capability over existing systems, including simultaneous voice, video, and mission data on a high-speed Internet protocol system.

"This latest satellite will expand the MUOS network's coverage over more than three-quarters of the globe, including significantly more coverage north and south than the current legacy voice-only system," said Iris Bombelyn, Lockheed Martin's vice president for narrowband communications.

Providing capabilities similar to smartphones, the MUOS system will replace the current Ultra-High Frequency Follow-On (UFO) communications system. MUOS satellites feature a Wideband Code Division Multiple Access (WCDMA) payload that provides 16 times more transmission throughput than the current Ultra High Frequency (UHF) satellite system.

MUOS-4 will follow MUOS-3 as the next satellite to join the U.S. Navy's MUOS communications network later this year. It's in final assembly and testing at Lockheed Martin's satellite manufacturing facility in Sunnyvale, Calif. MUOS-3 launched in January. *(Image courtesy of Lockheed Martin)*

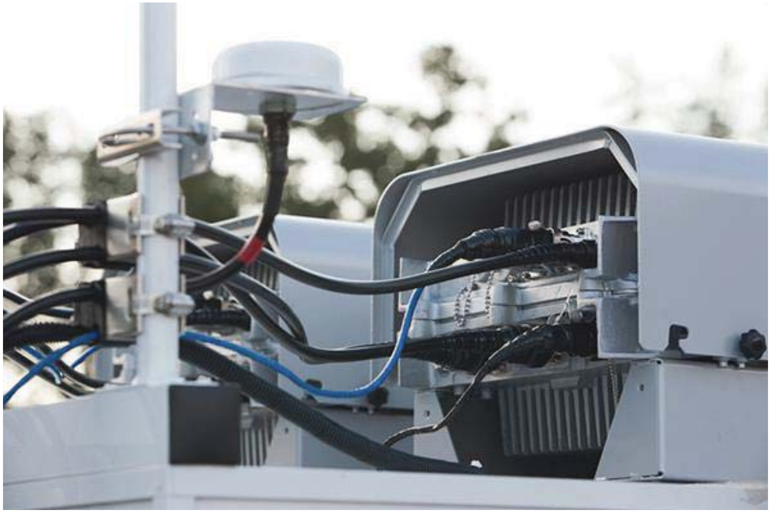
In addition, each MUOS satellite includes a legacy UHF payload that is fully compatible with the current UHF Follow-on system and legacy terminals. This dual-payload design, when coupled with support on the ultra-high frequency band, helps to ensure that there's a smooth transition from the outdated UFO system.

Lockheed Martin is under contract to deliver five satellites and the four associated ground stations for the MUOS network. The last ground station was handed over to the Navy in February and the fourth satellite, MUOS-4, is expected to launch later this year. The MUOS-1 was launched in 2012, and the MUOS-2 was launched a year later. Both are already fully operational. ■

LTE NODES SHOW Long-Range Communications Promise

LONG-TERM-EVOLUTION (LTE) TECHNOLOGY continues to find non-smartphone applications, as demonstrated by General Dynamics in recent testing. Supported by the Public Safety Communications Research Program (PSCR), the General Dynamics Mission Systems team tested the high-sensitivity Band Class 14 eNodeB for long-range LTE communications. Used in combination with vehicle-mounted modems, the eNodeB successfully operated at ranges up to 67 miles.

This technology has the potential to help emergency first responders in rural areas and provide critical information in areas where a network infrastructure is not fully built out. During the test, the equipment operated at two power levels: a standard 23-dBm modem and a 31-dBm vehicle modem. Such long-range communications are an integral part of FirstNet's National Public Safety Broadband Network,



General Dynamics Mission Systems and the Public Safety Communications Research Program recently completed long-range communications testing of the Band Class 14 eNodeB. (Image courtesy of General Dynamics Mission Systems)

which decreases operations expense and provides more coverage and capabilities for public safety users.

The testing is part of PSCR's Phase 2 boomer-cell testing, which builds upon Phase 1 and the demonstration range of Band Class 14 LTE. PSCR is a joint program from the National Telecommunications and Information Administration's (NTIA) Institute for Telecommunications Sciences and the National Institute of Standards and Technology's (NIST) Communications Technology Laboratory. General Dynamics Mission Systems continues to work in concert with PSCR to demonstrate technical interoperability. ■

HETNET INFRASTRUCTURE EXPECTED to Replace Many Macrocell Networks

DRIVEN BY THE GROWING INFLUX of mobile broadband traffic and increased network coverage requirements, wireless carriers are looking to move away from traditional macrocell-based networks. According to a recent SNS Research report, wireless carriers have instead begun to invest in a heterogeneous network (HetNet) infrastructure. The report is predicting that macrocell alternatives will account for over 80% of all mobile broadband traffic by 2020.

Annual spending in the HetNet ecosystem is expected to reach $40 billion in the next five years. This is due in large part to the open-source nature of current macrocell alternatives. A heterogeneous network is defined as a patchwork quilt of wireless coverage that incorporates a multitude of access technologies. Among these are strategically deployed small cells, carrier Wi-Fi, and distributed antenna systems (DASs). Usually installed in small buildings and public areas, these networks are designed for specific coverage and capacity requirements.

As opposed to macrocell networks, which depend on a series of large cellular base stations that often interfere with each other, the systems in a HetNet interact to extend wireless coverage over a large area. They can support a number of wireless vendors and technologies in the same place and at the same time.

This open-source paradigm has led to a Long Term Evolution (LTE) proposal for the 5-GHz unlicensed spectrum or LTE-U network. Originally developed by Qualcomm, this proposal seeks to introduce an alternative to carrier Wi-Fi by leveraging small-cell networks and carrier aggregation. Both are intended to increase user rates over the wireless coverage area. Between 2016 and 2020,

Wireless carriers today are less interested in the networks generated by large cellular base station arrays. Heterogeneous networks are now becoming a dominant force in the wireless industry. *(Image courtesy of ThinkStock.)*

LTE-U small cell shipments are expected to grow to nearly $2 billion annually, according to the SNS Research report.

As wireless carriers begin to move toward these networks, their investments will also benefit the growth of Centralized-RAN, or C-RAN, architecture. This network connects a large number of distributed radio receivers to a centralized baseband unit (BBU) pool, ultimately providing high bandwidth and low-latency communications.

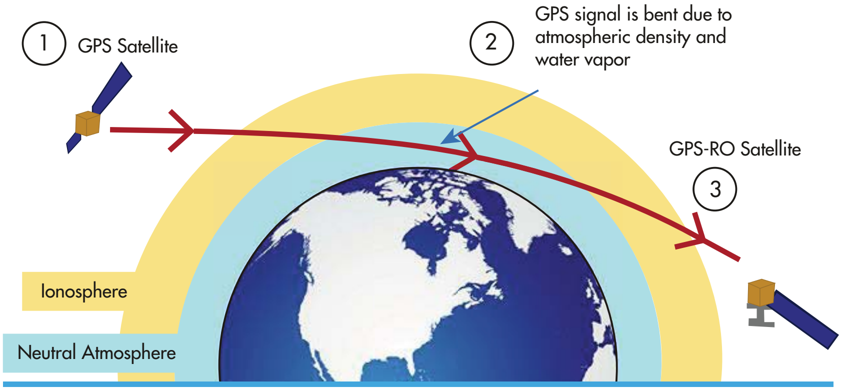
Until recently, the C-RAN architecture was used only to connect large cellular base stations, but several vendors have started to offer a small-cell C-RAN deployment. Airvana, for instance, recently installed a small-cell C-RAN system in Gross Coliseum at Fort Hays State University in Kansas. Optimistic that this growth will continue to the end of the decade, the SNS report is predicting that C-RAN investments will account for nearly 35% of the wireless market by 2020.

The shift to a HetNet infrastructure will be a volatile one. The market is expected to be highly fragmented in the early stages of this transition, as macrocell vendors attempt to muscle into the market with small-cell specialists. SNS Research speculates that a string of acquisitions by large companies, such as Nokia, will consolidate the value chain. ■

NEXT-GEN WEATHER SENSOR Reaches Lowest Atmosphere Layers

A NEWLY INTRODUCED weather instrument uses next-generation sensor technology to penetrate through clouds and storms, producing the highly calibrated data required to improve weather forecasting, climate monitoring, and space weather prediction. The Pyxis instrument from PlanetiQ tracks GPS signals traveling through Earth's atmosphere, concentrating them into dense, precise measurements of global temperature, pressure, and water vapor.

This is accomplished through GPS Radio Occultation (GPS-RO), which is similar to how data is collected via weather balloons, but on a global scale. Pyxis is reportedly the only GPS-RO sensor in such a small package that is powerful enough to routinely probe down into the lowest layers of the atmosphere, which also experience the most severe weather. In addition, it can track signals from the four most major satellite navigation systems: GPS, Galileo, Beidou, and GLONASS.



PlanetiQ's Pyxis weather instrument leverages next-generation sensor technology to penetrate through clouds and storms, producing the highly calibrated data required to improve weather forecasting, climate monitoring, and space weather prediction.

PlanetiQ's impending microsatellite constellation—an initial set of 12 will launch in 2016 and 2017—is set to deliver more than 8 million observations per day of temperature, pressure, and water vapor. This will provide approximately 10 times the amount of data available from currently on-orbit GPS-RO sensors. GPS-RO, specifically, has shown the highest impact per observation on forecast accuracy, making it particularly effective at improving predictions of high-impact weather. ■

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	RUDAT-6000-30	0-30 dB	±0.4 dB	0.25 dB	✓	-	✓	$395
	RCDAT-6000-30	0-30 dB	±0.4 dB	0.25 dB	✓	✓	-	$495
	RUDAT-6000-60	0-60 dB	±0.3 dB	0.25 dB	✓	-	✓	$625
	RCDAT-6000-60	0-60 dB	±0.3 dB	0.25 dB	✓	✓	-	$725
	RUDAT-6000-90	0-90 dB	±0.4 dB	0.25 dB	✓	-	✓	$695
	RCDAT-6000-90	0-90 dB	±0.4 dB	0.25 dB	✓	✓	-	$795
NEW	RUDAT-6000-110	0-110 dB	±0.45 dB	0.25 dB	✓	-	✓	$895
NEW	RCDAT-6000-110	0-110 dB	±0.45 dB	0.25 dB	✓	✓	-	$995
NEW	RUDAT-4000-120	0-120 dB	±0.5 dB	0.25 dB	✓	-	✓	$895
NEW	RCDAT-4000-120	0-120 dB	±0.5 dB	0.25 dB	✓	✓	-	$995

*120 dB models specified from 1-4000 MHz.
†No drivers required. DLL objects provided for 32/64-bit Windows® and Linux® environments using ActiveX® and .NET® frameworks.

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HIGH-MOBILITY MILITARY NETWORK Given the Go-Ahead for Full-Scale Production

THE U.S. ARMY has approved the Warfighter Information Network-Tactical (WIN-T) Increment 2 system, the latest technology in a growing network of highly mobile communications, for full-scale production and fielding through 2028. Designed and built by General Dynamics, the WIN-T Increment 2 system will provide soldiers on the ground with voice and data communications without the need for stationary command posts.

A Mine Resistant Ambush Protected (MRAP) vehicle is equipped with the U.S. Army's new mobile network, WIN-T Increment II. *(Image courtesy of General Dynamics)*

As the second phase of a three-pronged communications program, the WIN-T Increment 2 system is designed to support a highly mobile, self-forming network that can be relocated even as fixed infrastructure is removed. The WIN-T Increment 2 system will be installed onto mine-resistant and high-mobility vehicles. As a result, the network can move throughout the battlefield with no need to set up communications in a hostile environment. In general, it provides a major upgrade to the stationary WIN-T Increment 1 system, which had to be deployed on trailers and parked at strategic points on the battlefield.

Since it was introduced to the 10th Mountain Division in Afghanistan in 2013, four division headquarters and 12 brigade combat teams have been deployed with the WIN-T Increment 2 system. As the United States begins plans to remove ground forces from Afghanistan over the next several years, the WIN-T Increment 2 system could be deployed to help those forces transition from a fixed infrastructure.

The WIN-T Increment 3 system is the research and development component of the program. It will continue to improve the network so that it can function over a wider area, in more isolated regions, and in non-combat situations. ■

WIRELESS CHARGING GROUPS Merge to Build Industry Momentum

IN AN EFFORT to accelerate growth in the wireless charging industry, non-profit consortiums Alliance for Wireless Power (A4WP) and Power Matters Alliance (PMA) have signed a merger agreement. The new organization, to be renamed later this year, is supported by over 170 member companies in the global technology industry. These include board members AT&T, Broadcom, Qualcomm, Samsung Electronics, Procter & Gamble, and others. This lev-

el of support from the technology industry could result in a new wireless-power standard that works with all different kinds of products from a variety of manufacturers.

Before the merger agreement, both organizations had supported inductive and magnetic resonance standards for wireless-charging stations. These systems use inductive coupling between coils of wire to transfer power over short distances from a charging device to a wireless product. Because of their similar approaches to wireless charging, the organization is expected to introduce a new standard for use in consumer products, ranging from smartphones and computers to kitchen appliances and automobiles.

The wireless-power industry continues to face the challenge of convincing the public that this technology isn't limited to fixed charging stations and can provide an array of solutions for multiple industries. Ron Resnick, president of Power Matters Alliance, notes that the organization is still focused on engaging consumer interest.

Both organizations have retained key contributors within the technical, testing and certification, regulatory, and marketing divisions. This includes Kamil Grajski, president of the Alliance for Wireless Power, who will remain in an executive position as chairman. ■

PEOPLE

PASTERNACK ENTERPRISES—Appointed Bruce Yolken as the company's quality assurance manager. Yolken joins Pasternack with more than 30 years of quality assurance experience in the aerospace and defense sector.

NORTHROP GRUMMAN CORP.—Appointed Douglas A. Lawton vice president, Engineering Manufacturing and Logistics (EM&L) for two intelligence, surveillance, and reconnaissance (ISR)-related divisions at its Linthicum-based Electronic Systems sector.

RFMW LTD.—Announced that Mark Millhollin was hired as a supplier business manager. Millhollin will be responsible for developing and implementing strategic business plans for various suppliers on the RFMW line card.

OSSIA INC.—Made a pair of senior appointments to its leadership team. Dr. Ron Khormaei has been named vice president of engineering, and Dr. Siamak Ebadi has been named senior lead RF engineer.

CRANE AEROSPACE & ELECTRONICS—Named Mike Clark vice president of Microwave Components & Integrated Assemblies. In this role, Clark will be responsible for driving customer satisfaction and continued growth, as well as strategic direction of the business. ■

CONTRACTS

> **MOHR** Earns More with Navy Deal
>
> **COLOMBIA** Modernizes with R&S

MOHR Test and Measurement LLC (MOHR) —Won a five-year contract award from the U.S. Navy to supply high-resolution portable TDR cable testers. The contract is worth an estimated $5.3 million at commercial pricing. The Naval Supply Systems Command (NAVSUP) selected MOHR's new upgraded CT100 TDR, which features a new multicore CPU and unique collection of time and frequency domain analysis tools, for its General Purpose Electronic Test Equipment (GPETE) program. The CT100 TDR will be used to support shipboard, submarine, shore, and Marine Corps cable testing applications.

Rohde & Schwarz—Has been awarded by the Colombian Special Administrative Unit of Civil Aeronautics (UAEAC) a contract to modernize the country's civilian air traffic control (ATC) system over the coming months with a target completion date of February 2016. The nationwide modernization project will put Colombia in the top rank for civil aviation safety and operational efficiency in Latin America. Rohde & Schwarz will handle the system integration of its own equipment as well as subsystems supplied by third-party companies.The contract calls for the modernization of a total of 106 radio sites, including ATC towers, remote sites, and ACCs.

Jazztel—Will install a Marvell-powered G.hn networking solution from Comtrend, a leading global provider of advanced networking solutions, to accelerate the deployment of their Fiber-To-The-Home (FTTH) network.

FRESH STARTS

Lockheed Martin—Announced that the U.S. Air Force's newest infrared surveillance and missile warning satellites will be based on the company's modernized A2100 spacecraft, an update that improves system affordability and resiliency while also adding the flexibility to use future payloads. The fifth and sixth Space Based Infrared System (SBIRS) Geosynchronous Earth Orbit (GEO) satellites will receive this advanced spacecraft technology at no additional cost to the existing fixed-price contract. In response to the Department of Defense's need for more affordable and resilient systems, the Air Force and Lockheed Martin worked to add the A2100 bus update to the 2014 SBIRS block-buy contract, which already saved the Air Force more than $1 billion. The modernized A2100 adds further affordability by using common components, streamlined manufacturing and has a flexible design that reduces the cost to incorporate future, modernized sensor suites.

Anritsu Company—Has signed a formal agreement with Electro Rent whereby Electro Rent is a preferred reseller for Anritsu test solutions throughout the United States and Canada. Under terms of the agreement, Anritsu benchtop and field instruments will be available through Electro Rent.

As part of the agreement, Electro Rent will provide customers with sales and service support through its four offices throughout North America. Electro Rent has three regional U.S. offices in Norcross, Ga.; Pearland, Texas; and Van Nuys, Calif. The company's Canadian operations are based in Mississauga, Ontario.

Cobham Wireless—Launched the TeraVM elastic test bed, a first-to-market NFV test solution, allowing network function vendors and service providers to share lab assets between facilities. This enables engineers to create virtual test pods to "stress test"network functions, reducing ownership costs by eliminating the need for multiple labs all using proprietary hardware. Network vendors, service providers and enterprises with global operations traditionally have very low utilization of test assets, typically around 20%. Using the TeraVM elastic test bed, this can be brought up to 80-90% as traffic generation resources can be dynamically reallocated to where they are needed most.

Electro Enterprises Inc. —Was named an authorized distributor of GORE Microwave/RF Assemblies, serving the military-aerospace market in North America. With Electro stocking common configurations of Gore assemblies, product can now be shipped same-day to customers in North America. Electro Enterprises, a women-owned small business, is a global distributor of interconnect, electro-mechanical, wire, cable and harness assembly products to the aerospace, commercial, and military markets.

Custom MMIC—Appointed JS Commtech as its new technical representative covering the country of Korea. JS Commtech was founded in 2006 and has an established team of technical sales professionals offering state-of-the-art components and related technologies of the RF/microwave and wireless markets.

San-tron Inc.—Appointed Digiprotech as its new sales representative in India.Digiprotech was founded in 1987 to serve high-reliability and military specifications products for serving exclusively to Indian military, defense and aerospace markets.

TRM Microwave—Announced it has transitioned to a certified woman-owned small business as of June 22, 2015. The decision to transfer the future of TRM, a trusted supplier of defense-related passive RF components, from Anthony Tirollo to current CEO Wendy Tirollo coincides with the company's 45th anniversary.

RF Industries—Has completed the acquisition of Rel-Tech Electronics, a Milford, Conn.-based manufacturer of custom cable assemblies and wiring harnesses, for a total purchase price of up to $3,1 million. The acquisition of all outstanding shares of Rel-Tech consists of $2.1 million in cash, 50,467 shares of RFI's common stock valued at $200,000 and, if certain financial targets are met over a three-year period, cash earn-out payments of up to $800,000. Privately-owned Rel-Tech had revenues of approximately $7.7 million for the calendar year 2014.

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Model	Frequency (MHz)	Gain (dB)	Pout @ Comp. 1 dB (W)	Pout @ Comp. 3 dB (W)	$ Price (Qty. 1-9)
ZVE-3W-83+	2000-8000	35	2	3	1295
ZVE-3W-183+	5900-18000	35	2	3	1295
NEW ZHL-4W-422+	500-4200	25	3	4	1570
NEW ZHL-5W-422+	500-4200	25	3	5	1670
ZHL-5W-2G+	800-2000	45	5	6	995
ZHL-10W-2G	800-2000	43	10	13	1295
• ZHL-16W-43+	1800-4000	45	13	16	1595
• ZHL-20W-13+	20-1000	50	13	20	1395
• ZHL-20W-13SW+	20-1000	50	13	20	1445
LZY-22+	0.1-200	43	16	32	1495
ZHL-30W-262+	2300-2550	50	20	32	1995
ZHL-30W-252+	700-2500	50	25	40	2995
LZY-2+	500-1000	47	32	38	2195
LZY-1+	20-512	42	40	50	1995
• ZHL-50W-52+	50-500	50	40	63	1395
• ZHL-100W-52+	50-500	50	63	79	1995
• ZHL-100W-GAN+	20-500	42	79	100	2395
ZHL-100W-13+	800-1000	50	79	100	2195
ZHL-100W-352+	3000-3500	50	100	100	3595
ZHL-100W-43+	3500-4000	50	100	100	3595
LZY-5+	0.4-5	52.5	100	100	1995

Listed performance data typical, see minicircuits.com for more details.
• Protected under U.S. Patent 7,348,854

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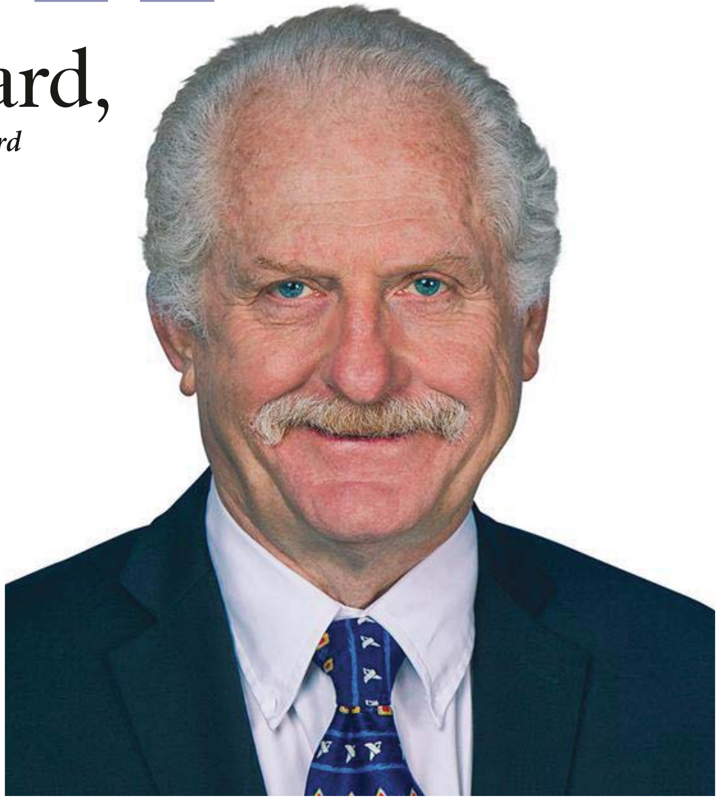
Inside TRACK with Dr. James Truchard,

Winner of Microwaves & RF*'s Living Legend award*

Interview by LOU FRENZEL Contributing Editor



LF: First things first, how does it feel to be a Living Legend?

JT: That's a great question. I think when you graduate from high school, the number of "gold stars" you receive starts to dwindle, so it's a real honor and pleasure to be recognized by *Microwaves & RF*. I truly appreciate receiving this award and it's certainly something that makes you feel like you're doing the right thing with your career.

LF: Your success is National Instruments, but what was the motivation or impetus that led you to founding the company? Give us a little background on the company itself from the beginning.

JT: National Instruments serves the science and engineering community and I view that as a highly leveraged position, because if NI can make these very important people in society more successful, we provide tremendous value to society as well. You'll see NI solutions in a wide variety of industries such as wireless communications, energy, and transportation, and I feel like NI can be more impactful by providing flexible solutions that make those scientists and engineers more productive than if we worked on each of those applications directly. So that is a big fundamental motivation of mine.

At NI, we work on all of the National Academy of Engineering's Grand Challenges through our customers, so having the ability to help these scientists and engineers solve complex problems is very rewarding. In starting the company, my goal was to be aligned with technology and be able to work with the forefront of technology, and we have certainly been able to do that.

Now, I also recognized that we had to be a good business. Because to have autonomy to do the things you want to do, you have to be a good business so that you can get that profit that allows you to have autonomy, instead of somebody else telling you what to do. So that was very much a motivation as well. I saw starting NI as an opportunity to provide good career paths for the very talented engineers and computer scientists that we have, so providing a career path with growth opportunities for both the company and the careers of my employees is very important to me.

LF: When was the company actually founded?

JT: The company was founded in 1976 and we actually moonlighted for three years until we went full time. Then we were able to effectively self-finance the company through that process.

LF: What is the one product that highlights your achievement?

JT: Our software platform with LabVIEW at the core has really been the most important thing that we have done, and this reaches out and enables our success in many areas. For example, one of our recent product launches, the LabVIEW Communications Systems Design Suite has extended our software platform into the research and prototyping of next-generation wireless communications space. As we saw at recent events like GLOBECOM and the Brooklyn 5G Wireless Summit, NI has enabled engineers to demonstrate algorithms in a fraction of the time that they used to take—In other words, show real working product designs more quickly and efficiently than ever before.

LF: What is the current focus of National Instruments? What are some of the current trends?

JT: So, at several levels—first off, a big focus for us is in the RF and communications space. Both in the design with the tools like LabVIEW Communications System Design Suite and our AWR suite of software for RF hardware design, and also with support from scientists and engineers for data acquisition. Another focus for NI has been embedded systems design, again using LabVIEW extensions in the industrial space. We have been very active in the development work of industrial applications where we have embedded solutions like CompactRIO. We did some very early work in defining what is meant in the industrial space with CompactRIO leading the way over the last decade.

LF: Your focus does seem to be in the RF and communications space. What percentage of the business is that?

JT: Well, it is growing. We don't break it out specifically, but it is one of the fastest-growing areas of opportunities for us. We have introduced breakthrough technology with the vector signal transceiver that is really redefining how measurements are made. It also can be used to prototype new algorithms. It can be used to build radar. The VST is very flexible, yet it primarily serves the test-and-measurement space. LabVIEW Communications System Design Suite is another major development on the software side that creates a highly differentiated tool that helps engineers design new systems, demonstrate algorithms, and the like.

LF: Have you done anything in the field of Internet of Things (IoT)?

JT: Yes. When consumers think of the Internet of Things, they often think about their consumer technologies like wearable devices, home automation, their mobile devices. At NI, we're more involved with the Industrial Internet of Things—developing complex, intelligent engineering systems that impact large-scale infrastructure with our hardware and software platform. NI's involvement in the Industrial Internet of Things spans from smart-grid applications to smart factories in a manufacturing setting.

LF: Somebody told me that you are still selling GPIB (General Purpose Interface Bus).

JT: That's right.

"Receiving this award is certainly something that makes you feel like you're doing the right thing with your career."

LF: It is still out there, isn't it?

JT: Well, the thing is, if you have a group of instruments, until the last one goes away, you still need that interface. And also, GPIB was a very good standard. It was parallel, it was fast, and in the early days, we actually built GPIB extenders so that we could talk to each other. So GPIB was pioneering in terms of performance and you had to go to 100M Ethernet before you got performance that rivaled GPIB. Now, with a large install base and by continuing to support GPIB, we make sure that all those instruments that are out in the field can be used. Can you imagine if nobody was doing that? How many instruments would not be useful because they couldn't be automated because they didn't have the right interface?

LF: Instruments tend to have a long life.

JT: That is exactly right. When I was in university, I was using equipment that was 40 years old. So I tell the story that there was General Radio, then there was Hewlett-Packard. And now there is National Instruments. General Radio had vacuum tubes, Hewlett-Packard had transistors, and NI has software.

LF: What advice about the future can you give readers of *Microwaves & RF*?

JT: I think that there is still a lot left to be discovered and invented, so I'd advise today's engineers to keep that positive view and remember that there is much more to come. As engineers, we will continue to make innovative technological breakthroughs that impact society and improve our quality of life.

For example, over the past decade we've seen how communications has dramatically changed how people work together, how they interact with each other, and has made us more connected than ever.

LF: And if test equipment companies such as yours don't make the test instruments, we will never be able to design the new products. So keep at it.

JT: Exactly. Thank you. mw

MODELING MULTIPLIERS THROUGH TERAHERTZ FREQUENCIES

TERAHERTZ FREQUENCY BANDS support short-range communications at high data rates. Designing transmitters and receivers at those higher frequencies requires command of the gallium arsenide (GaAs) Schottky barrier diodes that are capable of multiplying microwave signals into the THz range. Fortunately, lumped-element-equivalent-circuit (LEC) models have been developed to aid the design of planar GaAs Schottky diode frequency multipliers and mixers operating at frequencies to 3 THz.

In addition to LEC models, physics-based models have been used to simulate the carrier transport in GaAs Schottky diodes based on predictions using the Boltzmann transport equation (BTE) and Poisson's equation Another model for high-frequency circuits, the Monte Carlo (MC) model, is based on the microscopic modeling of the interactions of the Schottky charge carriers with the device's crystal lattice and external fields.

A group of researchers from the Technical University of Madrid (Madrid Spain)—Diego Pardo, Jesus Grajal, Carlos G. Perez-Moreno, and Susana Perez—performed a comparison of model predictions with measurements performed on diode multipliers designed and fabricated by the Jet Propulsion Laboratory (JPL) for frequencies from 200 to 2700 GHz.

A number of different devices were modeled. Comparison of simulations with measured results reveal that the models offer different levels of accuracy under different conditions, with the MC model shining in most cases. See "An Assessment of Available Models for the Design of Schottky-Based Multipliers Up To THz Frequencies," *IEEE Transactions on Terahertz Science and Technology*, March 2014, p. 277.

WAVEGUIDE SLOT ARRAY ANTENNA SNARES 120 GHz

AS LOWER-FREQUENCY BANDWIDTHS are consumed by communications and other applications, researchers attempt to find cost-effective methods to make use of millimeter-wave frequencies. Using the 60- and 120-GHz bands for short-range, high-data-rate communications is one such example. Dongjun Kim, Jiro Hirokawa, and Makato Ando from the Department of Electrical and Electronics Engineering of the Tokyo Institute of Technology (Tokyo, Japan), along with Jun Takeuchi and Ahihiko Hirata from the NTT Microsystem Integration Laboratory (Kanagawa, Japan), have proposed the design of a 4 × 4 element corporate-feed waveguide slot array antenna for the 120-GHz band.

This antenna achieves impressive performance levels, with gain of 21.1 dBi and efficiency of 80%. The antenna features a 1-dB-down bandwidth of 22 GHz from 118 to 140 GHz. The array antenna features two types of cavities to adjust mutual coupling effects. The outer cavities of the design provide sufficient mutual coupling to achieve effects similar to that of an infinite array.

The array antenna achieves uniform aperture distribution, while measured gain appears to be stable. See "4 × 4 Element Corporate-Feed Waveguide Slot Array Antenna with Cavities for the 120 GHz Band," *IEEE Transactions on Antennas and Propagation*, December 2013, p. 5,968.

ANTENNAS AND ARRAYS FIT ON ORGANIC SUBSTRATES

GROWTH OF APPLICATIONS in millimeter-wave frequency bands has raised the demand for compact antennas capable of handling them. Jia-Chi Samuel Chieh from Spawar Systems Center San Diego; Bing Pham and Anh-Vu Pham from the University of California at Davis; and George Kannell and Alex Pidwerbetsky from LGS Innovations from Bell Laboratory (Florham Park, N.J.) developed dual-polarized, aperture-coupled stacked patch antennas with substrate embedded air cavities for use at W-band frequencies.

The antennas were realized in a multilayer organic hybrid substrate using both Kapton and liquid crystal polymer (LCP). In particular, a single-element antenna achieved a 23-GHz bandwidth with 90-deg. beamwidth and better than 17.8-dB isolation. The researchers faced developing antennas at high frequencies with small wavelengths. Since the antenna feed is a critical part of the antenna design, the researchers explored both a general symmetric feedline and a microstrip balun.

An antenna was designed with interleaved Kapton adhesive and LCP layers, forming a substrate with embedded air cavities, with the Kapton substrate exhibiting a dielectric constant of about 3.2. Simulations were performed on the antenna design to study the effects of varying driven and parasitic patch characteristics, as well as the cavity height. Prototype low- and high-isolation antennas were constructed, and a T-junction power combiner was used to allow one-port measurements to be taken.

The simulated and measured results for the low-isolation design matched closely, with simulated isolation of better than 6-dB across the full W-band range. For higher isolation between horizontal and vertical polarizations, a differential feed was used. Better than 17 dB isolation was achieved, with a measured bandwidth of about 28 GHz from about 71 to 99 GHz. See "Millimeter-Wave Dual-Polarized High-Isolation Antennas and Arrays on Organic Substrates," *IEEE Transactions on Antennas and Propagation*, December 2013, p. 5,948.

YIG BAND REJECT FILTERS

Omniyig Model No.	Frequency Range (GHz)	Ins. Loss (dB)	Bandwidth at 40 dB (MHz)
M107RX	8.0 - 18.0	1.5	20
M104RX	4.0 - 18.0	2.0	8
M105RX	2.0 - 8.0	1.5	10

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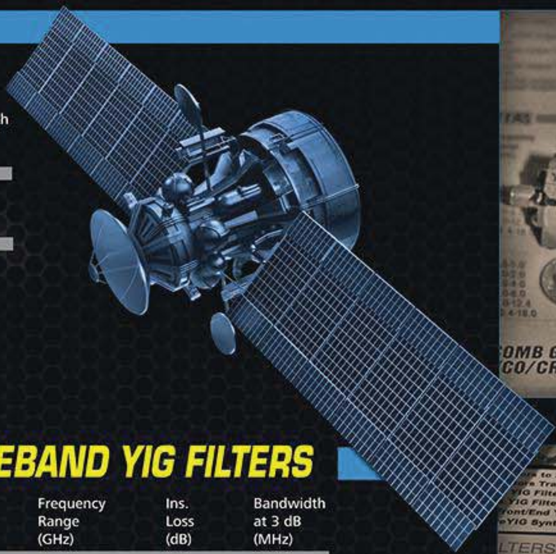

WIDEBAND YIG FILTERS

Omniyig Model No.	Frequency Range (GHz)	Ins. Loss (dB)	Bandwidth at 3 dB (MHz)
4-STAGE			
M3064	6.0 - 18.0	6.5	500 min
M2997	6.0 - 18.0	6.0	400 min
M3513	8.0 - 18.0	6.5	500 min

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STANDARD DETECTORS

Omniyig Model No.	Frequency Range (GHz)	k Factor	TSS (dBm)
Zero-Bias Schottky			
ODZ0004A	0.1 - 18.0	1200	-52
ODZ0328A	2.0 - 18.0	1200	-52
ODZ0441A	6.0 - 26.0	1000	-51

STANDARD LIMITERS

Omniyig Model No.	Frequency Range (GHz)	Insertion Loss (dB)	Leakage Power (dBm)
Pin			
OLP2645A	8.0 - 18.0	2.0	+19
OLP2726A	2.0 - 18.0	1.2	+19
PL473	0.5 - 12.0	1.8	+19
OLP2652	2.0 - 18.0	2.5	+20
Schottky Turn-on			
SL048	2.0 - 26.0	2.5	+14
OLD2635A	4.0 - 18.0	2.5	+14
OLD2733A	0.4 - 18.0	2.5	+14

Leakage Power Measured at P(in) = +30 dBm

STANDARD COMB GENERATORS

Omniyig Model No.	Input Frequency (MHz)	Output Frequency (GHz)	Output Power (dBm)
OHG10118	100	0.1 - 18.0	-40
OHG20218	20	0.2 - 18.0	-35
OHG51026	500	0.5 - 18.0	-28
OHG81026	1000	1.0 - 18.0	-18

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NETWORK ANALYZERS Target Production Testing

Network analyzers are reaching new performance levels, enabling greater throughput for high-volume manufacturing. Options are also available to equip network analyzers with increased test capability.

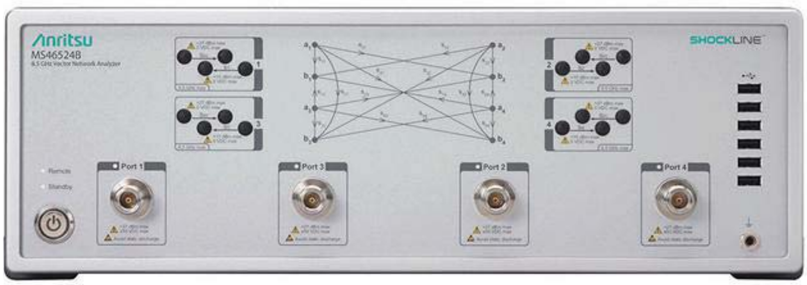
High-volume manufacturing requirements are driving the latest generation of vector network analyzers (VNAs). Mobile devices, network equipment, and data centers are being designed for commercial trends such as higher-speed mobile data. These devices need to be produced in very high volumes at low costs. Therefore, production throughput is an extremely important parameter for these applications. Recognizing today's production requirements, VNA suppliers are making an effort to deliver RF/microwave VNAs capable of increased throughput in high-volume manufacturing environments.

Anritsu's new Performance ShockLine MS46500B series of VNAs lowers the cost of test and speeds time to market in numerous testing applications to 8.5 GHz. These applications include mobile network equipment design and manufacturing, mobile devices, automotive cables, high-speed data interconnects, and system integration components.

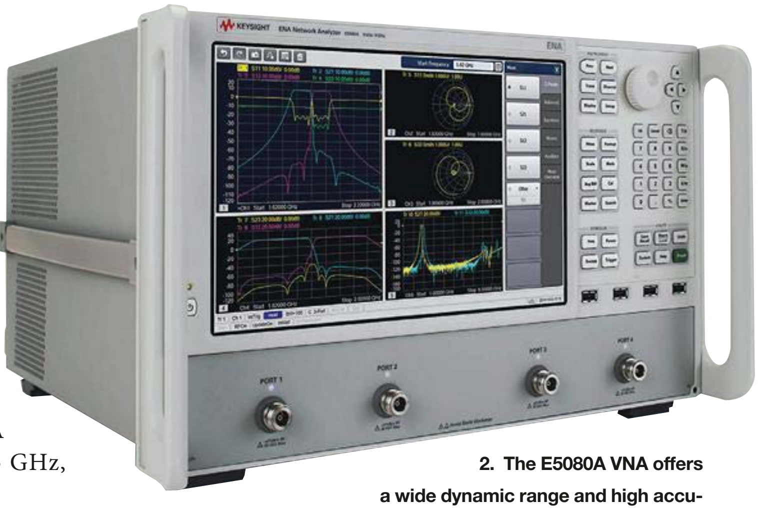
The MS46500B Series is made up of the two-port MS46522B and the four-port MS46524B models, expanding the ShockLine family to a broader range of test applications (*Fig. 1*). This series utilizes a modern architecture: The MS46522B has two independent sources and four receivers, while the MS46524B has four independent sources and eight receivers. All sources can sweep at the same time, allowing the measurement of forward and reverse S-parameters in a single sweep. Due to this unique simultaneous sweeping feature, the MS46522B is capable of making a full two-port measurement in half the time it would take to make the same measurement with a traditional single-source sweep, while the MS46524B can make a full four-port measurement in one-quarter the time of a conventional VNA. With shorter test times, the MS46500B Series significantly improves throughput in manufacturing environments.

IMPROVEMENTS IN DYNAMIC RANGE AND MEASUREMENT SPEED

Filters used in base transceiver stations (BTSs) in high-speed mobile networks have extremely steep skirts, rejecting out-of-band signals by as much as 110 dB. To accurately measure these components, a VNA with a wide dynamic range is needed. When using previous-generation VNAs, test times can be quite long when measuring devices with a wide dynamic range. Recognizing the need for VNAs to provide wide dynamic range at faster measurement speeds, suppliers have released VNAs with improved performance intended for these applications.



1. The MS46522B and MS46524B VNAs feature multiple simultaneous test-signal sources to speed swept measurements to 8.5 GHz. *(Photo courtesy of Anritsu)*



2. The E5080A VNA offers a wide dynamic range and high accuracy combined with fast measurement speed, to increase production testing throughput. *(Photo courtesy of Keysight Technologies)*

Keysight's new E5080A VNA provides improved performance compared to previous-generation models (*Fig. 2*). In comparison with the previous-generation E5071C VNA, the E5080A has 10 dB more dynamic range, with increased measurement accuracy. In addition, the likelihood of errors during manual filter tuning is reduced by the improved VNA performance. When comparing measurement speeds at the same dynamic range, the E5080A is about 10 times faster than the E5071C, enabling greater throughput to be achieved during production testing. The E5080A is available with frequency ranges of 9 kHz to 4.5 GHz, 9 kHz to 6.5 GHz, and 9 kHz to 9 GHz.

Copper Mountain Technologies recently released its Cobalt Series of VNAs, featuring models C1209 and C1220 (*Fig. 3*). The C1209 model is capable of analyzing a frequency range from 100 kHz to 9 GHz, while the C1220 model has a frequency range from 100 kHz to 20 GHz. This new series achieves fast measurement speeds by incorporating a hybrid dual-core DSP/FPGA signal processing engine along with new frequency synthesizer technologies. Dynamic range of more than 145 dB at a 1-Hz intermediate-frequency-bandwidth (IFBW) is achieved, allowing the Cobalt VNAs to maintain a wide measurement range at fast measurement speeds. This combination of wide dynamic range and fast measurement speed makes the Cobalt Series VNAs ideal for testing and tuning high-performance filters. When using 801 measurement points along with a 30-kHz IFBW, a complete S-parameter measurement of a BTS filter requires only 0.08 seconds, while maintaining more than 100 dB of measurement dynamic range.

In an effort to achieve high throughput at an attractive price, Rohde & Schwarz recently introduced a new VNA to its product line. The ZND model, which is a two-port VNA, enables users to easily measure S-parameters of components such as filters, connectors, and antennas. This VNA is intended for production environments, providing the required functionality at a low cost. The ZND offers a specified dynamic range to 120 dB, making it ideal to measure high-performance passive components. The ZND base model provides unidirectional measurements, with the option to upgrade to bidirectional measurement capability. The base model operates from 100 kHz to 4.5 GHz. The option to extend the frequency range to 8.5 GHz is also available.

The previously mentioned MS46500B Series from Anritsu also offers excellent dynamic range, low trace noise, and a fast sweep speed. This series addresses the S-parameter requirements of a complete range of passive components, including BTS filters, duplexers, and antennas.

PC-BASED VNAS

VNAs controlled by an external PC transfer all processing functions from the VNA's measurement module to an external PC, separating the measurement module from the processing module. The measurement results are brought to the external PC using software. These PC-driven VNAs offer several distinct advantages compared to VNAs with integral computers, making them ideal for many RF and microwave applications. By providing their own external PC, users can take advantage of the latest processors, better display capabilities, and the more reliable performance of an external PC, while simplifying maintenance of the VNA. In addition, the external PC can be replaced or upgraded at the user's discretion. Conventional VNAs, in contrast, already have a built-in computer, which can quickly become outdated. Thus, PC-driven VNAs offer greater flexibility by allowing users to have control of the processing module by supplying their own PC.

PC-driven VNAs also cost less than half the price of a conventional VNA, while still delivering equal or better performance. In addition, there are far fewer potential points of failure. The typical point of failure on a conventional VNA is the built-in processing module and its peripheral devices, such as the display, control knobs, and buttons. This problem is completely eliminated when using an external PC, which can be easily and inexpensively replaced by users according to their needs. Another advantage of a PC-driven VNA is external data storage. Since data is stored on the external PC rather than inside the VNA itself, the analyzer can easily be moved to different locations. A PC-driven VNA is also well suited for classified applications because test data is processed and stored on an external PC, which means there is no need for hard-drive purging in order to move the PC-driven VNA from a secure area. Maintenance time is reduced, and security improvements in classified or controlled installations are achieved.

Copper Mountain Technologies' PC-driven VNAs enable engineers to downsize their equipment, while capitalizing on the performance of PCs. A wide range of VNAs is offered, with varying features for different applications. These VNAs

3. The Cobalt series of VNAs relies on advanced signal processing to achieve wide dynamic range at fast measurement speeds to 20 GHz. *(Photo courtesy of Copper Mountain Technologies)*

have the same performance as traditional VNAs, while offering flexibility as they can be easily adapted to multiple users. This series is well suited for lab, production, field, and secure testing environments.

Anritsu's ShockLine VNA family also consists of the MS46121A and MS46122A USB Series. These series of VNAs eliminate the need to buy expensive instruments for simple S-parameter measurements. Multiple architectures are employed that reduce manufacturing costs, enhance calibration stability, and minimize measurement uncertainty. The one-port MS46121A is a series of two VNAs packaged in a compact housing, while the two-port MS46122A is a series of three VNAs packaged in a compact 1U chassis. An external PC controls these VNAs via USB connection, which runs the same graphical user interface (GUI) software as the rest of the ShockLine family of VNAs. The combination of small size and good performance makes the MS46121A and MS46122A VNAs ideal for passive device test applications where performance and small form factor are desired.

NEW ENHANCEMENTS

Suppliers are expanding the measurement capabilities offered by VNAs by introducing new options to their existing VNA products. These options serve as enhancements, enabling measurements to be performed beyond the VNA's traditional test capabilities.

Keysight recently announced a new capability, which adds high-performance spectrum analysis to its PNA and PNA-X Series VNAs. This option adds a fast spurious-signal search capability to these VNA series, replacing a standalone spectrum or signal analyzer. By replacing a standalone spectrum or signal analyzer, the size of test systems can be reduced. This spectrum analyzer option is implemented through firmware, which means no additional RF hardware is required to add spectrum analysis capability to the VNA. The incorporation of this functionality into a VNA simplifies system connections and saves time, improving test throughput by a factor ranging to 500 in comparison with existing approaches. Measurement results are comparable to those obtained with today's most sophisticated standalone spectrum or signal analyzers. This option also enables the VNA to perform simultaneous spectrum measurements on all test ports, providing unparalleled insight into the performance of a device with just a single set of connections.

Anritsu recently introduced intermodulation distortion (IMD) measurement options for its VectorStar platform, which expand the measurement capability to meet the need to conduct highly accurate and efficient IMD measurements. These options consist of a dual source, an internal RF combiner/switch, and the IMView software.The dual source and the internal RF combiner/switch enable the VNA to automatically switch from an S-parameter measurement to an IMD measurement, providing the capability to perform both S-parameter measurements and IMD measurements in one connection. The IMDView software option provides graphical interface and guidance for configuring IMD measurements, simplifying the setup of traces for IMD parameters. IMDView also offers the unique capability to modify tone parameters while viewing the results in real-time, enabling engineers to quickly determine optimum performance capabilities.

USER INTERFACE ADVANCEMENTS

Suppliers are increasing efforts to provide more intuitive user interfaces. Touchscreen features such as touch-driven trace displays and windows, as well as drag-and-drop functionality, provide a simplified user experience.

Keysight designed the E8050A's intuitive and flexible user interface to streamline flow. A variety of dialog menus assists users to easily setup measurements, while essential features can be directly accessed through the toolbar. The layout of traces and windows can be flexibly allocated with intuitive drag-and-drop operations, enabling users to overlay traces with different channel settings on the same window.

Rohde & Schwarz's ZND user interface is based on the interface of the ZNC and ZNB models. Designed to make VNA measurements easy to perform for users of all levels, the interface enables users to access all functions of the VNA in a maximum of three operating steps. In addition, the large touchscreen is fully integrated with the VNA's software. Drag-and-drop operation is incorporated, which allows users to quickly configure the VNA. Traces and channels can be arranged in any desired combination, enabling results to be displayed in a clear and straightforward manner.

Anritsu's ShockLine software provides a powerful GUI for test and engineering use. When attached to a touchscreen monitor supplied by the user, the GUI provides a full set of comprehensive capabilities. These capabilities include network extraction, embedding/de-embedding networks, and time-domain with time-gating. The GUI is a common feature among the entire ShockLine family of VNAs. mw

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CHRIS DeMARTINO | Technical Editor

Understanding Mixers and Their Parameters

Mixers remain an important part of most RF/microwave systems, prompting the need to understand this vital component and its parameters.

A MIXER IS a three-port component, which performs the task of frequency conversion. Mixers translate the frequency of an input signal to a different frequency. This functionality is vital for a wide range of applications, including military radar, satellite-communications (satcom), cellular base stations, etc. Mixers perform both upconversion and downconversion.

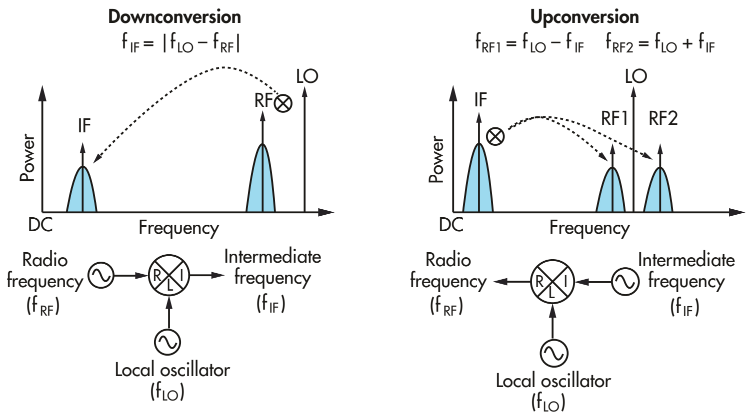
Two of a mixer's three ports serve as inputs, while the other serves as an output port. An ideal mixer produces an output that consists of the sum and difference frequencies of its two input signals. In other words:

$$f_{out} = f_{in1} \pm f_{in2}$$

The three ports of a mixer are known as the intermediate-frequency (IF), radio-frequency (RF), and local-oscillator (LO) ports. The LO port is an input port. The RF and IF ports can be used interchangeably, depending on whether the mixer is being used to perform upconversion or downconversion. The LO signal is typically the strongest signal injected into a mixer. The required LO drive level depends on several factors, including the mixer's configuration and device technology.

When a mixer is used to perform downconversion, an input signal enters the RF port and an LO signal enters the LO port. These two input signals produce an output signal at the IF port. The frequency of this output signal is equal to the difference of the RF input signal's frequency and the LO signal's frequency. When a mixer is used to perform upconversion, an input signal enters the IF port and an LO signal enters the LO port. These two input signals produce an output signal at the RF port. The frequency of this output signal is equal to the sum of the IF input signal's frequency and the LO signal's frequency.

A representation of downconversion and upconversion is shown in *Fig. 1*. Upconversion is normally part of a transmitter, while downconversion is typically used in a receiver.



1. These simple diagrams provide an illustration of frequency conversion.

MIXER PERFORMANCE PARAMETERS

A mixer's performance is determined by several different metrics. These performance metrics are specified in most mixer datasheets. The specifications, which are described below, help a system designer select an appropriate mixer to meet system requirements.

Conversion loss: In passive mixers, conversion loss is defined as the difference in signal level between the amplitude of the input signal and the amplitude of the desired output signal. In a mixer used for downconversion, the conversion loss is the difference between the RF input signal's amplitude and the IF output signal's amplitude. In a mixer used for upconversion, the conversion loss is the difference between the IF input signal's amplitude and the RF output signal's amplitude. Conversion loss is expressed as a positive number in decibels. Typical values of conversion loss can range from approximately 4.5 to 9 dB, depending on several factors. Conversion-loss values of 6 to 8 dB are common in standard double-balanced mixers, while triple-balanced mixers generally have a higher conversion loss than double-balanced mixers. It is also possible to achieve conversion gain in active mixers.

Isolation: Isolation is a measurement of the amount of power that leaks from one port to another. Isolation is defined as the difference in signal level between the amplitude of an input signal and the amplitude of the leaked power from that input signal to another port. When isolation is high, the amount of power leaked from one port to a different port is small.

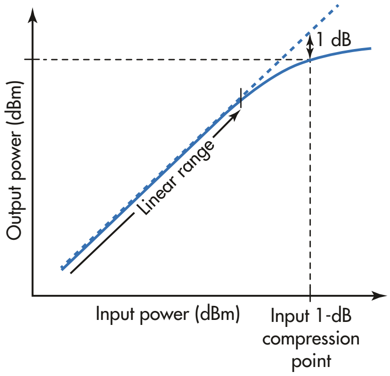
Three types of isolation are specified for most mixers: LO-RF isolation, LO-IF isolation, and RF-IF isolation. For example, if a 5-GHz signal with an amplitude of +15 dBm is injected into the LO port, a portion of this signal will leak into the RF port. If this LO input signal causes a 5-GHz signal with an amplitude of –20 dBm to be measured at the RF port, the LO-RF isolation is 35 dB. LO-IF isolation and RF-IF isolation are calculated in the same manner.

LO-RF isolation is critical in frequency downconverting systems because LO power can leak into the RF circuitry. If the LO-RF isolation is poor, the LO power can contaminate the RF line. Poor LO-RF isolation can also cause problems in frequency-upconverting systems when the LO frequency is very close to the RF output frequency. Because the LO frequency and the RF output frequency are so close, no amount of filtering can remove the LO leakage. As a result, that leakage interferes with the RF output, potentially degrading the RF output circuitry.

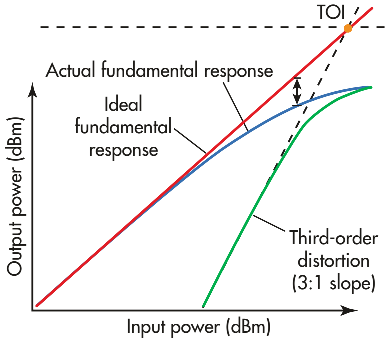
LO-IF isolation specifies the amount of leakage from the LO input signal to the IF port. When the LO-IF isolation is poor, problems can occur if the LO frequency is close to the IF frequency. In this case, the LO signal can contaminate the IF circuitry. With sufficient LO leakage, the IF amplifier will potentially be saturated. The conversion-loss flatness also may be degraded if the LO-IF isolation is insufficient.

RF-IF isolation is the final mixer isolation metric. Because the amplitudes of both the RF and IF signals are usually significantly lower than the amplitude of the LO signal, most systems designers will not find RF-IF isolation to be a major issue. However, high RF-IF isolation is usually a sign that the mixer will exhibit low conversion loss with good conversion-loss flatness.

1-dB compression point: A mixer's conversion loss remains constant when the mixer is in linear operation. As the amplitude of the input signal increases, the amplitude of the output signal rises by the same amount. However, once the input signal's amplitude reaches a certain level, the amplitude of the output signal ceases to exactly follow the input signal. The mixer deviates from linear behavior and its conversion loss begins to increase. A graphical representation of this is shown in *Fig. 2.* When a mixer's conversion loss increases by 1 dB, the 1-dB compression point has been reached. The 1-dB compression point of a mixer is defined as the amplitude of the input signal required to increase the conversion loss by 1 dB. A mixer's 1-dB compression point determines the upper limit of its dynamic range.



2. A graphical representation of 1-dB compression point.



3. A graphical representation of how TOI is derived.

For a mixer, 1-dB compression point is usually related to the LO drive level. Mixers with higher LO-drive-level requirements have a higher 1-dB compression point. Yet higher LO power also must be delivered to such mixers. In general, the 1-dB compression point is anywhere from 4 to 7 dB below the mixer's minimum recommended LO drive level.

Intermodulation distortion: Two-tone third-order intermodulation distortion (IMD) occurs when two signals simultaneously enter the mixer's IF or RF input port. In practice, this could happen in a multi-carrier signal environment. These two signals interact with each other and with the LO signal, which creates distortion. In a receiver, two-tone third-order IMD is a serious problem because it can generate third-order distortion products that fall within the IF bandwidth.

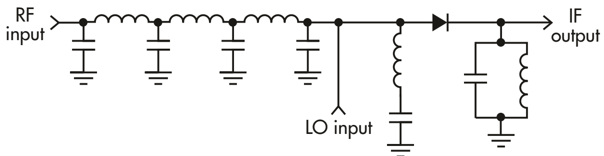
If f_{RF1} and f_{RF2} represent two separate RF input signals and f_{LO} represents the LO signal, the third-order distortion products generated at the mixer's IF port are:

$$Interferer_1 = 2f_{RF1} - f_{RF2} - f_{LO}$$
$$Interferer_2 = 2f_{RF2} - f_{RF1} - f_{LO}$$

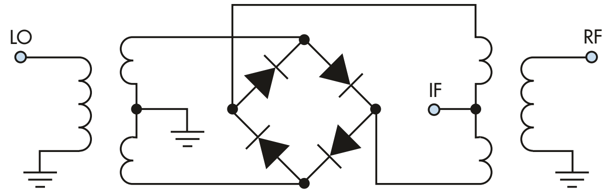
These third-order distortion products are extremely close to the desired IF output frequency. No amount of filtering can remove these unwanted distortion products. Thus, the signal-to-noise ratio of the received signal is degraded, highlighting the need to suppress these distortion products.

The third-order input intercept point (TOI or IP3) is a widely accepted figure of merit used to describe a mixer's capability to suppress third-order distortion products. TOI is used to predict the nonlinear behavior of a mixer as the amplitude of its input signal rises, which causes the third-order products to increase by a 3:1 ratio. For any 1-dB increase in the input signal's amplitude, the third-order products jump 3 dB *(Fig. 3).*

The TOI is the value of the input power when the line representing the fundamental output intersects with the line representing the third-order distortion products. The TOI is really just an extrapolated point, though, because the mixer



4. A mixer can be designed with a single diode.



5. A double-balanced mixer uses four diodes in a quad-ring format.

compresses before the lines actually intersect. Due to the negative impact that third-order distortion products can have in a system, it is desirable for a mixer to have a high TOI.

MIXER DESIGN TECHNIQUES

In theory, any nonlinear device can be used to create a mixer circuit. However, only a few devices satisfy the requirements needed to design mixers with acceptable performance. Devices that are commonly used to design modern mixers include Schottky diodes, gallium-arsenide (GaAs) field-effect transistors (FETs), and CMOS transistors. Various topologies can be used to create mixers. Mixers can be designed as either passive or active components.

Passive mixers primarily use Schottky diodes, although the FET resistive mixer has recently become another popular passive mixer. Active mixers use either FETs or bipolar devices. Schottky diodes, in comparison with FETs and bipolar devices, have the advantage of an inherently wide bandwidth. This is a major reason why diodes are still widely employed in the design of mixers.

Mixers can be designed with just a single diode, which is the simplest mixer topology. Balanced mixers that consist of two, four, or even eight diodes in a balanced structure build upon the single-diode mixer. The majority of mixers available today incorporate some form of mixer balancing.

A single diode can be used to create a mixer *(Fig 4)*. Here, the RF and LO signals combine at the anode of the diode. The LO signal needs to be large enough to switch the diode on and off, which causes the actual mixing process. The frequency components generated by single-diode mixers are:

$$f_{IF} = nf_{LO} \pm mf_{RF} \text{ (m and n are all integers)}$$

where f_{LO} = the LO input signal frequency; f_{RF} = the RF input signal frequency; and f_{IF} = the IF output signal frequency.

Although only one output frequency is desired (when n = 1 and m = 1), additional unwanted harmonics are generated by the diode's current-voltage (I-V) characteristics and the transconductance modulation caused by the RF signal. Because the single-diode mixer has no inherent isolation between the RF and LO ports, external filters also are needed to achieve isolation between ports. This need for external filtering makes it difficult to achieve wideband mixers with just a single diode.

Balanced mixers overcome some of the limitations of single-diode mixers. They do require baluns or hybrids, which largely determine the bandwidth and overall performance of the mixer. Inherent isolation between ports is achieved by balanced mixers as well as increased cancellation of intermodulation products. Common-mode noise cancellation is another advantage gained by balanced mixers. However, balanced mixers do require a higher LO drive level.

Single-balanced mixers consist of two diodes along with a hybrid. Although 90-deg. and 180-deg. hybrids can both be used to design single-balanced mixers, the majority of single-balanced mixers incorporate a 180-deg. hybrid. The 180-deg. hybrid's input ports are mutually isolated, enabling the LO port to be isolated from the RF port. This provides frequency-band independence and equal power division to the load. In comparison with single-diode mixers, single-balanced mixers also have 50% fewer intermodulation products.

Two single-balanced mixers can be combined to form a double-balanced mixer. Traditional double-balanced mixers are typically based on four Schottky diodes in a quad ring configuration. Baluns are placed at both the RF and LO ports, while the IF signal is tapped off from the RF balun. The IF signal can also be tapped off from the LO balun, but this would worsen the LO-IF isolation. For this reason, it is usually preferred to tap off the IF signal from the RF balun instead of the LO balun. An example of a double-balanced mixer is shown in *Fig. 5*. This mixer has high LO-RF isolation and LO-IF isolation along with moderate RF-IF isolation. Double-balanced mixers also have the benefit of reducing intermodulation products by as much as 75% in comparison with single-diode mixers.

An even more complex mixer circuit is the triple-balanced mixer. Triple-balanced mixers have separate baluns for the LO, RF, and IF ports, which enables them to achieve high LO-RF isolation, LO-IF isolation, and RF-IF isolation. Triple-balanced mixers also offer higher suppression of intermodulation products than double-balanced mixers. The downside of triple-balanced mixers is that they need a higher LO drive level. They also are greater in both size and complexity.

In summary, mixers are available in a variety of forms, with varying levels of performance. Several parameters are used to characterize a mixer's performance. Insight into mixers, as well as their parameters, can help system designers select the proper mixer for their system. The key parameters of a mixer, such as conversion loss, isolation, and intermodulation distortion, are critical factors for any system design. mw

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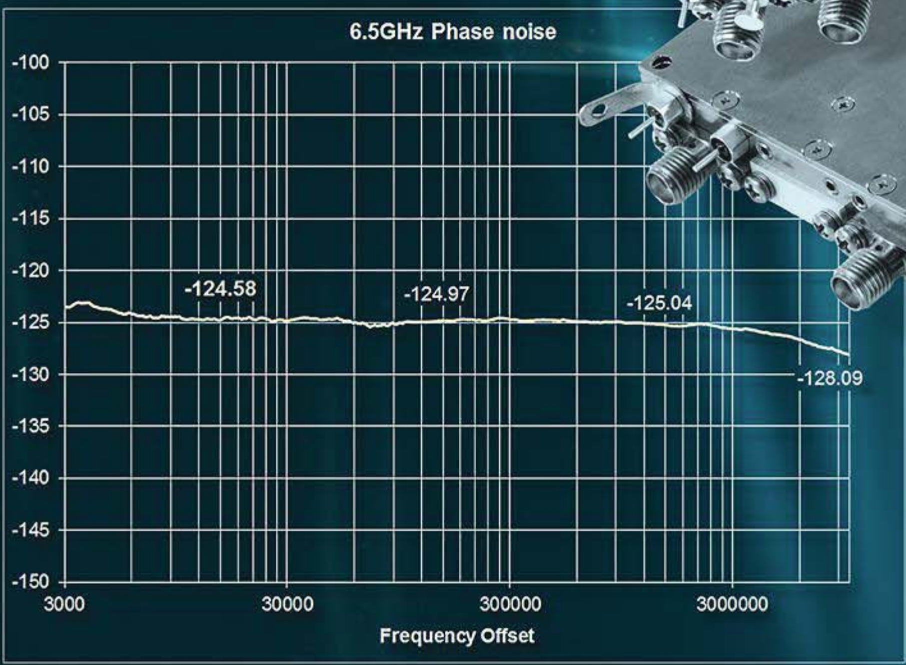

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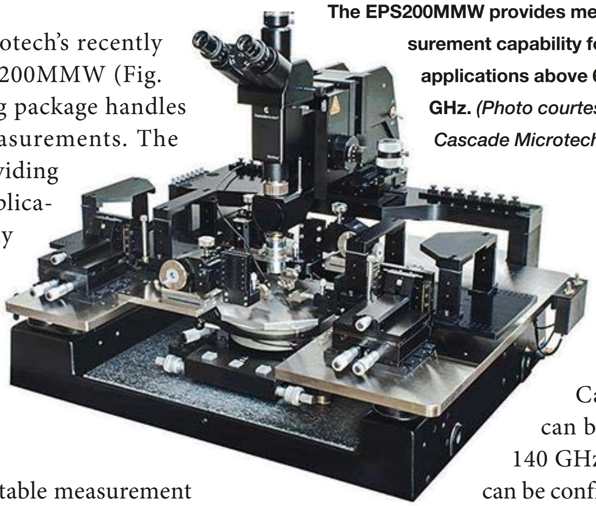
Probing Solutions Enhance Productivity

Probe stations, as well as probe-station software applications, must satisfy demanding test requirements. Enhancements in performance provide a multitude of benefits—like increased efficiency and accuracy.

THE LATEST PROBE stations are providing solutions to achieve accurate measurements for higher-frequency applications. For instance, innovative designs enable probing to be achieved at terahertz frequencies. In addition, new probe-station control software delivers increased test-and-measurement efficiency. With the latest software improvements, gains in speed and productivity are achieved.

An example is Cascade Microtech's recently released probe system, the EPS200MMW (Fig. 1). This pre-configured probing package handles manual 200 mm on-wafer measurements. The EPS200MMW is capable of providing measurements for advanced applications above 67 GHz, specifically targeting the 200 to 300 GHz frequency range and higher. Designed to provide functionality to achieve fast and accurate measurements, the EPS200MMW offers many key benefits.



The EPS200MMW provides measurement capability for applications above 67 GHz. *(Photo courtesy of Cascade Microtech)*

To achieve accurate and repeatable measurement results, probe placement with submicron accuracy on calibration substrates and devices under test (DUTs) is critical. This need is even greater at frequencies from 200 to 300 GHz and higher. The EPS200MMW addresses this need with its solid-cast frame, along with a platen featuring four-point support. Those aspects enable the EPS200MMW to deliver superior stability, which allows high accuracy to be easily achieved. High-quality contacts are maintained throughout measurements by means of an integrated vibration-isolation solution.

In addition, the EPS200MMW provides a short signal path from instrument to device, enabling high dynamic range and directivity to be achieved without compromising electrical accuracy and mechanical stability. Its fine-glide chuck stage also provides coarse movement with wide-ranging capability as well as being able to provide fine movement in the submicron range. The EPS200MMW includes the WinCal XE on-wafer calibration software, which allows calibration accuracy to be achieved at terahertz frequencies. The EPS200MMW is also designed for upgradeability, enabling it to be easily reconfigured to meet future project requirements.

The EPS200MW provides manual probing measurements, but the company is also delivering advanced semi-automatic probing systems. The Summit Series probe station from Cascade Microtech is a 200-mm fully integrated semi-automated on-wafer terahertz probing system. Calibrated measurement results can be achieved at frequencies from 140 GHz to 1.1 THz. The probe station can be configured with programmable positioners to allow rapid and repeatable submicron positioning accuracy, ensuring high precision at the probe tip.

INTERCHANGEABLE MODULES

With its family of manual, semi-automatic, and fully automatic probing systems, SemiProbe also provides probing solutions to meet test requirements. The company's Probe System for Life (PS4L) series of wafer probing systems is based on its patented adaptive architecture technology (*Fig. 2*). Unlike traditional systems, this technology allows all foundation modules, such as bases, stages, chucks, optics, manipulators, and more, to be interchangeable. As the environment or test conditions change, SemiProbe systems can be transformed on-site to meet these new demands, thus providing testing time and cost benefits.

The PS4L's platen has a large surface, which accommodates multiple probe types, environmental chambers, and instrumentation. All SemiProbe semi-automatic and fully automatic systems operate on the PILOT control application suite, which is designed employing SemiProbe's adaptive architecture. PILOT's object-oriented software allows users to integrate the probe system quickly and easily with a broad array of test instrumentation. Drivers for most types of test instrumentation are readily available. In addition, new interfaces can easily be added.

Flexibility also is a goal for J microTechnology, which offers a line of probe stations for researchers, designers, and quality-control professionals. With an emphasis on supplying affordable probe stations in today's market, these units are used for material research, semiconductor, solar, nanotechnology, and medical sensor applications.

For example, J microTechnology's LMS-3009 probe station is intended for the research of advanced active and passive components. It also serves as an educational tool, training university students in the discipline of microwave microprobing.

Designed for RF/microwave applications, the LMS-3009's features include a stereo zoom microscope and precision x-y-z positioning. Its benefits include its low cost, compact size, and easy setup. "With electronic components the size of coarse ground pepper, engineers and physicist need affordable test stations that give them optical and mechanical advantages," said Jerry Schappacher of J microTechnology.

SOFTWARE ADVANCEMENTS

With the emergence of the Internet of Things (IoT), it is estimated that 50 billion devices will be connected to the Internet by 2020. Huge amounts of data will move through the cloud, requiring semiconductor technology to convert data into serviceable information. Semiconductor manufacturers will be required to provide flexibility in test setups to accommodate a wide variety of designs. Demands will grow for increased correlation between instrumentation and equipment that can only be achieved through higher levels of integration.

Probe stations are satisfying these needs with strong software offerings. For example, Cascade Microtech recently released Velox 2.0, which is the latest version of the Velox probe-station control software. Velox 2.0 is designed to support the emerging demands of data processing, instrument integration, and processing flexibility. Collaboration on critical projects also is supported, allowing several users to work on a single recipe and share wafer maps across multiple stations.

Velox 2.0 consolidates the legacy Nucleus and ProberBench system software packages into a universal platform. It also is backwards-compatible with all current Cascade Microtech platforms. With emphasis on the automation of repeatable test and measurement processes, Velox 2.0 provides users with several options to simplify the setup and execution of automated sequences on their probe stations. Many automation features are now standard with Velox 2.0. AutoAlign, which is one of the automation features, measures die size and tracks wafer expansion. Cascade Microtech has committed to semi-annual upgrades of Velox, which provides users with increasing functionality as new capabilities are added.

For its part, SemiProbe has developed SPCal, which is a software application for vector network analyzer (VNA) calibration. SPCal provides step-by-step procedures to simplify and automate the calibration process, thereby reducing measurement time and eliminating errors. When integrated with the PILOT control software, SPCal delivers repeatable calibration with contact placement within 1 μm, maintaining a stable resistance between the substrate and the probe tip. The software supports most popular VNAs. Additional VNAs can be interfaced by using the SPCal ADD VNA feature. In addition, SPCal can perform S-parameter measurements and produce as many as four different plots with PILOT's Plotter application.

THE CONFIGURATION CHALLENGE

The configuration of a device characterization system presents many obstacles. Equipment must be sourced from multiple suppliers. It then needs to be configured and proven on-site before a device can be tested. Measurement equipment, wafer probers, and other components—each having their own firmware or software control—must all be integrated to ensure data correlation and measurement accuracy. Weeks or even months can pass before the first measurements are executed.

In response to the need to achieve faster time to first measurement, Cascade Microtech and Keysight Technologies have partnered by closely synchronizing Velox 2.0 with Keysight's WaferPro Express software. This wafer-level measurement solution for device characterization incorporates a semi-automated wafer probe station from Cascade Microtech along with a network analyzer or device parameter analyzer from Keysight. The WaferSync feature of Velox 2.0 is used when connecting a probe system to the WaferPro Express test executive. The interface and workflow are optimized for Cascade Microtech's semi-automated probe stations, enabling quick setup and execution of automated wafer-level characterization measurements. IC-CAP, Keysight's semiconductor device modeling software, has also been added to the WaferPro Express software bundle. Cascade Microtech's wafer-level probe stations, microwave and DC bias probes, and calibration tools—combined with Keysight's test instrumentation and measurement and analysis software—allow users to perform comprehensive measurements on all structures.

This adaptive architecture technology enables users to configure probe systems to meet specific application requirements. ***(Photo courtesy of SemiProbe)***

In summary, all of the latest probe stations offer a number of benefits, including the capability to perform accurate measurements at terahertz frequencies. Users also have the flexibility to configure systems to meet their specific requirements. In addition, software advancements provide the functionality to support the anticipated demands of the future. med

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Energy-Harvesting Antenna Aids Wireless Sensors

A compact antenna with an integrated rectifying circuit was simulated and fabricated for converting RF energy to dc voltage at ISM band frequencies.

Energy harvesting is an efficient method for powering different RF/microwave components for communications systems, including antennas. By harvesting energy for such applications as autonomous radio-frequency-identification (RFID) systems and wireless sensors, self-powered solutions can be developed without need of additional batteries. To demonstrate the possibilities, an energy-harvesting patch antenna array was designed to capture as much RF energy as possible from surrounding energy sources.

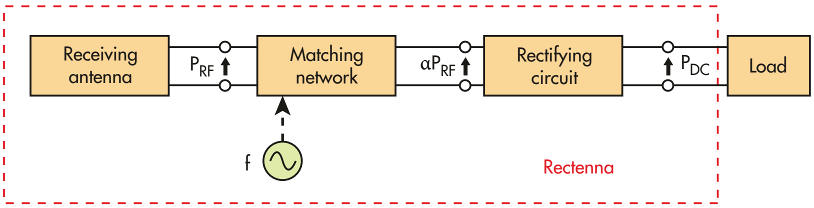
To minimize costs, the antenna was fabricated on low-cost FR-4 printed-circuit-board (PCB) material. The rectangular patch antenna array was developed for use in the Industrial-Scientific-Medical (ISM) band at 2.45 GHz, employing an additional slot on the rectangular patch element for added gain. The antenna design includes a turn-on light-emitting diode (LED) indicate captured energy at voltages from 0.01 to 3.94 V dc.

Light sensors and other electronic devices using "smart" technologies have already begun to affect many users' lives. Such sensors detect the level of darkness in a room and automatically turn on the lights at a specific level of light/darkness. This smart system not only helps improve the quality of life, but also contributes to energy and cost savings. This intelligent use of energy can be applied to remote controls without batteries and mobile-telephone chargers that operate with harvested energy.

Researchers have explored various methods for extracting ambient energy from an environment, then converting it into electrical energy for such applications as low-power sensors.[1] This scavenging of energy will enable many new "green" electronics devices due to self-powered wireless sensors and autonomous energy.[2] Energy is available in the environment for reuse from various sources, including solar power, magnetic energy, vibration, and RF/microwave energy. The latter is freely available in open space; it can be captured by the appropriate receiving antenna and rectified into usable dc voltage.

The use of battery power by a growing number of sensor-based wireless networks and other applications has increased rapidly in recent years, with batteries providing only limited lifespan and fixed energy supply rates. But an energy-capturing antenna, such as a patch antenna, can capture energy from the environment for use in place of the batteries. A number of different patch antennas exist, including meander-line antennas (MLAs),[3] linearly polarized antennas,[4] and circularly polarized antennas.[4] These different configurations will be examined to find the best antenna topology for energy harvesting, along with a circuit capable of converting RF signals into dc voltage for battery replacement.

For maximum coverage, most communications use antennas with omnidirectional radiation patterns. An energy-harvesting system relies on capturing some of this available energy. The amount of available energy is large, but only a small amount can be scavenged due to some energy being dissipated by heat or absorbed by other materials. The RF energy-harvesting system consists of a microwave antenna, a prerectification filter, a rectifying circuit, and a dc lowpass filter (LPF) that rectifies incom-



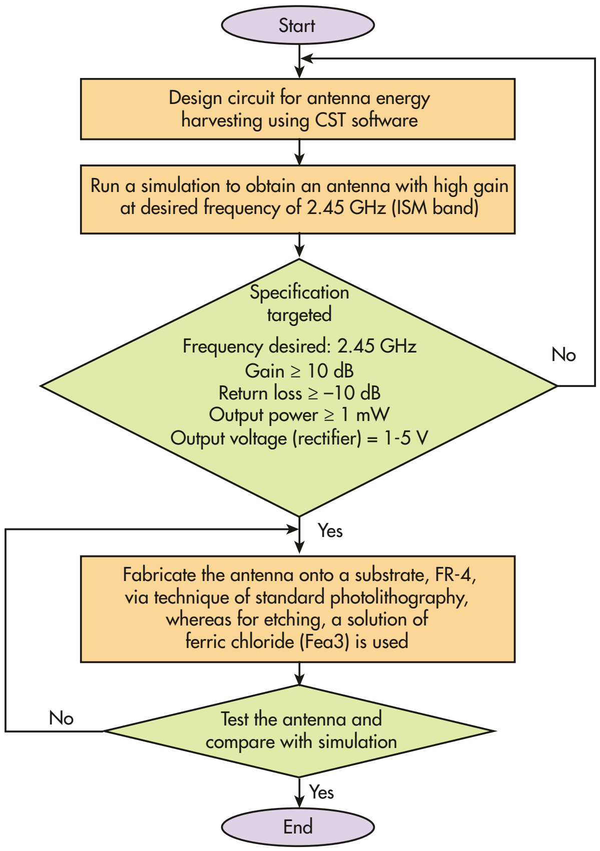
1. This block diagram shows the rectenna for use at ISM band frequencies.

ing electromagnetic (EM) waves into dc current. The rectifying circuit can be any one of several different types—e.g., a full-wave bridge rectifier or a single shunt full-wave rectifier.[5,6]

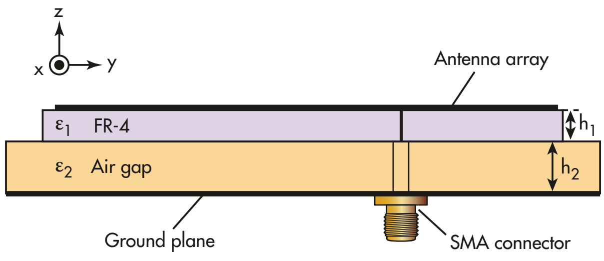
For optimum power transfer, a LPF is used for impedance matching between the antenna and the rectifier. Once a signal is rectified, a dc LPF is used to smooth the output dc voltage and current by attenuating the high-frequency harmonics present in the RF signals available in the environment. An attempt is made to collect maximum power before delivering it to a rectifying diode; next, the harmonics generated by the diode, which radiate from the antenna as lost power, are suppressed.[6]

A number of factors impact effective energy harvesting, including antenna transmitted power, antenna received power, conversion efficiency, and conversion circuit analysis.[7] To increase the conversion efficiency, several antenna designs must be implemented, including antenna arrays and circularly polarized antennas. The broadband antenna receives relatively high RF power from various sources, while the antenna array increases the incident power delivered to the diode for rectification.[6,7] *Figure 1* shows a block diagram of the rectenna.

The CST Microwave Studio Suite 2011 from Computer Simulation Technology (www.cst.com) was used to design and simulate the high-gain energy-harvesting antenna, while the



2. This system flow chart shows the design process for the energy-harvesting antenna system.



3. This is a side view of the energy-harvesting antenna.[8]

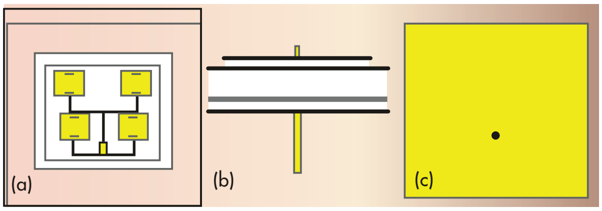
Advanced Design System (ADS) 2011 software from Keysight Technologies (www.keysight.com) was used for design and simulation of the rectifying circuit. The antenna and rectifying circuits were fabricated on FR-4 PCB material for comparison of actual measurements with simulations. *Figure 2* shows the flow of the antenna design process.

The antenna was designed for ISM-band applications and fabricated on the low-cost circuit substrate material using photolithography patterning and etching techniques *(Figs. 3 and 4)*. As *Fig. 3* shows, the antenna consists of a bottom ground plane, an air gap between the FR-4 circuit substrate and the microstrip patch, and an additional slot. The patch and the ground plane are comprised of copper. The antenna is excited by a coaxial feed connector at the center of the transmission line. For use at 2.45 GHz, the width and the length of the microstrip patch have been calculated by the following formula (given in ref. 9):

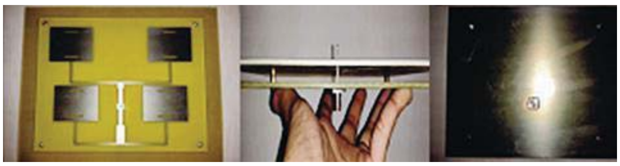
$$W = c/\{2f_0[(\varepsilon_r + 1)/2]^{0.5}\}$$

$$L_{eff} = c/[2f_0(\varepsilon_{r\ eff})^{0.5}]$$

where
c = the speed of light;
f = the operating frequency (2.45 GHz);
ε_r = the relative dielectric constant of the PCB substrate; and
$\varepsilon_{r\ eff}$ = the effective relative dielectric constant of the PCB substrate.



4. These different views show the (a) front, (b) bottom, and (c) back of the energy-harvesting antenna.



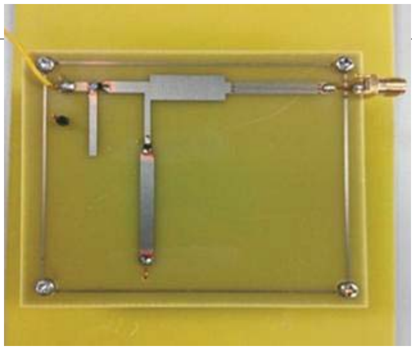
5. This is the design of the fabricated energy-harvesting antenna.

For good isolation, the antenna's adjacent elements should be separated by at least one-half wavelength (λ/2) at the desired frequency. Isolation tests were performed for antenna-element spacing of 5.8 cm (0.4737λ), 6.1 cm (0.4982λ), and 6.5 cm (0.5310λ). A spacing, x, of 6.1 cm was found to provide the best performance after optimization.

Microstrip antennas are often employed not only as single-element components, but also as arrays—especially when needed to create a pattern that cannot be achieved with a single-element antenna. The feed network for the microstrip array can be accomplished by using tapered lines to match 100-Ω antenna patch elements to a 50-Ω input port or to quarter-wavelength impedance transformations.

The current design employs tapered lines with the antenna array fed by a probe in the middle of the thickest transmission line, at an SMA-compatible impedance of 50 Ω. The dimension of the transmission line was calculated using the formula from ref. 10. For a characteristic impedance of Z_0 = 50 Ω, the impedance that is split into both feed lines is 100 Ω.

The design of the rectifying circuit was based on transmission-line calculations for the circuit. The basic rectifier design for the energy-harvesting system consists of one diode and one capacitor. This simple design was chosen to minimize diode losses. A model HSMS-286B diode from Agilent Technologies (now Keysight Technologies) was selected for its fast switching speed and low voltage drop.



6. A single-stage rectifier circuit was used with the antenna to convert RF energy to DC voltage.

SAMPLING SIMULATIONS

A parametric study approach was applied to ensure that the antenna operated at the required resonant frequency (2.45 GHz). Using this design method, adjustments were made to the length and width of the patch, as well as to the slot and length of the transmission line. The effects on return loss, gain, and impedance bandwidth were noted. The initial design was without the additional slot and the antenna operated at 2.4973 GHz with return loss of –12.178 dB. The fractional bandwidth was calculated as 2.96%, and antenna gain was 13.35 dB.

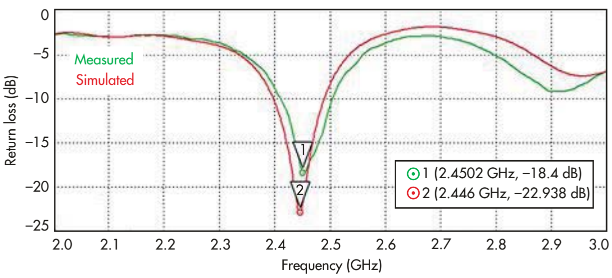
An additional slot was introduced to each single element of the antenna array to improve performance, per ref. 11; by doing so, the additional slot improved the antenna gain to 13.51 dB. Parametric analysis was performed with fixed design parameters, except for length and width parameters L_f, L_b, L_p, W_p, and L_{s1}.

The following values were applied to the antenna design: L_p = 45 mm, L_f = 25.5 mm, and W_p = 49 mm. The design was then simulated and the return loss was found to improve to –46.486 dB at 2.408 GHz. The calculated impedance bandwidth was 3.65% and the gain was 13.54 dB with 14.04-dB directivity.

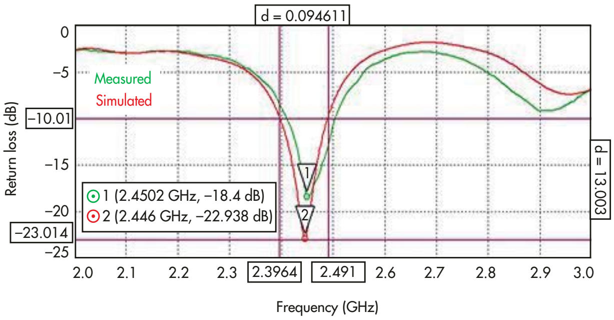
The antenna performance was then simulated using values from the parametric studies, and high gain was found for the antenna design with an additional slot and having values of W_p = 47 mm, L_p = 43 mm, L_f = 25.5 mm, and L_{s1} = 16 mm. This antenna operates at 2.446 GHz with –22.938 dB return loss and

COMPARING SIMULATED AND MEASURED RESULTS

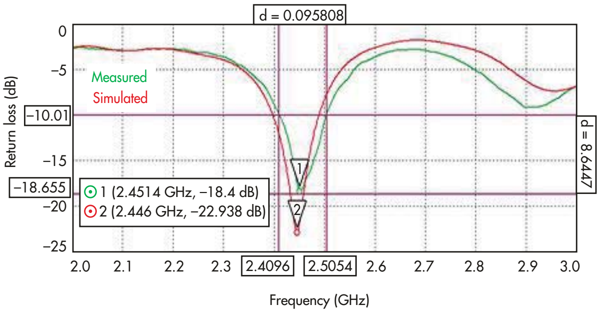
Antenna parameter	Simulation	Measurement
Return loss	(2.446 GHz, –22.938 dB)	(2.453 GHz, –18.258 dB)
Reflection coefficient	0.00508	0.01493
VSWR	1.01 < 2.00	1.03 < 2.00
Bandwidth (fractional bandwidth)	94.6 MHz (3.87 %)	95.8 MHz (3.90 %)
Radiation pattern	Angular width (3 dB) is 32.2 deg. (Directional pattern)	**Open environment:** Directional pattern (cross polar) **Chamber Room:** Directional pattern (copolar)
Directivity	14.18 dBi	15.57 dBi
Gain	14.08 dB	10.46 dB



7. These simulations and measurements show the best antenna frequencies in terms of return-loss performance.



8. According to computer simulations, the antenna bandwidth is 94.6 MHz.



9. According to measurements, the antenna bandwidth is slightly wider at 95.8 MHz.

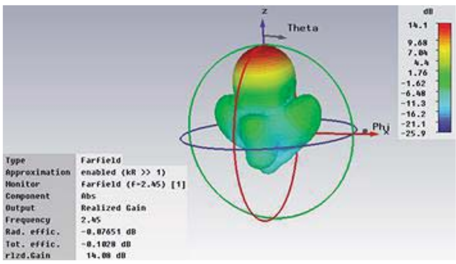
99.4-MHz (3.87%) impedance bandwidth. It yielded high gain of 14.08 dB with 14.18-dB directivity.

When only L_p was changed (to a value of 41 mm), the gain dropped to 13.79 dB. Some frequency shifting was observed: to 2.486 GHz with return loss of −15.931 dB. This indicated that the length of the patch affected frequency. Thus, to ensure operation in the ISM band at 2.45 GHz, L_p was set at 43 mm. The impedance matching for the antenna design at 2.446 GHz was 59.499326 – 8.460473 Ω with a line impedance, S1, of 61.18 Ω.

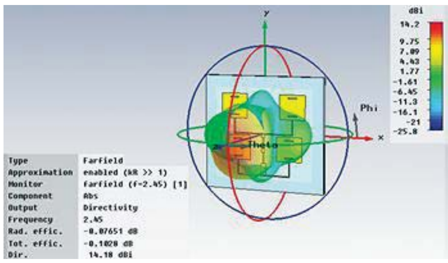
MAKING MEASUREMENTS

The antenna and rectifying circuit were measured separately before being integrated and measured again. *Figures 5 and 6* show the measurements of the output voltages of the rectifying circuit before and after this integration. Measurements were performed to determine return loss, radiation pattern, gain, and received power for the antenna array.

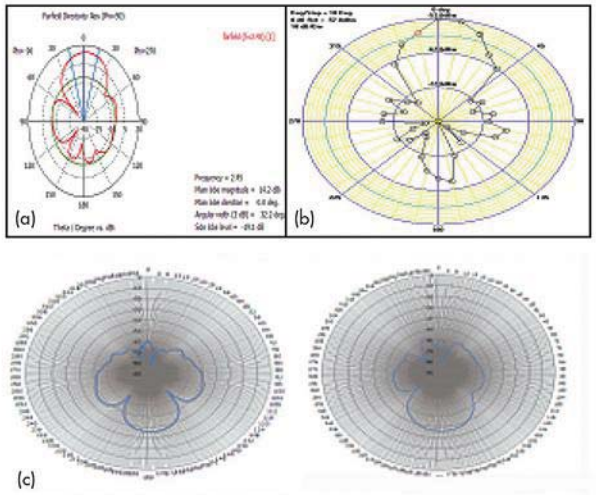
The antenna array was designed to operate with single-band functionality at 2.45 GHz for ISM-band applications.[12,17] *Figure 7* shows simulation and measurement results where the x-axis is frequency (GHz) and y-axis is return-loss magnitude (dB). Simulation indicated the best operating frequency as 2.446 GHz with −22.938 dB return loss. Measurements indicated that the antenna resonates best at 2.4502 GHz with −18.4 dB return loss. The measurements appeared to show 95% accuracy and nearly the same values as the simulation results. The optimum return loss was achieved with the introduction of the slot from ref. 18 and the corporate-feed-network method detailed in ref. 19.



10. These plots show the gain realized for the energy-harvesting antenna.



11. These plots show the directivity of the energy-harvesting antenna.



12. This is the radiation pattern for the energy-harvesting antenna.

The antenna bandwidth was determined at the upper frequency minus the lower frequency, both at their 3-dB-down points, as shown by simulation and measurement. *Figures 8 and 9* reveal the simulated and measured antenna bandwidths as 94.6 and 95.8 MHz, respectively. The measured results are slightly better than the simulation results, but both values are still relative similar. The bandwidth could be increased further by the use of a double slot introduced for each of the radiating elements in the patch antenna array and feed location in the feed network arrangement.[20]

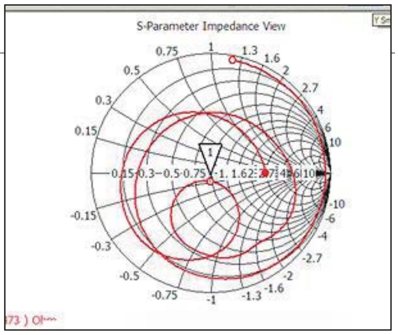
The desired gain for this multilayer 2-×-2 antenna array, with additional slot for each of the radiating elements, was greater than 10 dB, for good results when harvesting ambient RF energy. Theoretically, antenna gain depends on total power delivered to an antenna input terminal. Thus, by simulation *(Fig. 10)*, antenna gain of 14.08 dB was realized for a three-dimensional (3D) far-field view. The simulation of *Fig. 11* shows that the antenna yields high directivity of 14.18 dBi.

The directivity of each receiving antenna element is important where each must be directed, so that its maximum gain lobe is pointed toward the transmitting antenna to optimize the amount of received energy. An arbitrary minimum gain of 3 dB, which is the half-power beam width (HPBW), was chosen for the receiving antenna of the energy harvesting system.[21] Improvements in gain and directivity were due to the multilayer circuit structure used in the design, in which an air gap is placed between the FR-4 substrate and multislotted microstrip patch antenna.[22]

The antenna's radiation patterns also were simulated and measured. Based on the simulations of *Fig. 12(a)*, the antenna radiates/receives RF energy in a directional pattern which radiates more efficiently in some directions than in others. The HPBW (at 3 dB) is 32 deg. *(see the table)*; such a narrow beam width is the result of the thin FR-4 substrate material used for the antenna.

The magnitude of the antenna's main lobe is important, and the side lobe level must be reduced since it comes from an undesired direction.

Figures 12(b) and (c) compare measurements of the antenna in the open environment and in a test chamber. In



13. The antenna and its rectifier were carefully impedance-matched to a system characteristic 50 Ω.

both cases, the current in the antenna shows that the main radiating elements are at inside edges and near the probe feed.[23] As a result, the antenna offers a more directional radiating pattern and must be placed precisely near a transmitting antenna.

Impedance matching and even flow of surface currents are important for this antenna. Theoretically, an EM wave that travels through different parts of the antenna system may encounter differences in impedance. The matching process is necessary to transform the antenna's input impedance to the same impedance value for its transmission lines.

Therefore, the antenna must be integrated with the rectifying circuit in terms of impedance. Without good impedance matching, some wave energy will be reflected and the rectifying circuit will not have the energy available to convert to dc voltage.

Typically, a 50-Ω input impedance is used. The impedance matching in this antenna design is 59.49 – j8.46 Ω with a line impedance of 61.18 Ω, as shown in *Fig. 13*. The impedance matching is ideal to a 50-Ω input impedance.[23]

This antenna showed good agreement between simulated and measured results. The system, which consists of an antenna and rectifying circuit, operates at 2.4514 GHz with measured output voltage of 3.94 V dc. It is a design that shows good potential for use in a variety of ISM-band applications that could possibly be freed of their needs for batteries. mw

Note: For references, see the online version of this article at mwrf.com.

Design Feature

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Making the Most of Ultranarrowband Modulation

Looking to achieve high data rates with minimal consumption of bandwidth? Ultranarrowband modulation provides the promise of effective communications—with the proper filtering.

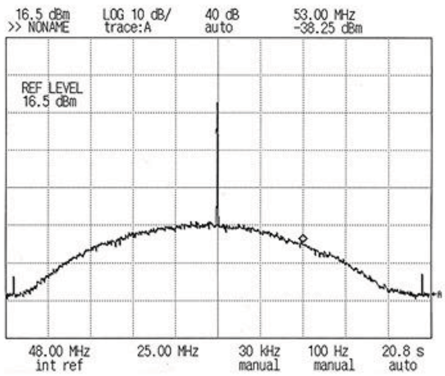
Ultranarrowband (UNB) modulation is an efficient method for transmitting information without using sidebands around a carrier. Also known as very-minimum-sideband-keying (VMSK) modulation or minimum-sideband (MSB) modulation, UNB modulation uses the lower sideband for modulated information and removes the upper sideband by means of filtering. When used properly, it can be an effective means of getting the most from available frequency bandwidth.

UNB modulation can be created in several ways. As an example, changing the modulation angle in binary-phase-shift-keying (BPSK) modulation from 180 to 90 deg.—and using a bandpass filter (BPF) with negative group delay—will yield a UNB modulation format with noticeable improvements in bandwidth efficiency and sensitivity. UNB techniques attempt to only employ carrier frequencies. This renders the sideband frequencies useless, making it possible to remove them and shrink the bandwidth required to send and receive signal information.

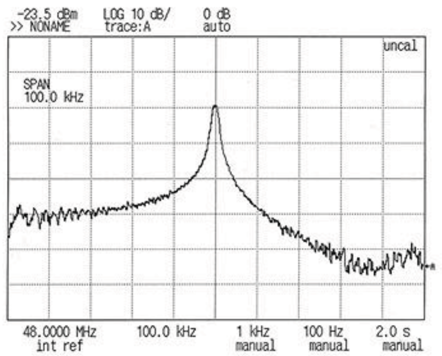
BPSK modulation using a 180-deg. change in phase has a spectrum ± bit rate without a carrier. It is a double-sideband, suppressed-carrier (DSB-SC) communications format. Shifting to a 90-deg. change in phase injects a carrier into the spectrum, but leaves the sidebands intact. When random data is used, the sidebands are still present, but down 32 dB (*Fig. 1*).

With a single ASCII character, the sidebands are strong, with clearly visible individual frequencies. With random data, the sidebands essentially disappear and become low-level signal components without individual frequencies. *Figure 1* displays random data modulation at a data rate of 12 Mb/s.

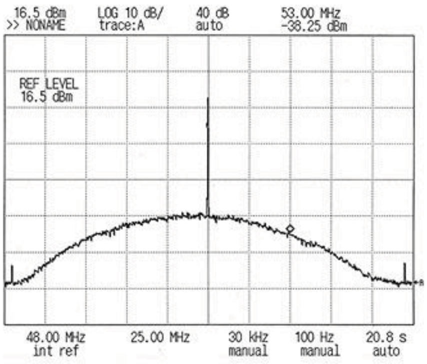
Figure 2 shows a spectrum-analyzer display of the passband for a series-emitter, negative-group-delay filter. The 3-dB bandwidth is approximately 500 Hz. One such filter stage is usually sufficient to satisfy regulations for transmit and receive functions in a UNB system. *Figure 3* presents the



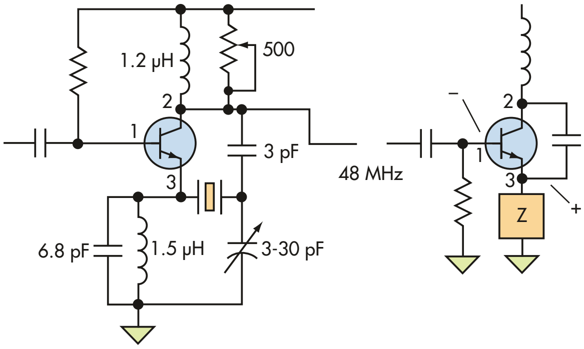
1. This spectrum-analyzer screenshot shows a signal with UNB modulation at a random data-modulation rate of 12 Mb/s.



2. This spectrum-analyzer display reveals the passband of a series-emitter, negative-group-delay BPF with approximate 3-dB bandwidth of 500 Hz.



3. This spectrum-analyzer screen offers a display for 90-deg. shifted BPSK (UNB) modulation after one stage of negative-group-delay filtering.



4. This represents a negative-group-delay filter with feedback.

spectrum with 90-deg. BPSK (UNB) modulation after one stage of negative-group-delay filtering.

In these UNB modulation efforts, the spectrum is reduced from a 1-cycle/b data rate to 1 Hz. This results in a significant improvement in signal-to-noise ratio (SNR) and improved bit-error-rate (BER) performance. With BPSK modulation, a 1-Mb/s signal occupies bandwidth that is 1 MHz wide; with UNB modulation, it is one cycle wide. With UNB modulation, there are no discretely visible sideband frequencies. BPSK at 180 deg. has no carrier; all of the energy is in the visible sidebands. With a 90-deg. phase shift, all of the usable energy is in the carrier and, with random data, there are no visible sidebands.

The reduction in bandwidth also means a reduction in noise. The noise (N) in a signal is directly proportional to bandwidth, in accordance with the relationship N = kTB, where T is temperature, B is bandwidth, and k is Boltzmann's constant. The reduced spectral bandwidth for UNB modulation also increases signal transmission and reception range. Or, for a given coverage and BER, power can be cut by 40 dB or more. Because transmitted/received UNB signals are singular, they don't need differential encoding at signals required by 180-deg. BPSK modulation.

For UNB, the BER is theoretically the same as for BPSK modulation despite the latter format's wider bandwidth. But measurements show a 3-dB improvement in SNR with UNB modulation due to the use of one signal instead of the two required in DSB-SC (using BPSK).

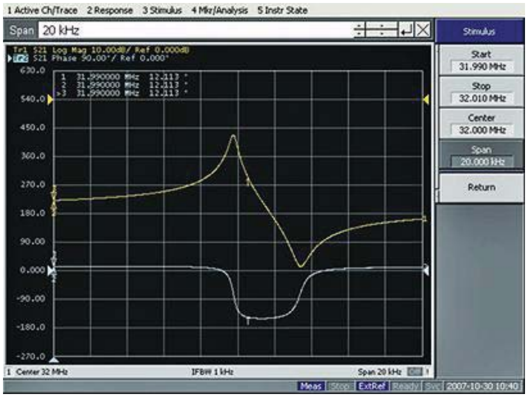
Of course, UNB requires the use of special filters, with negative or zero group delay (*Fig. 4*). The modulation format simply will not work with a conventional BPF with positive group delay. In these demonstrations, the filter in the UNB receiver had a bandwidth of 500 to 1000 Hz at the 3-dB points. Because of the narrow bandwidth of the filter, UNB channels can be spaced 10 to 15 kHz apart instead of the much wider megahertz channel spacing required for BPSK modulation.

UNB modulation has been successfully implemented using a series-emitter filter; it has positive feedback and can cause oscillation when excessive gain is applied. The filter is a Q multiplier circuit where the gain is controlled by means of a 200-Ω resistor.

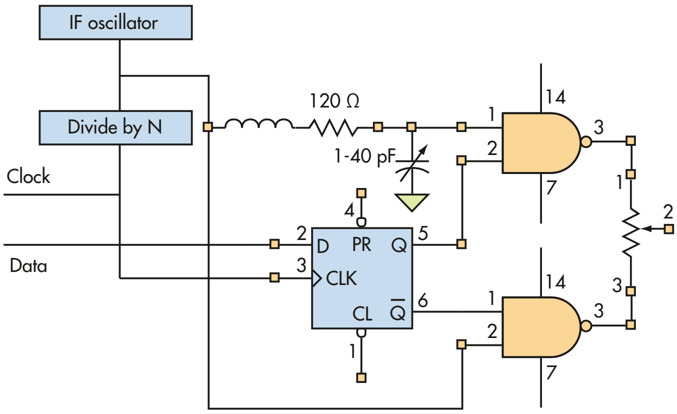
Several other circuits can cause negative group delay,[1] but this circuit offers the best shoulder reduction *(Fig. 2)*. Without filtering, the sidebands are down 32 dB. The transistor in this circuit is used in a manner that resembles an operational amplifier having positive and negative inputs.

In a network analyzer display of the negative-group-delay filter (*Fig. 5*), the amplitude response is colored yellow and the phase response is colored blue. For a negative-group-delay filter, the phase shifts from positive to negative. For a positive-group-delay filter, the phase shifts from negative to positive. The 3-dB bandwidth of this particular negative-group-delay filter is between 500 and 1000 Hz. This plot is for the series emitter filter without feedback. Negative-group-delay filters can be cascaded for additional shoulder reduction.

Figures 6 and 7 show block diagrams for a UNB system, with 48-MHz intermediate frequency (IF) using 90-deg. modulation and performing at a data rate of 12 Mb/s. It is working at four IF cycles per data bit. The data clock for this UNB system



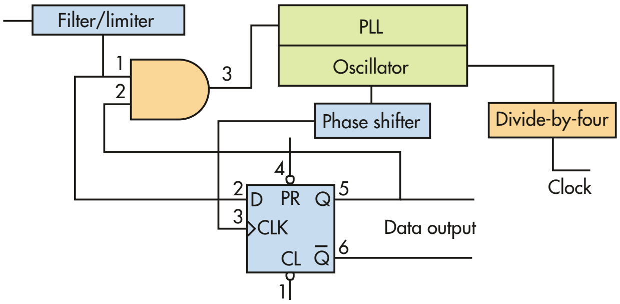
5. This is a network analyzer display for the negative group delay filter.



6. This UNB transmitter employs a 90-deg. phase shift, with phase LC adjusted.

can be obtained by counting down from the detected carrier. A 12-Mb/s data rate is essentially determined by a divide-by-four operation on the 48-MHz IF (48/4 = 12 Mb/s).

Resonator crystals are subject to a change in frequency with temperature. The narrow bandwidth of the series emitter filter could cause the filter to drift off frequency at temperature extremes. To correct for this problem, a 1N4148 diode and thermistor can be incorporated into the UNB circuitry.



7. This block diagram represents the UNB data detector (receiver).

In the receiver of *Fig. 7*, the raw data from the limiter is AND gated with the data. This causes only one phase of the two phases to be passed to the phase-locked loop (PLL). This in turn eliminates the need for differential encoding, and delivers an improvement of 2 dB in SNR. The total theoretical improvement over a 180-deg. BPSK system is 5 dB. The BER follows the Q function curve.

In case there are periods where no data is being sent, a single character should be employed as a filler. To prevent strong sidebands, this character should be an FF Hex character, ensuring that the carrier remains even as all sidebands are removed. The gated input to the AND gate in *Fig. 7* is continuously held high.

In this present example, UNB modulation is essentially end-to-end pulse-width modulation. When there is no signal, there are no sidebands. When a signal occurs that is past the transition, the signal is continuous wave (CW) and there are no sidebands—they occur at the start of a pulse.

Most UNB circuits operate at CMOS levels. Therefore, a limiter and amplifier must be used in the receiver to raise the filtered output for the detector and provide a sufficiently large dynamic range for the signal. In demonstration circuits, a model AD8309 logarithmic amplifier with limiting output and 500-MHz bandwidth from Analog Devices (www.analog.com) has proven satisfactory. mw

Note: For references and additional figures, see the online version of this article at mwrf.com.

JACK BROWNE | Technical Editor

Scrutinize the Specs to Identify the Right Switch

Selecting an RF/microwave switch requires understanding the needs of an application and sorting through different switch types with considerably different performance levels.

Switches for RF/microwave applications have evolved into many forms, from slower, higher-power electromagnetic switches to the fastest diode switches for smaller signals. Microelectromechanical-systems (MEMS) technology, which has made its own distinct splash in this crowded field, further enriches the assortment of high-frequency switches and switch technologies for specifiers. Selecting the right switch for the job becomes a matter of understanding what these different switch technologies can do and how well each switch type suits different applications.

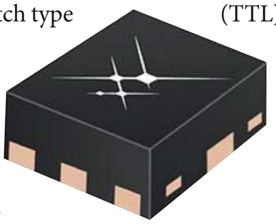
Perhaps the best way to compare and ultimately pinpoint the right microwave/RF switch is to study the different operating parameters, including frequency range, bandwidth, power-handling capability, switching speed, insertion and return loss, isolation, VSWR, power consumption, linearity, and reliability.

High-frequency switches are based on a number of different technologies, such as electromechanical, solid-state, and MEMS switches, and each offers advantages and drawbacks. Most applications can help specifiers define the performance limits required for a switch, and knowing the general capabilities of each switch type can simplify the selection process.

For example, insertion loss stems from a switch circuit's parasitic circuit elements—resistance, capacitance, and inductance—and how they essentially form a lowpass filter with attenuation as a function of frequency. Switch insertion loss is unavoidable and some amount of attenuation is acceptable. Ideally, though, insertion loss should be as low as possible to minimize signal attenuation through a switch.

Voltage standing wave ratio (VSWR) is the ratio of reflected to transmitted electromagnetic (EM) waves. Reflections can occur when EM signals change media—e.g., from a coaxial connector to a switch's printed-circuit board (PCB). Reflections will occur at any change in impedance.

When comparing switches and their parameters, it's important that parameters are normalized, such as comparing loss at the same frequencies. Some parameters, like switching speed, can be defined in various ways. For example, switching speed is typically interpreted as the duration from a certain level of a digital control signal to a certain level of an RF/microwave signal, such as the time from a 50% transistor-transistor-logic (TTL) signal to 90% RF signal.



This GaAs FET IC switch operates from 20 MHz to 6 GHz in a micro-lead-frame-dual (MLFD) surface-mount package measuring 1.0 × 1.0 × 0.5 mm. *[Photo courtesy of Skyworks Solutions (www.skyworksinc.com)]*

SWITCH TYPES

Electromechanical switches, commonly used in test systems, typically deliver outstanding electrical performance over wide frequency bandwidths, with high power-handling capabilities, low loss, and high isolation. They are physically larger and more expensive than other switch types. Moreover, they rely on the physical movement of a switch element to achieve conducting ("on") or open-circuit ("off") switch positions, which limits their operating lifetimes compared to solid-state and MEMS types of switches. Due to the physical movement within the switch, switching speed is also limited versus other switch types.

Solid-state switches, commonly based on PIN diodes or GaAs MESFET devices, employ electronic switching. These high-speed components often switch with the aid of logic control, such as TLL driver circuitry. Usually they're limited to lower signal power levels than electromechanical switches, with narrower bandwidths. Switching speeds, though, are typi-

> High-frequency switches are based on a number of different technologies, such as as electromechanical, solid-state, and MEMS switches, and each offers advantages and drawbacks."

cally in the microsecond range, versus the typical millisecond speeds for electromechanical switches.

MEMS switches, relative newcomers to RF/microwave applications, exhibit some of the traits of the other two switch types. MEMS switches are essentially electromechanical switches formed with semiconductor-sized structures. They feature low insertion and return loss and high isolation, but are limited in speed compared to solid-state switches. Power-handling capability also is limited when compared to electromechanical switches.

All three switch types can be compared by means of a standard set of operating parameters, as noted earlier. However, one or two parameters often stand out as the most important for a particular application, such as insertion loss and isolation across a frequency range. In some cases, switching speed may be the key, and achieving extremely fast switching speed, such as with a PIN diode solid-state switch, will mean sacrificing considerable power-handling capability.

A PIN diode switch can achieve microsecond switching speed (unlike MEMS and electromechanical switches that range in the milliseconds). Power-wise, though, it can only handle one or two watts (similar to a MEMS switch), compared to 100 W or more for some electromechanical switches.

Some tradeoffs are fairly clear for RF/microwave switches (e.g., RF power for switching speed), while others are more subtle (e.g., loss and isolation with bandwidth). Also, while electromechanical switches generally offer the best combination of loss and isolation with wide bandwidth, developers of solid-state monolithic-microwave-integrated-circuit (MMIC) diode and field-effect-transistor (FET) switches constantly strive to improve their products. Now solid-state switches feature bandwidths of 40 GHz and more, albeit with limited power-handling capabilities compared to electromechanical switches.

RF/microwave switches are further differentiated by several operating modes and traits. Switches can operate as failsafe or latching components, and be absorptive or reflective in nature. A failsafe switch is able to function without power applied; in this scenario, its common port will be connected to one of its output ports. On the other hand, a latching switch will not operate without power applied—its common port will not be connected to any of its output ports.

In addition, a switch may be reflective or absorptive. When turned off, a reflective switch offers open ports (in a high impedance state), while an absorptive switch has ports at the characteristic impedance of the system (typically 50 Ω). A make-before-break switch makes contact with a new switch channel before cutting power to the original switch path. A break-before-make switch breaks contact with one signal path before it forms another switch path.

Switches can also be sorted out in terms of whether they can perform cold or hot switching functions. Cold switching refers to no signal being applied to a switch when changing states, while hot switching is the opposite—a signal can be applied to a switch when changing states.

Switch physical configurations vary according to the number of poles and throws, as well as the package style. Many switch suppliers offer products ranging from simple single-pole, single-throw (SPST) switches to complex single-pole, 16-throw (SP16T) varieties. Such components can be used to control one or more receiver channels, depending on the number of throws, but will be limited in size according to the type of package.

Waveguide switches, for example, require housings large enough to mount the input and output waveguide flanges. Similarly, coaxial switches require package size sufficient to mount the required number of coaxial connectors. Coaxial packaging will become smaller at higher frequencies due to the shrinking size of the connectors needed to handle higher frequencies.

At lower frequencies, for example, larger Type-N connectors are used for coaxial switch packaging, which limits the package's ability to scale down to smaller sizes. At higher frequencies, connector types such as SMA, 2.9-mm, and 2.4-mm connectors can be mounted on more compact housings.

Of course, when miniaturization is required, solid-state and MEMS switches hold tremendous advantages over electromechanical switches, since they can do away with coaxial connectors and fit into surface-mount packages *(see figure)*. In this case, the limitation of one or two watts of power-handling capability for solid-state and MEMS switches is offset by the availability of surface-mount and compact pin packages that allow switches to be mounted on PCBs for compact circuits.

A number of suppliers offer good switch products across many different frequency ranges, performance levels, and sizes. Often times, an application's requirements will define the type of switch for that application, such as power-handling capability or switching speed. Breaking down a switch search, by starting with the type of switch, can at least help to accelerate the specifying process and eliminate time spent considering inappropriate switch types for a particular application. mw

MARKING MIXERS FOR THE NEXT APPLICATION

MICROWAVE MIXERS ARE essential building blocks for a fair share of high-frequency receivers. Mixers can be specified either as discrete components or as functions on integrated circuits (ICs), and they are critical to the performance of many different types of systems. For those who are new to high-frequency mixers, a 12-page application note from Marki Microwave, "Mixer Basics Primer: A Tutorial for RF & Microwave Mixers," provides an excellent introduction.

This note explains the workings of an RF/microwave mixer in straightforward language, detailing the functions of the RF, local oscillator (LO), and intermediate-frequency (IF) ports. It provides the simple mathematical relationships of the three mixer signals and explains how a mixer can be used for frequency upconversion and downconversion alike.

Although almost any nonlinear device could be used to build a frequency mixer, certain devices are traditonally used in specific types of applications. For example, GaAs field-effect transistors (FETs) and silicon CMOS transistors often are used for mixers in applications where cost must be contained and performance is not critical. When performance is more of an issue, devices such as Schottky diodes are typically employed for applications well into the microwave frequency range.

Both single-diode and multiple-diode mixers are reviewed for their strengths and weaknesses, with Schottky diodes providing optimal frequency-conversion performance for high-frequency mixers. Unfortunately, Schottky diodes also have their shortcomings, including some transconductance modulation in a diode which can result in additional, unwanted frequency components generated by a single-diode mixer. Multiple-diode mixers, based on four or eight diodes, also are examined; the note explores how some sacrifice in loss performance versus single-diode mixers can deliver frequency conversion with decreased modulation products.

The literature explains the design of how single-balanced mixers can be created with low loss and flexible operation using four diodes in a four-port hybrid junction configuration. This design approach offers higher conversion efficiency than a single-diode mixer with enhanced isolation between mixer RF and LO ports.

For anyone seeking a solid tutorial on RF/microwave mixers, this application note represents an excellent starting place.

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UNDERSTANDING HOW ANTENNAS BEHAVE ON MOVING VEHICLES

HIGH-FREQUENCY ANTENNAS FACE no shortage of challenges—even without the added complication of being integrated into the electronic systems of motor vehicles. But on a moving vehicle, an antenna must perform while in motion and with ever-changing terrain conditions, with signal barriers and reflectors constantly changing the performance of the antenna. To better understand how antennas can be designed for such applications, Remcom offers an eight-page white paper, "Using Simulation to Optimize Safety, Performance and Cost Savings When Integrating an Antenna Onto a Platform." It details the use of computer simulation tools to model the performance of antennas under moving conditions, identify problems, and find potential solutions.

The white paper notes that simulation offers an advantage in antenna analysis speed compared to building and testing each antenna design. The time savings can be considerable when designing antennas with computer software versus scheduling anechoic chambers and performing measurements on different antenna designs (once they have been physically assembled). Of course, the challenge is in achieving simulated results that are relatively close in value to measurements on a physical design.

But modern electromagnetic (EM) simulation software, such as the XFdtd software from Remcom, is capable is highly accurate predictions compared to measured results. The white paper provides the results of antenna simulations performed at the U.S. Army Communications-Electronics Research, Development, and Engineering Center (CERDEC) using the XFdtd software and an in-house ray-tracing tool. Antenna radiation patterns are shown with and without a vehicle "attached" to the antenna and how the vehicle impacts the radiation patterns.

The efficiency provided by the software allows many different antenna designs to be evaluated for a given vehicle, compared to the long times that would be required for actual antenna fabrication, integration, and testing. In addition, the software makes it possible to investigate the possible hazards of antenna radiation to personnel driving or sitting within the vehicle.

While the white paper is a simplified look at EM simulation, it is highly focused on an antenna application, and useful for those faced with integrating an antenna into a vehicle of any kind.

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Product Feature

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POWER MONITOR Keeps Tabs on LMR System Performance

This instrument monitors power and VSWR performance up to 16 channels and is scalable to accommodate any-sized radio system operating between 144 and 960 MHz.

Challenges often rear up when trying to maintain the long-term reliability of commercial, industrial, and government land-mobile-radio (LMR) wireless-communications systems. Most of these systems must endure hostile environmental conditions, wear, rough handling, and even tampering. Many system owners continue to operate systems without reliable remote monitoring of component performance levels, such as radios, power combiners, transmission lines, and antennas.

Fortunately, though, a solution exists in the form of the Channel Power Monitor from Bird Technologies (www.birdrf.com). It evaluates and monitors LMR systems operating from 144 to 960 MHz by checking the key elements of the transmission path in real time and alerting users of degraded performance or failures. The Channel Power Monitor tracks LMR system/component performance metrics over time, observing gradual performance degradation.

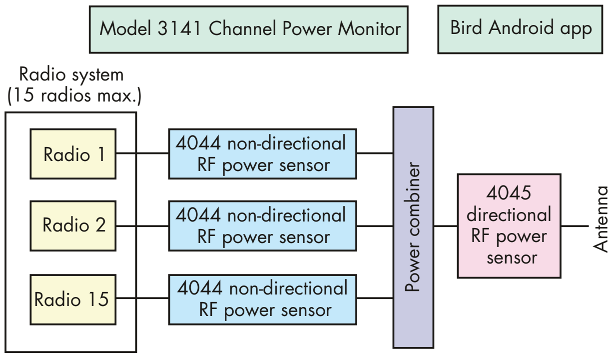
The model 3141 Channel Power Monitor Display *(Fig. 1)* occupies a single (1U) rack-mount space and can be set up and monitored either through a control panel on the front of the unit or via an Internet connection and a network-accessible webpage. Each website configured with a Channel Power Monitor has its own webpage to display measurements *(Fig. 2)*, including forward and reflected power and voltage-standing-wave ratio (VSWR) at each key point in the LMR system.

The 3141 physically hosts the webpages. They provide integral Internet access, allowing for setup and configuration of the alarm functions with simple-network-management-protocol

1. The model 3141 Channel Power Monitor occupies a single (1U) standard rack space. It features an integrated Web server with SNMP-based messaging, and accommodates up to 16 power sensor inputs.

Channel	Channel Forward Power	Channel Reflected Power	Channel VSWR
Solon Fire	37.7 Watts	0.0 Watts	1.01
Solon Police	50.7 Watts	0.0 Watts	1.01
Ambulance	48.6 Watts	0.0 Watts	1.01
Fire1	34.0 Watts	0.0 Watts	1.01
Police1	34.4 Watts	0.0 Watts	1.01
465.75 MHz	45.6 Watts	0.0 Watts	1.01
466.25 MHz	0.0 Watts	0.0 Watts	1.00
466.75 MHz	7.2 Watts	0.0 Watts	1.02
User 1	Disabled	Normally Open	OK
User 2	Disabled	Normally Open	OK
User 3	Disabled	Normally Open	OK

2. This is a typical webpage generated by the Channel Power Monitor. It shows various parameters for each channel and allows users to configure the system as well as create out-of-spec limits to trigger alerts.



3. A typical system employing the Channel Power Monitor uses sensors placed between each radio for measurements of individual radio output power and after the final system power combiner, where forward and reflected power and VSWR are measured.

(SNMP) messaging capability that sends alerts via e-mail or as a text message to a mobile communications device.

Since reliability depends on so many factors, it's impossible to know with absolute certainty that a radio or one of its components will fail. However, in many cases, total failure is preceded by a reduction in RF output power or an increase in VSWR. These situations can be difficult to spot, especially when intermittent, without being able to view radio performance over time. The 3141 addresses this issue by logging time-stamped data for up to eight weeks for each sensor, which can be offloaded as a .csv file in Microsoft's Excel software (www.microsoft.com).

The Channel Power Monitor Display operates with a set of Bird's directional and non-directional RF power sensors to form a system that can handle as many as 15 radio channels. It's expandable to any size by adding expansion units and sensors that interface with the Channel Power Monitor Display.

A typical system is designed so that power sensors are placed between each radio and the final system power combiner *(Fig. 3)*. The power sensors help measure power through the LMR system's component radios and transmission lines, as well as after the final system power combiner, where measurements can be made on forward and reflected power and LMR antenna VSWR. With such positioning, it's possible to spot degradation or failure at specific points rather than just after the combiner (indicating only a problem with the system as a whole).

The Channel Power Monitor takes advantage of two specific sensors. The model 4044 power sensor from Bird Technologies measures RF power to 100 W and, in the LMR communications-systems measurement setup, operates between the radio and combiner. Bird's model 4045 power sensor handles measurements up to 500 W. It's placed after the output of the system combiner to read final system output-power levels.

This power-sensor-based measurement approach helps boost reliability when measuring and monitoring LMR communications systems. Some radio monitoring instruments rely on a scanning receiver to sweep over a broad frequency range, which offers the advantage of making frequency-specific measurements—but at 20% accuracy (approx.). Thus, the instrument would trigger an alert only after, say, a significant reduction in LMR-system RF output power that could dramatically reduce system performance.

In contrast, the power sensors in the Channel Power Monitor offer accuracy of 5%. These power sensors are traceable to the National Institute of Standards and Technology (NIST, www.nist.gov), which provides much finer-grained measurements for earlier problem detection.

The 3141 includes a push-to-talk input for each radio in an LMR system. The instrument features power consumption of only 10 W from a 120/240-V ac power supply. It's fully functional over a range of 0 to +50°C (95% humidity, non-condensing) and delivers accurate measurements at altitudes as high as 10,000 ft. The table reveals more detailed specifications for the monitor instrument and the sensors.

P&A: $1800 (3141 Channel Power Monitor Display), $195 (4044 power sensor), and $550 (4045 power sensor); stock. mw

BIRD TECHNOLOGIES, 30303 Aurora Rd., Solon, OH 44139, (866) 695-4569, e-mail: sales@birdrf.com, www.birdrf.com

CHANNEL POWER MONITOR DISPLAY	
Number of channels	Up to 16 (standard); expandable
Dimensions	1 rack unit (5.25 × 19 × 1.75 in.)
Weight	2 lb.
Power required	120 /230 V ac, 10 W
Operating temperature range	0 to +50°C
Humidity	95%, non-condensing
Altitude	10,000 ft..
Features	Push to talk inputs (each radio), internal web server, SNMP messaging, compatibility to Bird Android app, data logging, multiple soft and hard contact alarms
RF power sensors	
Frequency range	144 to 960 MHz
RF power handling Model 4044 Model 4045	 100 W CW 500 W CW
Insertion loss Model 4044 Model 4045	 Less than 0.10 dB Less than 0.05 dB
Accuracy	±5% of reading
Passive-intermodulation (PIM) distortion	at least –145 dBc
VSWR Model 4044 Model 4045	 <1.07:1 <1.20:1
Operating temperature range	0 to +50°C

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USB Control Switch Matrices

Model	# Switches (SPDT)	IL (dB)	VSWR (:1)	Isolation (dB)	RF P_{MAX} (W)	Price $ (Qty. 1-9)
NEW USB-1SP4T-A18	1 (SP4T)	0.25	1.2	85	2	795.00
USB-1SPDT-A18	1	0.25	1.2	85	10	385.00
USB-2SPDT-A18	2	0.25	1.2	85	10	685.00
USB-3SPDT-A18	3	0.25	1.2	85	10	980.00
USB-4SPDT-A18	4	0.25	1.2	85	10	1180.00
USB-8SPDT-A18	8	0.25	1.2	85	10	2495.00

NEW USB and Ethernet Control Switch Matrices

Model	# Switches (SPDT)	IL (dB)	VSWR (:1)	Isolation (dB)	RF P_{MAX} (W)	Price $ (Qty. 1-9)
RC-1SP4T-A18	1 (SP4T)	0.25	1.2	85	2	895.00
RC-2SP4T-A18	2 (SP4T)	0.25	1.2	85	2	2195.00
RC-1SPDT-A18	1	0.25	1.2	85	10	485.00
RC-2SPDT-A18	2	0.25	1.2	85	10	785.00
RC-3SPDT-A18	3	0.25	1.2	85	10	1080.00
RC-4SPDT-A18	4	0.25	1.2	85	10	1280.00
RC-8SPDT-A18	8	0.25	1.2	85	10	2595.00

*The mechanical switches within each model are offered with an optional 10 year extended warranty. Agreement required. See data sheets on our website for terms and conditions. Switches protected by US patents 5,272,458; 6,650,210; 6,414,577; 7,633,361; 7,843,289; and additional patents pending.

†See data sheet for a full list of compatible software.

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International Microwave Symposium

New Products Shine at 2015 IMS

Record crowds at this year's show were treated to an impressive display of new component, system, test, and software products at more than 900 exhibition booths.

NEW PRODUCTS OVERWHELMED many of the more than 8,600 visitors at the recent 2015 IEEE International Microwave Symposium (IMS) in Phoenix, Ariz., with hundreds of exhibitors (at more than 900 booths) unveiling their latest designs in hardware, software, and test equipment. Here's a roundup of just a few of the many new offerings seen at IMS, as the industry continues to extend to a growing number of application areas.

As an example of a building-block product designed to reach across industries, Qorvo (www.qorvo.com) unveiled a family of plastic-packaged gallium-nitride (GaN) power transistors for military radios and radar systems. The input ports are impedance matched to 50 Ω to simplify use. The +32-VDC transistors are supplied in 3-×-3 mm packages and usable from 30 MHz to 3 GHz. The product line includes the model TGF2965 with 6 W output power (at 3-dB compression) at 2 GHz and model TGF3015-SM with 11 W output power (at 3-dB compression) at 2.4 GHz.

Also for commercial and military applications, TRAK Microwave (www.TRAK.com) displayed communications subassemblies and network timing modules for terrestrial and satellite-communications (satcom) applications (*Fig. 1*). The lineup included the model MFC147 block upconverter for satcom use from 13.75 to 14.50 GHz. Powered by a 25-W GaN amplifier, the upconverter features extensive surface-mount-technology (SMT) components and a rugged design well suited for airborne environments. TRAK also offered a dual-band Ku-band frequency downconverter for very-small-aperture-terminal (VSAT) applications.

Still showing its knack for high-level integration in small spaces, Analog Devices (www.analog.com) introduced its model ADF5904 monolithic microwave integrated circuit (MMIC). The four-channel, 24-GHz receiver downconverter fits into a 5 mm-×-5 mm plastic LFCSP housing. Each of the receiver downconverter's four on-chip receive channels employs a single-ended connection to an antenna for simple transmission-line design and circuit layouts for receiver systems. The MMIC downconverter achieves 22-dB receive channel gain with 10-dB noise figure across a 250-MHz bandwidth.

Also on hand at IMS was Freescale Semiconductor (www.freescale.com), which launched a pair of wideband GaN transistors in an advanced plastic package. The model OM-270 package, available in two- and eight-lead configurations, extends the firm's plastic packaging technology to a miniature outline with GaN compatibility. The model MMRF5015N GaN transistor (*Fig. 2*) is capable of 100-W CW output power with

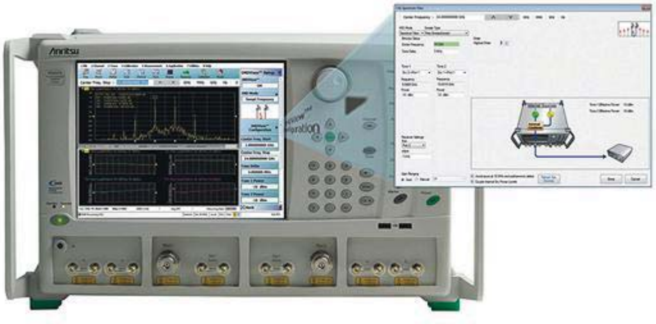
1. A wide range of multifunction modules includes frequency upconverters and downconverters for commercial and military use. *(Photo courtesy of TRAK Microwave)*

2. High-power GaN transistors are now available for commercial and military use in low-cost plastic packages. *(Photo courtesy of Freescale Semiconductor)*

3. This pair of low-frequency filters employs BNC connectors. *(Photo courtesy of Crystek)*

4. The SRX line of coaxial connectors, adapters, and cable assemblies helps minimize PIM in high-frequency systems. *(Photo courtesy of San-tron)*

5. For signals through 2.5 GHz, the model VSG25A vector signal generator is truly a handful. *(Photo courtesy of Signal Hound)*



6. The VectorStar line of VNAs was greatly enhanced by the new IMDView software for IMD measurements. *(Photo courtesy of Anritsu Corp.)*

12-dB gain across a wide bandwidth of 200 to 2500 MHz. The +50-VDC device provides 40% efficiency over that bandwidth. The model MMRF5011N GaN transistor delivers 10-W CW output power from 20 to 2600 MHz when operating from a +28-VDC supply.

Several plug-and-play evaluation tools from NXP Semiconductors N.V. (www.nxp.com) were introduced in support of the company's latest (ninth) generation of laterally diffused metal oxide semiconductor (LDMOS) power transistors. The evaluation tools, which allow developers to use codes from National Instruments' LabVIEW software for final programming, include a package for S-band radar applications and a power amplifier package that is said to provide a 30% performance improvement due to enhanced thermal management.

Offering its latest BNC-equipped lowpass filters (LPFs) and highpass filters (HPFs) was Crystek Corp. (www.crystek.com). The CLPFL line of BNC LPFs includes models with passbands extending to 90 MHz, including DC to 10 MHz, DC to 25 MHz, DC to 50 MHz, and DC to 90 MHz. These LPFs achieve filtering with a ninth-order Chebyshev filter response with high out-of-band rejection. The CHPFL series of BNC-based HPFs incorporate a seventh-order Chebyshev filter response. All of the filters (*Fig. 3*) are rated to handle input power levels to +36 dBm (4 W) and operating temperatures from –40°C to +85°C.

San-tron (www.santron.com) addressed the growing interest in minimizing passive intermodulation (PIM) in communications systems with its SRX line of low-PIM coaxial connectors, adapters, and cable assemblies (*Fig. 4*). The firm claimed typical PIM performance of –158 dBc for cable assemblies terminated with SMA and Type-N coaxial connectors and PIM performance as low as –168 dBc with 0.141-in. diameter flexible cable terminated with eSeries 7/16 connectors.

INNOVATIVE SOFTWARE LAUNCHES

On the software wide, ANSYS (www.ansys.com) intrigued visitors with the latest 3D electromagnetic (EM) simulation capabilities in its High Frequency Structure Simulator (HFSS) software. Show attendees learned how this popular simulation software uses 3D layout and optimization techniques to speed and improve the accuracy of circuit design (a video is also available on the company's website). The latest version of HFSS employs advanced solvers, including method-of-moments (MoMs) and finite-element-model (FEM) solvers, to derive solutions for high-frequency circuits and components, including a plethora of 3D effects.

For those in search of new measurement solutions at the 2015 IMS, Signal Hound (www.signalhound.com) impressed visitors with its cost-effective approach to test equipment, notably with its model VSG25A vector signal generator (*Fig. 5*). The USB-powered and controlled signal source covers a frequency range of 100 MHz to 2.5 GHz and can fit in a shirt pocket. It provides output levels from –40 to +10 dBm and a modulation bandwidth as wide as 100 MHz, and is priced at only $495.

More improvements to its test instruments were on the way from Anritsu Co. (www.anritsu.com), which offered intermodulation-distortion (IMD) options for its VectorStar vector network analyzers (VNAs). The capabilities include the new IMDView software (*Fig. 6*) with straightforward graphical user interface (GUI) for simple IMD measurements on amplifiers. The IMDView software allows operators to modify key parameters while checking the test results, to quickly determine optimum operating conditions for an amplifier under test.

Also from Anritsu is the MA24208A/MA24218A line of USB power sensors for true root-mean-square (RMS) power measurements from 10 MHz to 18 GHz, with the help of a PC. The USB power sensors read levels from –60 to +20 dBm with damage protection to 1 W (+30 dBm) for continuous-wave (CW) power inputs and as high as +34 dBm for peak levels of 10 μs or less. The power sensors can be used with any Windows-based PC running the PowerXpert measurement software.

Another IMS exhibitor with big news was Eastern OptX (www.eastern-optx.com), which introduced its Series 8000 test system, a multiple-channel, bidirectional radio path replicator for testing multiple RF/microwave radios or wireless systems simultaneously over different propagation paths. The system employs fiber-optic delay-line technology to replicate a wide range of propagation paths and provides a versatile RF interface that supports testing of all wireless standards, including Bluetooth, WiMAX, GSM, and LTE cellular. mw

JACK BROWNE | Technical Contributor

Synthesizer Modules Extend to 82 GHz

These compact frequency synthesizer modules now cover higher millimeter-wave frequency bands of 27 to 40 GHz, 50 to 67 GHz, and 76 to 82 GHz.

MILLIMETER-WAVE APPLICATIONS are poised to grow, with radar systems in cars and high data rates now being achieved over short-range communications links. Nevertheless, affordable test capabilities are needed to support the growth. Enter the new QuickSyn Lite line of modular frequency synthesizers from the Microwave Components Group of National Instruments, intended to simplify testing at millimeter-wave frequencies through 82 GHz.

All three of the QuickSyn Lite compact frequency modules *(see figure)* include serial Serial Peripheral Interface (SPI) bus and Universal Serial Bus (USB) control interfaces, enabling connection to DC power sources and a personal computer (PC) for ease of control. In addition, a soft front panel allows a user to access frequency control and frequency sweeps plus 32-kpoint LIST mode settings. The signal sources boast embedded firmware that allows them to be used as part of integrated automated-test-equipment (ATE) systems, as well as to serve as local oscillators (LOs) in different applications. The frequency synthesizers use a standard temperature-compensated crystal oscillator (TCXO) that is factory calibrated to a Global Positioning System (GPS) standard as the internal frequency reference,

This compact frequency synthesizer module is available for generating low-noise test signals at 27 to 40 GHz, 50 to 67 GHz, and 76 to 82 GHz.

At the low frequency end of the scale, the model FSL-2740 provides +17-dBm minimum output power from 27 to 40 GHz at a 2.92-mm connector; it is well suited for testing Ka-band satcom systems and backhaul digital radio applications. It offers 1-Hz frequency tuning resolution with standard frequency tuning speed of 1 ms; frequency tuning speed of 100 μs is available as an option. The compact synthesizer module features frequency temperature stability of ±1 ppm and an aging rate of ±1 ppm/year.

The model FSL-2740 frequency synthesizer module suffers harmonics of −40 dBc and spurious levels of −60 dBc. Its single-sideband (SSB) phase noise is typically −103 dBc/Hz offset 10 kHz from a 40-GHz carrier and −119 dBc/Hz offset 10 MHz from a 40-GHz carrier.

The next-highest-frequency synthesizer, FSL-5067, provides at least +17 dBm output power from 50 to 67 GHz at a coaxial 1.85-mm connector, with 1-Hz frequency tuning resolution and 1 ms frequency switching speed. The model FSL-5067 synthesizer module exhibits harmonic levels of −40 dBc and spurious levels of −60 dBc. Its SSB phase noise is typically −100 dBc/Hz offset 10 kHz from a 67-GHz carrier and −117 dBc/Hz offset 10 MHz from the same carrier.

The highest-frequency model FSL-7682 frequency synthesizer module delivers at least +10 dBm output power from 76 to 82 GHz via a WR12 waveguide interface. It is well suited for testing 77-GHz automotive radar systems and their components. The module provides similar frequency stability and aging rates as its two lower-frequency counterparts.

The model FSL-5067 synthesizer module operates with harmonic levels of −40 dBc and spurious levels of −60 dBc. Its SSB phase noise is typically −98 dBc/Hz offset 10 kHz from an 82-GHz carrier and −115 dBc/Hz offset 10 MHz from the same carrier.

All three synthesizer modules operate with an internal 10-MHz frequency reference, which can be accessed from a connector on the module. Output connectors are 2.92- and 1.85-mm coaxial connectors for the two lower-frequency synthesizers and WR12 waveguide for the 76-to-82-GHz unit. P&A: starting at less than $4,000. mw

NATIONAL INSTRUMENTS, Microwave Components Group, 4600 Patrick Henry Dr., Santa Clara, CA 95054; (408) 610-6810, *www.ni-microwavecomponents.com*

JACK BROWNE | Technical Contributor

Fast USB Sensors Read Power Levels to 18 GHz

This pair of USB-powered and -controlled power sensors read power levels over a wide 80-dB dynamic range and across a frequency range of 10 MHz to 18 GHz.

POWER MEASUREMENTS are critical for gauging the performance of both wired and wireless RF/microwave systems. On that note, a pair of power sensors developed by Anritsu Co. leverages the flexibility of the Universal Serial Bus (USB) to use personal computers (PCs) as assistants when making power measurements.

The two USB power sensors, the 10-MHz-to-8-GHz model MA24208A and the 10-MHz-to-18-GHz model MA24218A, offer high accuracy despite being low cost. Each uses a patented triple-path architecture to perform true RMS power measurements over a wide dynamic range.

The MA24208A and MA24218A *(see figure)* provide a dynamic power-measurement range of –60 to +20 dBm across their respective frequency ranges, with level accuracy of ±0.5 dB or better. They suit an assortment of power measurements, including average power measurements of continuous-wave (CW), multiple-tone, and digitally modulated signals independent of the modulation bandwidth.

The compact instruments can be used with their own internal trigger or with an external trigger. Advanced triggering capabilities simplify time-dependent power measurements of signals as found in systems such as Long-Term Evolution (LTE), WiMAX, and Global System for Mobile (GSM) wireless-communications systems. The USB power sensors can also handle production-line testing, with fast measurement speeds for outstanding throughput in production-test applications.

The power sensors perform more than 1,600 readings/s for continuous measurements, and more than 11,000 readings/s for buffered measurements. In fact, for true ease in setups and measurements, the USB power sensors deliver accurate test results without need of zeroing for power levels of greater than –45 dBm.

The USB power sensors are protected against damage from "over-zealous" input power levels of as much as +30 dBm for CW signals and up to +34 dBm for pulsed power peaks of less than 10 μs at 10% duty cycle. The portable power sensors will connect to any computer with a USB 2.0 interface and draw power from the bus, with current consumption of about 410 to 450 mA.

In addition to the USB port, the MA24208A and MA24218A are equipped with Type-N male connectors. The power sensors weigh 397 g (0.88 lb.) and measure 110 × 46 × 25.6 mm excluding the Type-N connector. They're characterized for accurate measurements over an operating temperature range of 0 to +50°C.

The MA24208A and MA24218A USB power sensors perform fast and accurate power measurements across a wide dynamic range and total frequency range of 10 MHz to 18 GHz.

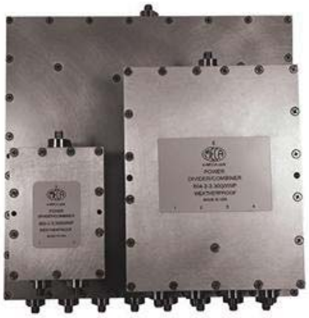
Both sensors are compatible with most of the company's handheld instruments, including the Site Master cable and antenna analyzer, the Spectrum Master handheld spectrum analyzer, the Cell Master cellular base-station analyzer, and the VNA Master vector network analyzer (VNA).

The MA24208A and MA24218A can be used with any Windows-based PC and operated by means of the PowerXpert analysis and control software from Anritsu. The software contains drivers for the power sensors and applications to speed and simplify power measurements. A straightforward user's guide is available for free download, with the software, in PDF format on the firm's website. mw

ANRITSU CO., 1155 East Collins Blvd., Suite 100, Richardson, TX 75081; (800) 267-4878, (972) 644-1777, Fax: (972) 671-1877, *www.anritsu.com*

Rugged Power Dividers Span 0.5 to 6.0 GHz

A LINE OF rugged coaxial power dividers from MECA Electronics has been expanded to include two-, four-, eight-, and 16-way dividers capable of handling 30 W continuous-wave (CW) input power from 0.5 to 6.0 GHz. The units are designated models 8xx-2-3.250WWP, where xx = 02, 04, 08, and 16 for the number of output ports. As an example, model 802-2-3.250WWP is a two-way power divider with typical insertion loss of 0.6 dB from 500 MHz to 6 GHz and maximum insertion loss of 1.3 dB across that frequency range. It maintains amplitude balance within 0.3 dB and achieves typical isolation between ports of 22 dB. The typical input VSWR is 1.25:1 and typical output VSWR is 1.20:1. The power divider maintains phase balance within 5 deg. across the frequency range. It measures 4.46 × 2.50 × 0.92 in. and weighs 12 oz.



The power dividers increase correspondingly in size and weight along with the number of ports. The largest member of the group, model 816-2-3.250WWP, is a 16-way power divider with worst-case insertion loss of 4.5 dB and typical insertion loss of 2.5 dB from 500 MHz to 6 GHz. It maintains amplitude balance within 1.2 dB across that frequency range, with worst-case phase imbalance of 15 deg. Typical full-band isolation is 20 dB. The 16-way power divider offers 1.30:1 typical input and output VSWR. It measures 17.00 × 7.96 × 0.92 in. and weighs 10 lbs.

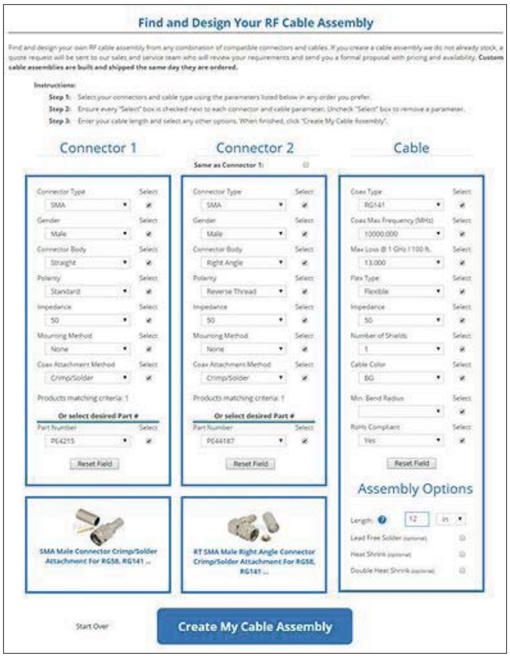
All four power dividers are o-ring sealed and provided in RoHS-compliant aluminum housings with stainless-steel connectors. The power dividers are IP67 weatherproof rated and suited for both indoor and outdoor applications. They are available with a variety of connector types, including Type-N and SMA connectors. All of the power dividers are designed for operating temperatures from –55 to +85°C.

MECA ELECTRONICS, INC., 459 East Main St., Denville, NJ 07834; (973) 625-0733, *www.e-MECA.com*

Web Tool Helps Build Coaxial Cables

COAXIAL CABLE ASSEMBLIES usually require specific connectors at either end, along with a particular type of cable (e.g., one of the flexible or semi-rigid variety). But just as importantly, a cable assembly must meet a set of performance requirements, including minimal loss for a given frequency range. While most cable/connector suppliers provide full test results with an order, the latest on-line software tool from Pasternack Enterprises—Cable Assembly Designer—allows cable assembly specifiers to experiment with different combinations of cables and connectors (and quickly view the performance results for each combination). Pasternack supplies more than 1,300 different connector types and 115 varieties of coaxial cables for more than 250,000 different potential combinations.

Cable Assembly Designer provides a work screen with simple, three-step instructions and three columns for the two connectors and the cable. For the connector columns, users can select connector type, connector body (such as a straight or right-angle connector), gender, polarity, impedance, and even the connector-to-cable attachment method (like a crimp/solder attachment). For the cable column, users can choose cable type, maximum frequency, maximum loss per 100 ft. of cable at 1 GHz, impedance, number of shields, the minimum bend radius, and whether or not the cable is RoHS-compliant. An assembly screen shows pictures of each connector along with options for a cable assembly, including an optional heat shrink, lead-free solder, and even custom labeling.



The selection screen ensures that all the parameters needed to meet the performance requirements for a cable assembly have been entered, including the desired length and number of assemblies. The tool sends a request for quote (RFQ) to Pasternack's sales and service team for rapid response on pricing, availability, and a part number for the cable assembly. The RF Cable Assembly Designer is available at www.pasternack.com/t-custom-cable-designer.aspx.

PASTERNACK ENTERPRISES, INC., 17802 Fitch, Irvine, CA 92614; (866) 727-8376, (949) 261-1920, FAX: (949) 261-7451, www.*pasternack.com*

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Bias Tees Power 10 MHz to 40 GHz

A LINE of bias tees introduced at the recent IEEE International Microwave Symposium (IMS) event includes units covering a total frequency range of 10 MHz to 40 GHz. Suitable for biasing active components and systems, bias tees in the BTHC series cover 500 MHz to 4 GHz, with bias tees in the BTS series spanning 10 MHz to 18 GHz, and in the BTHF series operating from 10 MHz to 40 GHz. The high-current BTHC series can handle current levels to 7 A. The bias tees, which are available as RoHS-compliant components, are matched to 50 Ω and designed for use at operating temperatures from –55 to +100°C. For example, model BTHF-40G operates from 10 MHz to

40 GHz with typical insertion loss of 1.5 dB. Minimum return loss is 12 dB with minimum VSWR of 1.70:1. The bias tee provides minimum dc port isolation of 25 dB and handles 250-mA maximum dc current. In contrast, model BTHC-4G operates from 500 to 4000 MHz with 0.7-dB typical insertion loss and 15-dB minimum return loss. The device exhibits maximum VSWR of 1.50:1 with 25-dB minimum bias port isolation and is able to handle 7-A current. Most units are supplied with SMA connectors.

TTE FILTERS LLC, 11652 West Olympic Blvd., Los Angeles, CA 90064; (310) 478-8224, *www.tte.com*

Power Amplifier Ranges from 6 to 18 GHz

CLASS AB linear power amplifier model BHE69189-50 is a rugged rack-mount unit capable of at least 40-W, 3-dB output power and 50-W typical saturated output power with 45-dB typical gain at 40-W output power from 6 to 18 GHz. Second- and third-harmonic rejections are better than –12 and –22 dBc,

respectively, with third-harmonic rejection of better than –60 dBc. The amplifier, based on the latest gallium-nitride (GaN) solid-state device technology, is rated for a maximum RF input overdrive level of +10 dBm. It measures 19.0 × 22.0 × 3.5 in. and weighs 40 lbs., and comes with standard Type N female connectors (SMA or TNC connectors are optional).

COMTECH PST, 105 Baylis Rd., Melville, NY 11747; (631) 777-8900, FAX: (631) 777-8877, E-mail: sales@comtechpst.com, *www.comtechpst.com*

CuBe Gaskets Help Reduce EMI Levels

A LINE of Fingerstock copper-beryllium (CuBe) gaskets is well-suited for use as electromagnetic-interference (EMI) absorbers in electronic-equipment enclosures. The materials are formulated to provide high reliability. Gaskets come in a wide range of styles and sizes, and operate in spaces from 0.010 to 0.410 in. Available as thin as 0.002 in., soft gaskets can be supplied for applications where low compression force may be part of achieving a secure EMI seal.

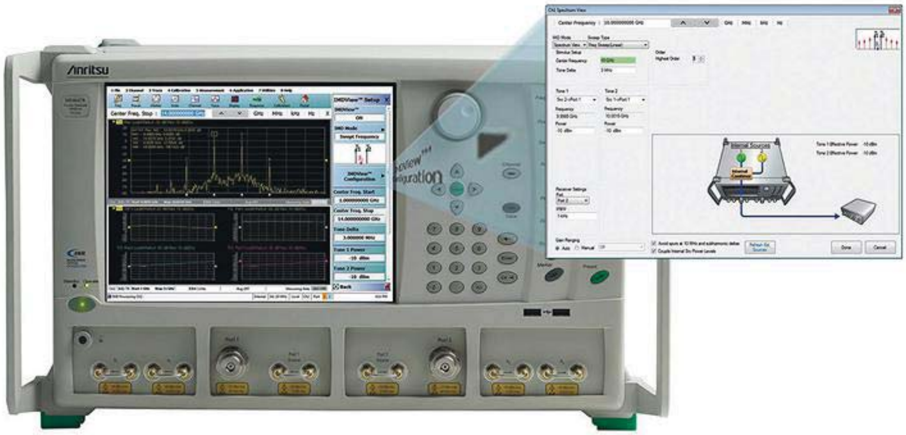
LEADER TECH, 12420 Race Track Rd., Tampa, FL 33626; (866) TECH-EMI, (866) 832-4364, FAX: (813) 855-6921, *www.leadertechinc.com*

SP20T PIN Diode Switch Channels 4 to 18 GHz

MODEL P20T-4G8G-80-T-515-SFF is an absorptive, single-pole, 20-throw (SP20T) PIN diode switch designed for use from 4 to 18 GHz. It maintains insertion loss at 4 dB or less and provides 80-dB isolation. The SP20T switch achieves 2-μs switching speed (50% TTL to 90% RF or 10% to 90% RF) with maximum VSWR of 2.0:1. It incorporates a TTL-compatible driver for ease of system integration and works with 5-b decoded TTL control. The switch-

ing runs on 300 mA at +5 V dc and 200 mA at +15 V dc, and is rated for an operating temperature range of –20 to +85°C. It comes with SMA female connectors.

PLANAR MONOLITHICS INDUSTRIES (PMI), 7311-F Grove Rd., Frederick, MD 21704; (301) 662-5019, FAX: (301) 662-1731, E-mail: sales@pmi-rf.com, *www.pmi-rf.com*



Software Augments VNA IMD Measurements

A NUMBER of options added to the VectorStar family of vector network analyzers (VNAs) were developed with the intent of aiding intermodulation (IMD) measurements. New IMDView software delivers a straightforward graphical user interface (GUI), which makes complex IMD measurements much easier with a VNA. The software and VNA combination allows operators to modify key parameters while witnessing the effects of those changes. In addition, the software helps track frequency bands of interest and power levels of the two tones used in the IMD measurements. An internal RF combiner/switch option provides single-connection IMD measurements without the need to reconnect cables in a measurement setup. This reduces setup and measurement time and improves overall accuracy by reducing concatenation errors.

ANRITSU CO., 490 Jarvis Dr., Morgan Hill, CA 95037-2809; (408) 778-2000, FAX: (408) 776-1744, *ww.anritsu.com*

VCXO Squeezes into Small Cells

A COMPACT voltage-controlled crystal oscillator (VCXO), which was exhibited at the recent IEEE IMS, saves space in small communications cells, such as femtocells. The RoHS-compliant VCXO provides high-speed CMOS (HCMOS) or low-voltage positive-emitter-coupled logic (LVPECL) outputs, and handles fundamental frequencies from 100 to 250 MHz. The miniature VCXO can be supplied in surface-mount housings measuring just 7.0 × 5.0 mm or 5.0 × 3.2 mm. Typical jitter performance is 0.5 ps for HCMOS units and 0.2 ps for LVPECL units. Standard frequencies include 100, 122.88, 125, and 156.25 MHz.

CTS ELECTRONIC COMPONENTS INC., a subsidiary of CTS Corp., (800) 982-5737, (508) 435-6831, E-mail: frequencysales@ctscorp.com, *www.ctscorp.com*

Downconverter Translates Dual Bands to 12.75 GHz

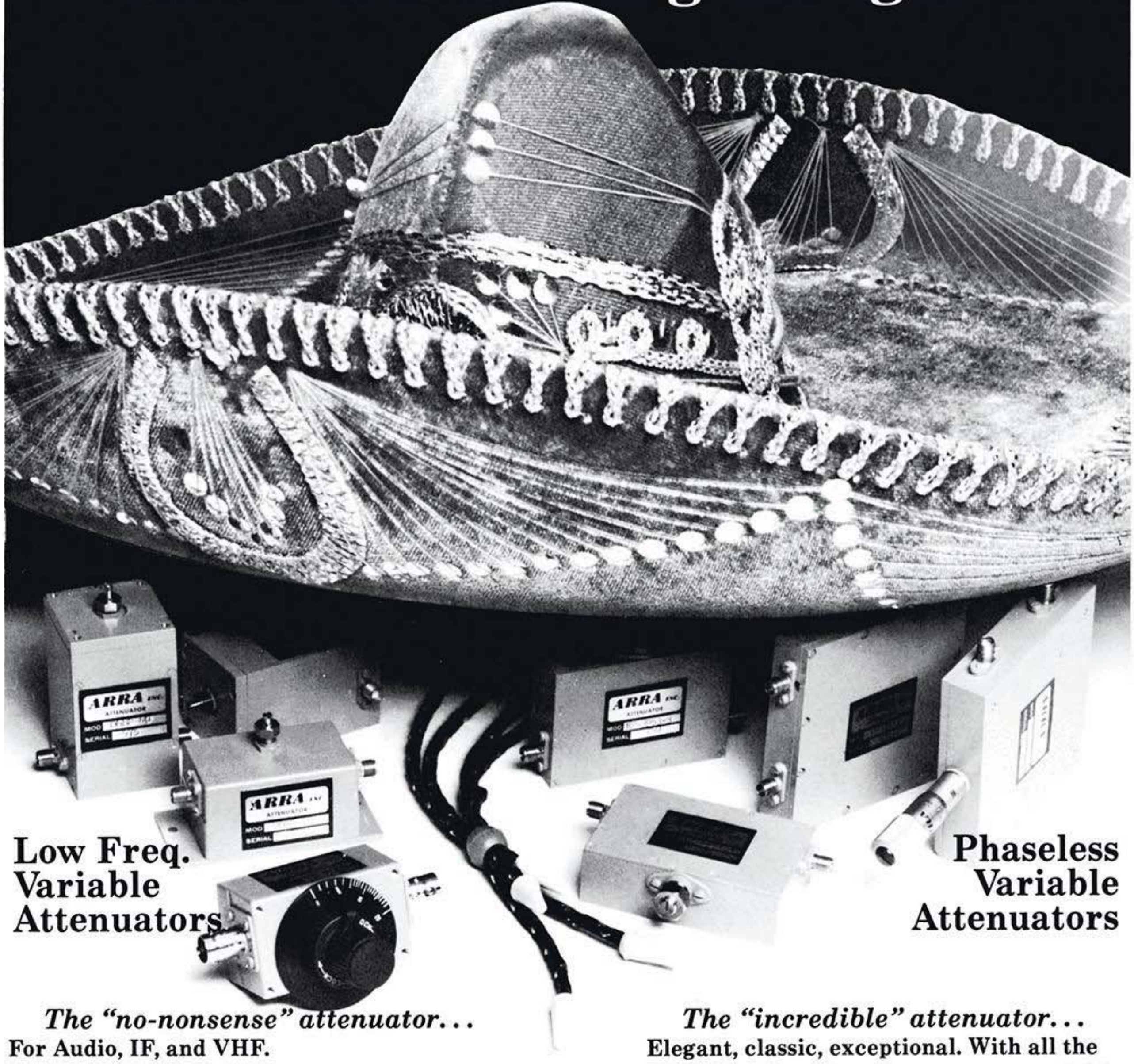
DUAL-BAND DOWNCONVERTER model MFC146 translates frequency bands of 10.7 to 11.7 GHz and 11.70 to 12.75 GHz with low noise figure and low phase noise. Supplied in a compact, rugged, low-profile enclosure, the Ku-band downconverter suits very-small-aperture-terminal (VSAT) satellite-communications (satcom) applications such as in-flight entertainment systems and unmanned-aerial-vehicle (UAV) communications. It delivers intermediate-frequency (IF) bands of 950 to 1950 MHz for the 10.7- to 11.7-GHz band and 1100 to 1250 MHz for the 11.70- to 12.75-GHz band. Noise figure is typically around 9 dB and no worse than 13.5 dB, while phase noise is no worse than –95 dBc/Hz. Spurious performance is better than –90 dBc while group-delay variations are ±1 ns. The downconverter, which includes digital band selection and built-in-test-equipment (BITE) circuitry, runs on +7.5 and ±12 V dc; a 10-MHz external reference is required.

TRAK MICROWAVE, (888) 901-7200, (813) 901-7200, FAX: (813) 901-7491, E-mail: sales@trak.com, *www.trak.com*

Broadband SPDT Switch Receives Design Support

FOR BROADBAND signal control, Richardson RFPD announced full design support for the model PE42524 HaRP reflective single-pole, double-throw (SPDT) switch die from Peregrine Semiconductor. The UltraCMOS switch, which operates from 10 MHz to 40 GHz, achieves 47-dB isolation and only 2.2-dB insertion loss at 30 GHz. The active port return loss is 17 dB at that same frequency. Isolation remains 33 dB at 40 GHz while insertion loss climbs to only 5.5 dB at 40 GHz. The switch chip is well-suited for applications in broadband communications and test equipment.

RICHARDSON RFPD, 1950 S. Batavia Ave., Suite 100, Geneva, IL 60134; (630) 262-6800, FAX: (630) 262-6850, *www.richardsonrfpd.com*



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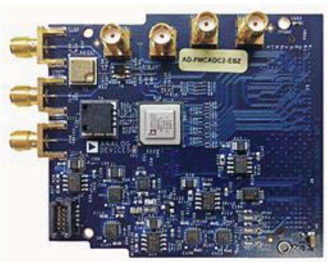
Major navigation system deal inked p|S11
Radar technology keeps evolving p|S12
Packaging solutions for aviation p|S16



HIGH-SPEED ADCs Tame Wideband EW Receivers

MODERN ELECTRONIC-WARFARE (EW) system designers are facing numerous challenges when attempting to develop effective solutions, including increased spectral congestion and more sophisticated surveillance techniques. Designers also are being pushed to reduce development times, driving them to employ custom hardware and firmware to achieve required levels of performance within size, weight, and power constraints.

Fortunately, by properly applying high-speed data converters and fast digital-signal-processing (DSP) components, such as field-programmable gate arrays (FPGAs), effective EW solutions are possible. To demonstrate, a reference design employing high-speed analog-to-digital converters (ADCs) from Analog Devices (www.analog.com) and FPGAs and channelization IP from Altera (www.altera.com) offers an effective solution for EW systems—one that enables fast time to market for EW and digital RF memory (DRFM) systems.

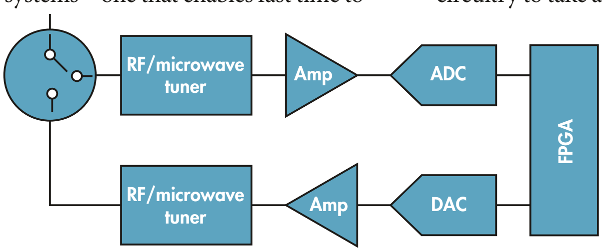
EW systems, which identify and counter electronic threats such as tracking radar systems, are commonly categorized either as electronic-support (ES), electronic-attack (EA), or electronic-protect (EP) systems. ES systems intercept and measure signal parameters to identify the source and perform threat analysis. EA systems generate jamming signals to overpower the pulsed signals from a target radar.

Radar systems can also be "confused" by the use of a DRFM, an integrated circuit or subsystem that can generate false radar return signals to deceive a radar. EP systems concentrate on processing and storing incoming signals to construct a signal database.

Traditionally, these systems were developed on an analog electronic platform, but newer systems rely more on digital circuitry to take advantage of the signal-processing capabilities available in modern programmable logic devices (PLDs).

Threat detection from unknown targets in these systems requires a receiver that can operate over a wide frequency band

(continued on p. 20)



1. This signal chain is found in typical electronic-warfare (EW) receivers.

STRONG GROWTH PROJECTED for Military Radar Systems

VISIONGAIN (www.visiongain.com) has announced the availability of a massive 10-year (2015-2025) projection of global military radar markets, with strong growth projected for the next decade. The report includes reviews of leading defense contractors, including BAE Systems, General Dynamics, Lockheed Martin, Northrop Grumman, and Raytheon Co. Predictions refer to the three major forms of radar systems: airborne, naval, and land-based.

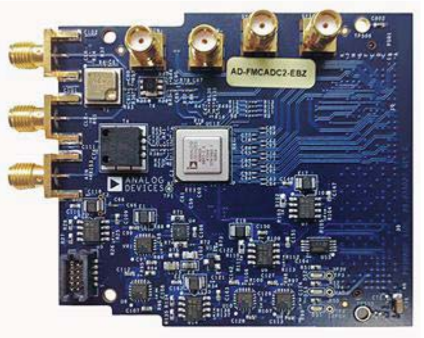
The 279-page report contains over 220 tables of data and predictions on the major radar markets and systems. It projects the global military radar systems market to reach $9.42 billion in 2015, with growing demand for military radar systems and technology throughout the forecast period. Growth is spurred by the needs of many nations to upgrade their radar technology, to perform surveillance and weapons control, and even to monitor their borders for potential terrorist threats.

Applications for radar systems continue to expand in air, naval, and ground-based applications, and many other military applications, such as electronic countermeasures (ECM) and electronic-warfare (EW) systems, depend on radar systems for their successful operation.

(News continued on p. 6)

defense electronics

In This Issue



C1

FEATURES

C1 **COVER STORY:**

HIGH-SPEED ADCs TAME WIDEBAND EW RECEIVERS
High-speed analog-to-digital converters are available with suitable bandwidths to support the design of wideband, wide-dynamic-range channelized electronic-warfare receivers.

.

S12 RADAR TECHNOLOGY GUARDS FROM LAND TO SEA
Since World War II, radar technology has been evolving worldwide into many types of CW and pulsed systems.

S16 PACKAGING SOLUTIONS FLY IN AVIATION APPLICATIONS
System enclosures must provide proper thermal management while keeping shock and vibration at bay.

S12

S6

S16

S2 **EDITORIAL**

NEWS SHORTS

C1 STRONG GROWTH PROJECTED FOR MILITARY RADAR SYSTEMS

S6 RADAR TECHNOLOGY STRENGTHENS KOREAN SURVEILLANCE EFFORTS

LITHIUM-ION BATTERIES DRIVE MILITARY VEHICLES

REPORT EXPLORES LEAD-FREE ELECTRONICS FOR MILITARY AND AEROSPACE APPLICATIONS

S8 ROYAL CANADIAN NAVY ENLISTS WIDEBAND RADIOS

IFS TOOLS HELP DYNCORP MANAGE IN AFGHANISTAN

S9 TACTICAL RADIOS BUILD UPON EMBEDDED FPGAs

DARPA PROGRAM PUSHES FOR HYPERSONIC MATERIALS

S10 PROGRAM SEEKS IMPROVED ASSESSMENT OF TARGETS

CONTRACTS

S11 NAVIGATION SYSTEMS STEER MILITARY VEHICLES

PORTABLE SCANNER SOUGHT FOR IMPROVED THREAT DETECTION

NAVY TUNES TO MERCURY SYSTEMS FOR RADIO SPARES

S22 **PRODUCTS**

S24 **ADVERTISERS INDEX**

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Radar Grows
Beyond Military Needs

RADAR SYSTEMS and technologies have long been synonymous with military applications. Starting with World War II, as vehicles and weapons began their march toward greater sophistication, requirements for radar systems have followed suit. With their capabilities to "see" targets from a distance, radar has long been invaluable.

Radar technology has evolved into many different forms of systems, from basic continuous-wave (CW) systems to more complex systems with different lengths of pulses and modulation formats. In most cases, military radar systems are attempting to detect and identify targets that are not supposed to be detected. But radar technology has grown a great deal over the years, and is increasingly used in non-military applications for detecting such things as weather patterns and vehicle speeds on interstate highways.

With regard to the latter, radar has been used by law enforcement professionals since the 1950s for vehicle speed detection. Ironically—following the behavior practiced by military forces when using electronic countermeasures (ECM) systems to detect and thwart enemy radar, electronic-warfare (EW), and other military electronic systems—civilians now purchase radar detectors for their vehicles to help locate police radar sources.

In the hospital, the use of radar systems is growing quickly for medical purposes—specifically, for noncontact monitoring and measuring of vital signs. Radar technology detects the movements of key organs, such as the lungs and heart. Initial medical radar systems involved CW signals, but more recent systems have been designed to use pulsed signals as in advanced military radar systems. The pulses provided more capabilities, like measurements of organ movements.

Non-military uses for radar technology continue to expand. Vehicular radar systems, for example, are now employing 77-GHz with Doppler techniques for such functions as adaptive cruise control and pe-crash collision-avoidance warnings. As leading semiconductor suppliers develop more affordable millimeter-wave devices at such high frequencies, radar developers can offer competitive prices that spread these radar-based products to the masses.

Military users depend more on radar with each new conflict and advance in weaponry. But they are no longer alone, as civilian and industrial users continue to appreciate the benefits of this versatile technology. de

JACK BROWNE, *Technical Contributor*

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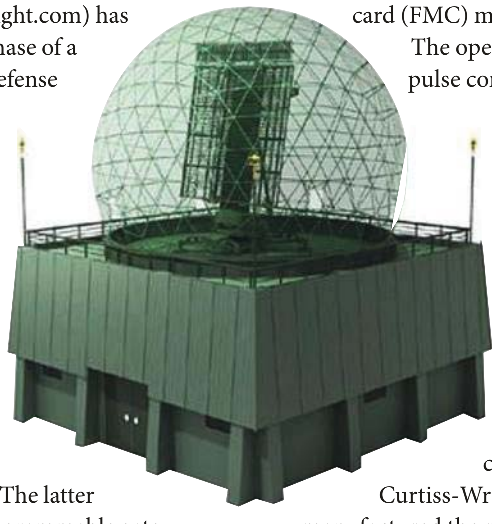
RADAR TECHNOLOGY Strengthens Korean Surveillance Efforts

THE DEFENSE SOLUTIONS DIVISION of Curtiss-Wright Corp. (www.curtisswright.com) has completed the development phase of a contract from South Korean defense contractor LIG Nex1 (www.lignex1.com) to supply commercial-off-the-shelf (COTS) radar processing module technology. The technology is targeted for the Korean Army's Next-Generation Local Air Defense Radar and Korean Air Force's Long-Range Surveillance Radar programs.



As part of the contract, Curtiss-Wright provided its latest OpenVPX modules to LIG Nex1, along with a variety of supporting modules. The latter includes a high-performance field-programmable gate array (FPGA), single-board computer (SBC), digital signal processor (DSP), network switch, and FPGA mezzanine-card (FMC) modules.

The open-architecture modules enable the pulse compression and beamforming functions for LIG Nex1's surveillance radar systems. The development phase for the two radar systems began in 2012 and was recently completed. LIG Nex1 has shown advanced radar-technology capabilities during the three-year development period. These include performing multiple digital beamforming and pulse-compression techniques using radar signal-processing algorithms with several of the Curtiss-Wright SBC modules. The company manufactured the modules for this contract at its facility in Ottawa, Ontario, Canada. ■

LITHIUM-ION BATTERIES Drive Military Vehicles

THE XCELION 6T LITHIUM-ION (Li-ion) battery has been developed by Saft (www.saftbatteries.com) as a drop-in replacement for traditional lead-acid batteries in military vehicles. The new battery is claimed to provide the equivalent power of two lead-acid batteries for a fraction of the weight and volume. The Li-ion battery was recently selected by leading defense contractor Lockheed Martin (www.lockheedmartin.com) for its Joint Light Tactical Vehicle (JLTV) products. The new batteries, which will be used to power modern communications and sensor systems in military vehicles, offer higher energy densities and longer operating lifetimes than lead-acid batteries.

Saft has been involved in a two-year program to develop the batteries as a commercial-off-the-shelf (COTS) product at reduced cost, for use in industrial and commercial markets. According to Thomas Alcide, president of Saft America and general manager of Saft's Specialty Battery Group: "By reducing the cost and time to build the Xcelion 6 battery, Saft is ready to offer this product to replace lead-acid batteries, not only on all military vehicles worldwide, but also for many commercial applications."

The Saft 6T Li-ion battery is a +28-V dc unit capable of 60-Ah current that has been designed within the dimensions of a traditional lead-acid battery for vehicular use. It can be used for vehicle starting, lights, ignition, and other military systems, including jammers, communications, and control equipment on board the vehicle. ■

REPORT EXPLORES LEAD-FREE ELECTRONICS for Military and Aerospace Applications

LEAD-FREE SOLDER has had considerable effects on commercial and industrial electronics assemblies and printed-circuit boards (PCBs), and may have growing impact on military and aerospace applications. This assessment comes courtesy of a market research study by IPC—Association Connecting Electronics Industries (www.ipc.org). The IPC report, "Issues and Outlook for Lead-Free Electronics in Military and Aerospace Applications," explores current and future expectations for lead-free solder use within high-reliability applications.

The study examines the costs of reworking circuit assemblies into

lead-free formats and how such transformations will affect production processes and costs. As Sharon Starr, IPC director of market research, notes: "Many manufacturers today must depend on a dual supply chain to accommodate both leaded and lead-free processes. The study finds that maintaining dual processes, along with the growing scarcity of some leaded components, adds extra costs." The study also investigates the expected effects of scarce leaded components, as more electronic parts move to a lead-free format. The cost of the report is $250 each for IPC members and $500 each for nonmembers. ■

ROYAL CANADIAN NAVY Enlists Wideband Radios

ROCKWELL COLLINS recently completed delivery of 85 wideband radios to the Royal Canadian Navy (RCN) fleet in support of the advanced SubNet Relay (SNR) system. The model 721S radios enable data rates to 2 Mb/s within 500-kHz channels. The drop-in, software-defined-radio (SDR) technology is a replacement for legacy Rockwell Collins AN/GRC-171 radio systems, weighing 60% less than its predecessor. "The RCN is a strong supporter and early adopter of the Canadian-developed SNR capability, which is now fielded internationally," says Alan Prowse, vice president and managing director for the Americas for Rockwell Collins (www.rockwellcollins.com).

The model 721S radio incorporates the firm's patented Clarity technology, which eliminates background noise in both transmit and receive modes and provides four times the communications coverage compared to legacy radios. The radio is fully interoperable with legacy radios in use by coalition armed forces. ■

IFS TOOLS Help DynCorp Manage in Afghanistan

MANAGING AND MAINTAINING systems in Afghanistan under pressure is not easy, but tools from software developer IFS (www.ifsworld.com) have helped DynCorp. International (www. dyn-intl.com) to literally keep the peace. DynCorp. International upgraded its IFS Applications software tools to support ongoing U.S. Department of Defense (DoD) projects in aviation maintenance deployed within Afghanistan. DynCorp supports several DoD contracts and is using IFS Applications to provide additional capabilities for two of the company's aviation programs. Consequently, this will assist in the transition of capabilities to national organizations within the country.

DynCorp is exploiting the IFS Fleet and Asset Management software program—along with its supply-chain capabilities—to support helicopter maintenance in Afghanistan, helping to manage a fleet of more than 100 aircraft. As Steven Schorer, president of DynCorp International, explains: "We chose IFS Applications to gain a wider range of tools. Their solution enables us to increase our maintenance management and logistics functions, access information from multiple locations, and empower our team members to best support our global customers." ■

TACTICAL RADIOS Build Upon Embedded FPGAs

CERTIFICATION BY the National Security Agency (NSA) requires a radio that can provide secure voice and data communications across a wide range of conditions. The Falcon III wideband tactical radio from Harris Corp. (www.harris.com) has earned Type-1 certification from the government agency.

Inside each radio, field-programmable gate arrays (FPGAs) from Altera (www.altera.com) help the systems achieve lower size, weight, and power and lower cost (SWaP-C), in addition to enabling the NSA Type-1 certification. The Cyclone V FPGAs are fabricated with a 28-nm semiconductor process.

To earn the security approval, Altera successfully completed the NSA Information Assurance Directorate (IAD) Secure Implementation Guidelines (SIG) document, which provides unified government recommendations on the use of security settings. The FPGAs help the radios to achieve radio modem and cryptography functionality, while also reaching SWaP goals with longer battery operating lifetime in the field.

Altera is also working with the NSA IAD on SIG documents for its 20- and 14-nm FPGAs, as well as its systems-on-chips (SoCs). ■

DARPA PROGRAM Pushes for Hypersonic Materials

HRL LABORATORIES, LLC (www.hrl.com) will be developing new materials for hypersonic vehicles as part of the Materials Development for Platforms (MDP) program managed by the Defense Advanced Research Projects Agency (DARPA). The new materials are intended to reduce the weight and cost of vehicle aeroshells while withstanding the challenging conditions encountered during hypersonic flight.

The MDP program was introduced to compress the development time of typically 10 years for new materials to a more-manageable 2.5 years. Materials for hypersonic flight must travel through air at more than five times the speed of sound, which can generate exterior temperatures in excess of several thousand degrees Fahrenheit.

The HRL team will attempt to combine innovative additive-manufacturing techniques with new high-temperature materials. It will take advantage of such materials as polymer-derived ceramic materials and sandwich architectures to create optimized structures.

The team leader, Dr. Tobias Schaedler, explains: "Sandwich panels are used throughout the aerospace industry for lightweight, load-bearing structures, but their use in high-temperature applications has been limited by the availability of structurally robust high-temperature cores and scalable fabrication techniques. Our goal is to solve these challenges and develop ceramic sandwich structures that enable weight savings across a wide range of high-temperature applications." ■

PROGRAM SEEKS Improved Assessment Of Targets

AS PART of a two-year contract with the U.S. Air Force Research Laboratory, Modus Operandi (www.modus-operandi.com) is developing improved software components for an Air Force targeting platform known as CATALiST. This targeting platform is designed to improve the analysis and assessment of battlefield targets, and Modus Operandi's workflow modules will provide enhanced "intelligence" for the battlefield tool. The Melbourne, Fla.-based software developer's workflow modules will also automate what is now a time-consuming manual process for the identification of battlefield targets.

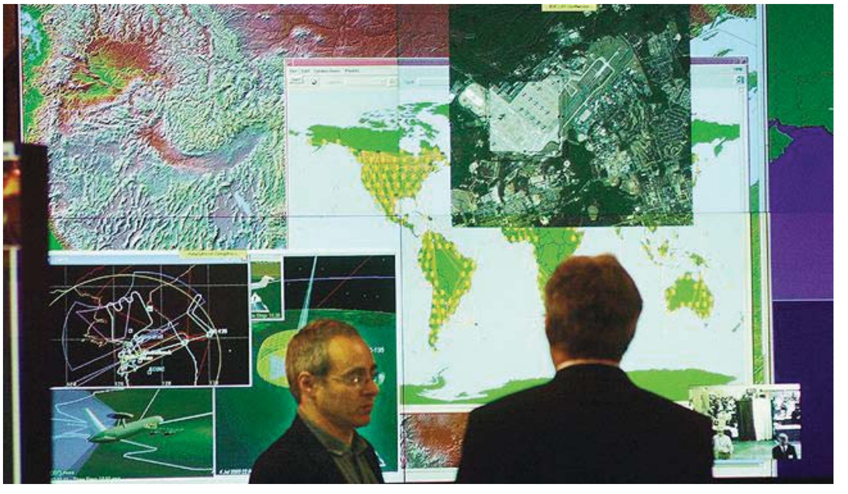
The workflow modules will be based on automating the processes for collecting and assessing targeting information, using a semantics-based approach similar to the well-known Internet-based Facebook application. The smart targeting solution will also use open-source software along with the software tools already developed by the AFRL, working in a Rome, N.Y. research facility.

The targeting software tools employ knowledge management technology, as well as data analysis and visualization technologies to perform effective identification and processing of targeting information. The AFRL admits that it currently works with manual targeting processes and hopes to automate these functions with the new software modules. The intent is for the modules to assist in avoiding collateral damage, such as the identification of false targets, and other sensitive phased of target selection. The modules will be part of a full-featured targeting process that will leverage analytical tools to reduce human error. ■

Navigation Systems Steer Military Vehicles

KVH INDUSTRIES (www. kvh.com) has received a $1.5-million contract for the delivery of tactical navigation systems for an undisclosed armored vehicle application. The system in question is a variant of KVH's TACNAV TLS and TACNAV Light, which helps military vehicle personnel maintain full situational awareness. KVH's TACNAV military vehicle navigation systems, which are used by U.S. Army and Marine Corps customers, provide unjammable precision navigation, heading, and pointing data for vehicle drivers, crews, and commanders. According to the terms set forth in the contract, hardware shipments for the order are expected to be made in 2015. Program management and engineering services will be provided as part of this order.

"KVH's TACNAV navigation solution is an important tool for U.S. and allied warfighters, providing precision navigation as well as coordination of vehicles in critical situations," says Dan Conway, executive vice president of KVH's guidance and stabilization group. "The system serves as a crucial resource for navigation and battle management, keeping soldiers safe and out of harm's way wherever they travel." ■



Portable Scanner Sought for Improved Threat Detection

AS PART of the war on terrorism, the United States Department of Defense (DoD) has awarded a $2.1-million contract to Decision Sciences (www.decisionsciencescorp.com) for development of a new type of portable electronics scanner for threat detection. The contract is from the DoD's Combating Terrorism Technical Support Office (CTTSO) for Decision Sciences International Corporation (DSIC)—an advanced technology provider of security and detection systems—to build a scanner for use in domestic and overseas applications.

"We are very pleased to once again have an opportunity to work with the Department of Defense through CTTSO and support its critical mission to combat terrorism at home and abroad through technical innovation," says Dr. Gene Ray, chief executive officer of DSIC.

As part of the contract, DSIC will create a prototype system capable of detecting small amounts of explosive materials within portable electronic devices, such as mobile telephones and laptop computers. The MMPDS uses muons and electrons to detect shielded and unshielded nuclear and radiological threats, as well as explosives, narcotics, and other materials within electronic devices. ■

Navy Tunes to Mercury Systems for Radio Spares

THE U.S. Naval Warfare Center, Crane Division (NSWC) has awarded a $7.1-million indefinite-quantity/indefinite-delivery (IDIQ) contract to Mercury Systems (www.mrcy.com) for advanced RF tuners, digital receivers, and related equipment. The radio gear is meant to serve as spares during the installation of the AN/SLQ-32(V)6 electronic countermeasure system on U.S. Navy and Coast Guard ships. Work on the contract, which will be performed at Mercury's Chelmsford, Mass. facility, is expected to be completed by May 2020. The AN/SLQ-32(V)6 is part of the Navy's Surface Electronic Warfare Improvement Program (SEWIP), an upgrade to the AN/SLQ-32 electronic warfare (EW) anti-ship missile defense system.

According to Charlie Hudnall, general manager of Mercury's Embedded Sensor Products group, "The Navy's requirement to deny or degrade hostile uses of the electromagnetic spectrum has placed new demands on existing electronic warfare systems…"This contract reaffirms Mercury's leading-edge capabilities in RF, digital signal processing and data movement." ■

JACK BROWNE | Technical Contributor

Radar Technology
Guards from Land to Sea

Since World War II, radar technology has been evolving worldwide into many types of CW and pulsed systems for commercial, industrial, and military/aerospace applications.

RADAR SYSTEMS are essential elements in any military organization's defense efforts, whether on land or at sea. They are simple in concept: transmit a pulse and then receive the reflections from a target to extrapolate information about that target. To civilians, radar technology is considered important but fairly standard among the different armed forces.

Nevertheless, the number of different radar systems and technologies in use by the armed forces is quite staggering. These systems are constantly undergoing improvements as RF/microwave components and subsystems evolve—for instance, the availability of higher-power gallium-nitride (GaN) semiconductors in smaller packages.

Radar technology has evolved a great deal from its origins in World War II. Not only is it now integrated into systems for land, sea, and air defense-related applications, but it has been adapted for prediction weather, medical use, and even at millimeter-wave frequencies for automotive use in collision-avoidance systems.

In its simplest form, a radar consists of a transmitter that broadcasts pulsed signals in search of a target, whether known or unknown. A radar receiver detects pulse reflections from a target and the amplitude of those signals—along with the differences in time of arrival and the time that the pulses were transmitted—to determine information about the target, including size, location, and direction.

Military radar is used to detect a wide range of targets, including land vehicles, ships, aircraft, projectiles, missiles, and satellites. Radar is also used to guide weapons to a particular target, and helps navigate ships and aircraft. Pulse radar systems are the most essential forms of radar, using repetitive strings of short pulsed signals to identify a target. Some of these systems rely on simply receiving the reflected pulse echoes to determine information about the target from the nature of those returning signals.

Some rely on decoding the Doppler frequency shift of the returning signals in order to reject the radar returns from targets that are not moving. This simplifies the detection of, for example, a ground vehicle, from the surrounding environment (known as clutter). Some of these pulse Doppler radar systems are further designated moving-target-indicator (MTI) radar for their capabilities in detecting moving targets from the objects and environment around them.

MTI pulse Doppler radar systems tend to use low pulse repetition frequencies (PRFs) to achieve an unambiguous target range measurements, such as a PRF in the hertz range. Standard pulse Doppler radar systems are more likely to use a higher PRF—more in the kHz range. A low PRF enables accurate measurements of target range while a higher PRF is more capable of accurate measurements of target speed.

Because aircraft themselves are moving as they attempt to make MTI radar measurements, they employ a variation of the MTI radar system known as the airborne moving-target-indicator (AMTI) radar. Since stationary clutter is moving relative to the moving radar system on the aircraft, these additional Doppler effects must be corrected in an AMTI to execute accurate moving-target measurements.

Synthetic-aperture-radar (SAR) systems are typically moving systems, such

The next-generation AN/SPY-6 air and missile defense radar (AMDR) system is planned for the DDG-51 destroyer starting in 2016. *[Photo courtesy of Raytheon Co. (www.raytheon.com).]*

as on satellites or aircraft, with an antenna beam oriented perpendicular to the direction of travel. An SAR system analyzes sequentially received signals and adds them for analysis, creating a high-resolution image of a target. An inverse SAR (ISAR) works with Doppler frequency shift to obtain movements of a target relative to the movement of the radar system, such as on an aircraft.

SAR and ISAR systems also are referred to as imaging radar systems. The U.S. Defense Advanced Research Projects Agency (DARPA) currently is seeking a radar system that's able to provide the performance of an SAR system, but one that's more cost effective, through its recently announced Advanced Scanning Technology for Imaging Radar (ASTIR) program.

These are just a few examples of the many types of pulsed radar systems used on land, at sea, and in the air by military forces. Radar systems can also operate with continuous-wave (CW) signals. CW radar systems transmit and receive signals at the same time, and depend on the Doppler frequency shift of a moving target to identify it from returned signals from non-moving objects.

CW radar systems can measure the radial velocity of targets from their Doppler frequency shift and determine the direction of arrival of a received signal—but not the range of the target. This basic radar format is typically used for such applications as target tracking and vehicle speed detection.

By using a variation of this radar type, frequency-modulated CW radar (FM-CW radar), the transmitted frequency is continually changing. With such a system, the frequency of the reflected radar signals will differ from the frequency of the transmitted signals according to the changes with time, and it is possible to determine the range of a target according to the proportional changes in modulated frequency with time.

The range of a target also can be determined by using CW signals and changing the phase of the transmitted signals, with the received changes in phase corresponding to the range of the target.

Of course, radar technologies continue to evolve and advance, as major military contractors explore different approaches to improve radar performance at lower power levels. For example, Lockheed Martin (www.lockheedmartin.com) announced encouraging results of testing on a new type of radar system the firm calls a digital beamforming system.

The new technology overcomes the classic shortcoming of phased-array radar systems to seamlessly track multiple targets at the same time, using a dedicated radar beam for each target of interest. It combines advances in digital-signal processing and antenna technologies to synthesize multiple beams from a large array of data that has been received by a radar receiver and digitized.

For the air, Northrop Grumman (www.northropgrumman.com), a pioneer in the active electronically scanned array (AESA) radar system, has outfit F-35 fighter planes with this scanning beam radar system for some time.

For the sea, Raytheon Co. (www.raytheon.com) has developed a next-generation AMDR system in its AN/SPY-6 system. It features a modular design with S- and X-band radar subsystems. It is planned for installation on the DDG-51 flight destroyer *(see the figure)* starting in 2016. The advanced radar system is claimed to be 30 times more sensitive than previous seaborne radar systems.

Mobile counter target acquisition (CTA) radar systems provide a 360-deg.threat detection capability against incoming weapons. Deployed as the AN/TQP-53 truck-mounted mobile radar system and the AN/TQP-50 Humvee-mounted lightweight counter mortar radar, the radar technology uses pulses at different wavelengths and directions to detect different targets.

MORE ROBUST SEMICONDUCTORS

Radar systems are building on progress in high-power RF/microwave semiconductors, notably higher output-power levels available from GaN discrete transistors and monolithic-microwave-integrated-circuit (MMIC) amplifiers. Such semiconductor devices are supporting generation of more than 100 W per device at frequencies through 18 GHz, enabling the miniaturization of high-power land-, sea-, and air-based radar systems. They also enable less reliance on electron-tube amplification, such as traveling-wave-tube amplifiers (TWTAs) for higher power levels at microwave frequencies.

However, with these higher-power semiconductor devices comes a need for improved heat dissipation, and advanced materials are making GaN amplifiers, and higher power levels from microwave semiconductors, possible. In fact, GaN devices often are fabricated as a combination of materials, such as GaN on silicon carbide (GaN-on-SiC) transistors.

Heat-tolerant SiC materials are used in the transmit/receive radar modules so that they can handle higher power levels without overheating, as well as achieve longer detection ranges with high accuracy. Such capabilities are invaluable in tracking multiple enemy targets. de

AHMET TASSEKI | Project Manager MAXIMILIAN SCHOBER | Marketing Manager

Packaging Solutions

Fly in Aviation Applications

Due to the special requirements of aviation applications, system enclosures must provide proper thermal management while also holding up against high levels of shock and vibration.

ELECTRONIC COMPONENTS and systems in aviation applications must endure extreme stresses and strains. Altitudes of over 16,000 m and speed of more than 800 km/h at wide temperature ranges can challenge even the best-designed packaging. Fortunately, air-transportation-rack (ATR) housings have become the *de facto* standard for electronic equipment used in aircraft.

Known as ARINC 404, these ATR cases essentially define equipment dimensions for avionics applications, offering standard mounting options and integrated hardware and cooling. With modular one-half, three-quarter, full, and one-and-one-half ATR sizes, these cases can be cost-effectively used in avionics installations—they're able to withstand shock and vibration to levels of 40 g. The cases also provide excellent protection against equipment-endangering elements such as moisture, sand, and dust.

In general, ATR chassis are designed for operating temperatures from −55 to +85°C. Ambient temperature is about +50°C. If power dissipation in an avionics electronic system is less than 120 W, passive cooling usually is the norm. All heat sources will make contact with the housing shell to dissipate heat, enabling heat sources such as the central processing unit (CPU) to transfer heat to the clamshell, and then to the equipment case via wedge locks.

The case surface can be equipped with cooling fans to aid in the conduction of heat, even in an airtight (IP67 or higher) enclosure. This protects system circuit boards and the power supply from environmental influences and minimizes maintenance under harsh conditions.

1. This lightweight ATR chassis system is designed with thermal management, EMC, and dust/dirt protection. *(Photo courtesy of POLYRACK)*

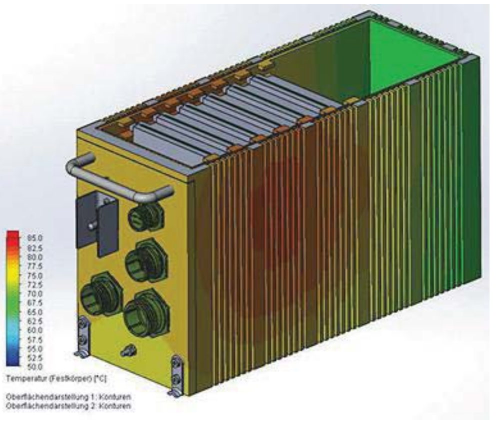
For systems at higher power ratings, additional forced cooling is usually in order. Cooling fins, which are arranged in the direction of ventilation, are covered with an outer plate. Ventilation channels thus form between the outer plates and the actual case. Ventilation is generally installed at the rear of an ATR chassis; the air inlet can be located either at the front or at the sides.

Cool air is pulled in via the air inlet vents and transferred through the ventilation channels, with cooling accomplished by means of conduction and forced-air cooling. This requires fans that are suitable for use at high altitudes, and that deliver the required performance under challenging conditions.

At the same time, the ventilation device must suit the prevailing operating temperatures and atmospheric moisture to ensure a steady air flow even at high pressure. In aviation applications within dry, dusty regions, a washable, electrostatic-discharge (ESD) air filter can help screen out dirt and dust. Hermetically sealed thermostats and fan-fail functions that provide early warning of overload further boost thermal-management reliability.

"Ruggedized" cases typically employ conduction cooling. An aluminum thermal conductor forms a stable mechanical reinforcement; a circuit board can be affixed to them at several points. Double walls guarantee a shock-resistant construction, as do module rails, covers, screws, and other assembly hardware. ATR cases are usually made of aluminum to achieve the lightest weight possible.

Aluminum construction offers an additional benefit: It provides protection against electromagnetic (EM) radiation and permits open grounding across the conductive surface. Electromagnetic compatibility (EMC) plays an important role for system integrity in avionics systems and must be incorporated into the design of a case from component level. To guarantee high EMC, a system should be constructed hermetically.



2. This thermal image shows the temperature flow through an ATR electronic equipment chassis. *(Image courtesy of POLYRACK)*

Removable parts require an EMC/IP combination gasket to prevent interference from external sources and limit emission of interfering signals. Within a system, interference between different boards can be prevented by mechanically separating signal and power areas.

At POLYRACK, one-half short ATR chassis are equipped with plug-in boards completely encased in a metal frame or two metal half shells (clamshells) and screwed to the board *(Fig. 1)*. This not only guarantees EMC protection, but also optimum heat dissipation. The boards are secured in card guides with extractor handles that are easy to manipulate.

Wedge locks provide additional stability against shock and vibration, plus protection against ESD. They also establish the thermal contact between the card and the case wall to dissipate the heat.

Packaging systems for aviation applications must be designed so that they can withstand high levels of shock and vibration. Each has a different impact on an electronic system's components. Shock is a single-pulse event with a certain force, with shock values ranging between 5 and 10 g in industrial systems and to 100 g in military or naval systems.

Shock can subject card and connector contacts to a high level of stress and contact surfaces may become damaged. To counteract this, the type of construction, the choice of material and components, and the application and the installation mode of the system at the site of operation are important packaging considerations.

Vibration, on the other hand, is defined as continuous oscillation with a variable force along one or more axes. Because of vibration, electronic components or materials can resonate, components can break or be damaged mechanically, and screws can loosen over time.

To protect an electronic system from shock and vibration, a POLYRACK ATR chassis interconnects parts by means of dip soldering. This ensures good stability and avoids screw failures, while also enhancing heat transfer. The chassis incorporates VPX backplanes with pilot pins to ensure extra stability of plug-in cards; the slots can be coded by way of the pilot pins. In addition, POLYRACK secures critical components by means of adhesion and uses a "free-floating" assembly concept when mounting assemblies and subassemblies in the case.

Passive isolators are an additional option for damping shock and vibration in electronic-equipment enclosures. Such an isolator consists of a spring that absorbs the shock or vibration and a damping element to dissipate the energy, sometimes as much as 80% of the initial load. The spring is either a wire-rope isolator made of stainless-steel stranded cable or an air spring system.

A one-half short ATR chassis from POLYRACK meets all military requirements for thermal management and EMC/ESD protection *(Fig. 2)*. It complies with the ARINC 404A standard and was designed in accordance with the strictest specifications from security and defense technology. It is qualified to MIL-STD-810G, which tests the reliability of devices subjected to extreme temperatures, high atmospheric pressure, and acceleration forces, among other factors.

This ATR chassis also complies with standards for electrical supply systems in aircraft to MIL-STD-704 and with EMC requirements in accordance with MIL-STD-461. It is suitable for use in airborne fighters and helicopters, as well as in land-based and naval systems.

New materials were deployed in the ATR chassis—e.g., aluminum 606–T651 and other certified materials. Such advanced materials enable lightweight construction, optimal heat dissipation, protection against shock and vibration, and the capability to function at high altitudes. Salt-bath brazing supports the lightweight construction vital for aircraft.

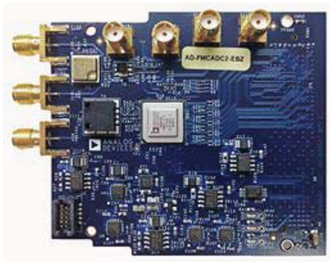
The POLYRACK ATR chassis operates with a conduction-cooled power supply in accordance with VITA 62. Other ac and dc inputs are also available as options. Thanks to a special power supply and the use of special connectors, the chassis meets EMC requirements. All removable case components are sealed with a two-component (2K) material for IP and EMC protection.

The chassis backplane employs OpenVPX technology in accordance with VITA 65 requirements. This allows the extrusion to be scaled and configured to almost any specification and offers a flexible basis for specific technologies with various standards. It works at bit rates to 10 Gb/s, with five 3U slots available in the ATR chassis. In addition to VPX, the system can be configured with CPCI, VME, and VMEX backplanes.

The standard POLYRACK ATR model is available in 13 sizes and versions for compliance with different standards; further customization is also available. In addition, POLYRACK can adapt chassis and shells according to individual custom requirements or on the basis of particular standards, to meet specific custom requirements for equipment packaging. Especially in military and aerospace systems, such packaging needs tend to be quite specialized, and these customization capabilities are able to fill a wide range of provisions. de

(continued from p. 1)

to identify threat signals and initiate countermeasures. Typical EW systems may operate from dc to 20 GHz. In addition to wide-bandwidth requirements, practical EW systems should provide high dynamic range, high sensitivity, and accurate pulse characterization; new systems are being pushed to examine the bandwidths of interest faster with greater levels of detection sensitivity.



2. This 2.5-Gsample/s FMC board provides synchronization support for high-speed AD9625 ADCs.

More complicated situations arise when incoming signals to an EW system arrive from numerous sources, each of which must be identified. Independent of intentional interference from adversaries, increased spectral congestion has made effective detection of threat signals even more challenging.

Demands for EW systems with smaller size, lighter weight, and lower power (SWaP) are making development cycles for new systems longer and more difficult. However, next-generation off-the-shelf solutions coupled with programmable building blocks are providing EW systems that can meet these difficult challenges. Two of the key building blocks critical for any EW system are the ADC and real-time channelization intellectual property (IP).

In many cases, the transition from analog to digital realms is a limiting factor in ES, EA, and EP systems. A system designer is often faced with the tradeoffs of minimizing cost and system size, as well as achieving an optimal balance between the need to increase instantaneous surveillance bandwidth and the requirement to minimize the effects of in-band high-power signals. Even if the ADC has excellent performance, the radio front end must be capable of preserving the signal quality, which results in a relentless push for high performance and low cost.

Figure 1 shows a simple EW system. The key features of the system are the RF receiver, used for frequency downconversion and selection of the frequency band of interest for interrogation; the ADC(s) used to convert signals from the analog domain to digital form; and the DSP engine—typically an FPGA—configured to detect, determine, analyze, and manage the storage of signals of interest. DRFM and EA systems also include a corresponding transmission signal chain with a high-speed digital-to-analog converter (DAC).

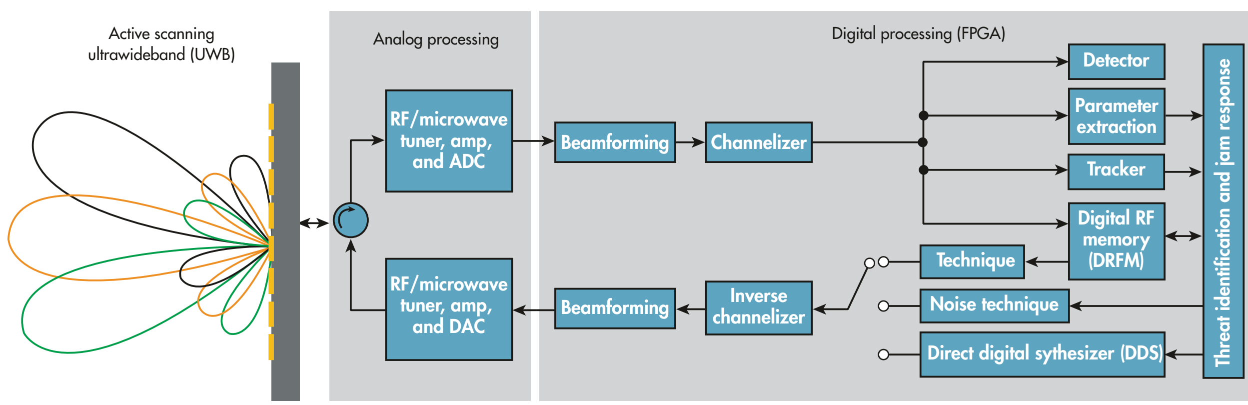
Historically, any increase in the instantaneous bandwidth of an EW receiver required either multiple overlapping receivers or an interleaved system architecture. Overlapped receivers each digitize a portion of the required bandwidth with digital signal processing that recombines the data contributions and observable spectrum from each channel.

An interleaved system architecture, in contrast, is often used with calibration to minimize the phase, offset, and gain differences between multiple data converters. Both approaches are generally expensive to implement, with DSP often customized for optimum performance.

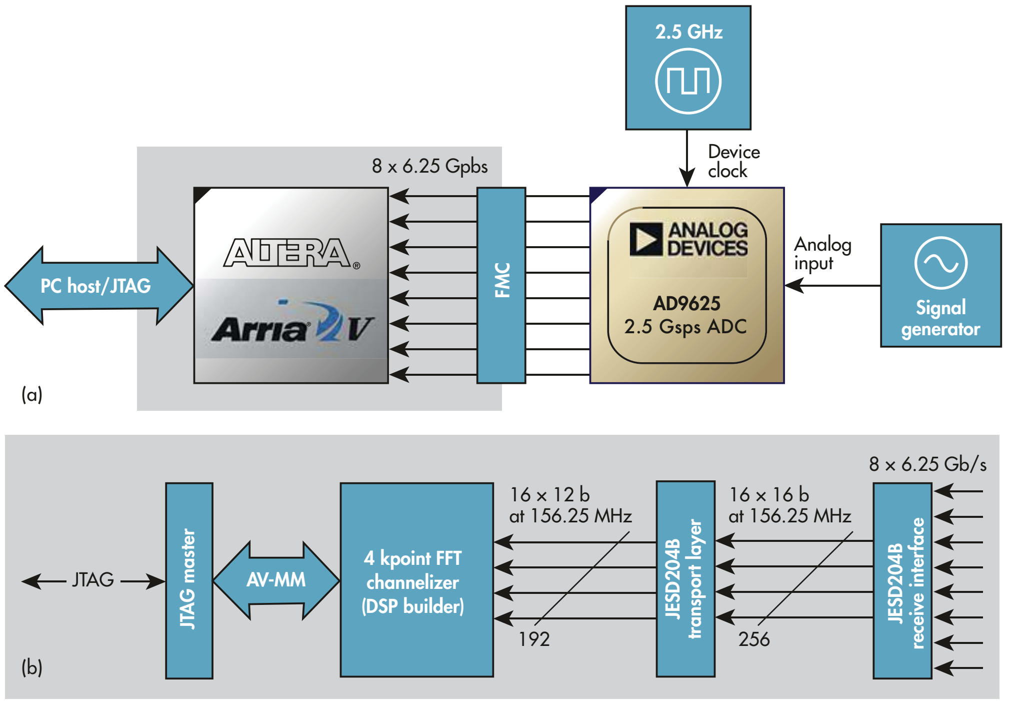
Newer high-speed sampling ADCs—such as the model AD9625 from Analog Devices—represent solutions for next-generation EW systems. Model AD9625 is a 2.5-Gsample/s, 12-b ADC designed for high-bandwidth ac performance.[1] It provides typical wideband signal-to-noise ratio (SNR), and spurious-free dynamic range (SFDR) of 57 and 80 dB, respectively, for a 1-GHz input bandwidth.

The AD9625 ADC can handle a small-signal analog bandwidth of more than 3 GHz, providing a system designer with significant intermediate-frequency (IF) location flexibility. This data converter is one of many signal-processing devices from Analog Devices that supports both parallel and serial interfaces, including the JESD204B standard.[2]

To facilitate rapid prototyping and system developments, the AD9625 ADC is available as a VITA 42/FPGA mezzanine connector (FMC) card platform *(Fig. 2)*. This platform provides reference designs showing how to optimize the signal conditioning prior to the ADC in a receiver design.



3. This block diagram represents a typical electronic-warfare (EW) system.



4. This system block can be used to demonstrate the ADC interface and the channelizer function in a typical EW receiver.

NEW CHANNELIZER MODEL

One common component in these systems is the digital channelized receiver or channelizer *(Fig. 3)*. The channelizer splits a wide input bandwidth into smaller component bandwidths to separate signals of interest from noise and interferer signals. Most digital channelized receivers consist of a filter bank and fast Fourier transform (FFT) processing.

One of the challenges in developing new EW receiver systems is that every new EW design or upgrade usually requires a more complex channelizer. To accelerate the development of the channelizer and reduce internal research and development (IRAD) costs, Altera developed a super-sample-rate FFT IP and finite-impulse-response (FIR) filter IP core that is capable of handling multi-gigasample-per-second data-converter inputs.

An example test setup can be used to demonstrate the ADC interface and the channelizer function in a typical EW receiver *(Fig. 4)*. In this setup, a signal generator produces a sinusoidal tone as the input to the AD9625 ADC. The digital output of the ADC is connected to an Altera Arria-V system-on-chip (SoC) development kit using an industry-standard FMC interface.

The samples received by the JESD204B interface are fed to the channelizer IP, which is configured to receive 16 samples concurrently using 16 input wires. Depending on the number of FFT points, a full FFT frame is divided into multiple time slots.

The channelizer IP was developed using the DSP Builder Advanced (DSPBA) software, a model-based design flow tool from Altera Corp.[3] It enables signal-processing engineers to design, evaluate, and verify algorithms in Matlab/Simulink simulation environments. Once an algorithm has been optimized, the software can be used to generate a code that's able to be deployed on Altera FPGAs for the EW receivers.

The channelizer output is stored in on-chip memory and verified through an Altera system-in-the-loop (SIL) tool. The SIL tool uses a Matlab API to trigger on-chip registers to begin logging for data visualization. Once triggered, a single iteration of FFT processing is executed and the resultant data is stored in on-chip static random-access memory (SRAM). The Matlab API extracts data through an Altera Avalon memory map from the SRAM to a Matlab host.

Integration of the IPs is performed by means of the Qsys integration tool from Altera Corp.[4] A Qsys project was created to integrate the channelizer IP and JESD204B IP. In addition to channelizer IP integration, the project incorporates control functionality to support an SPI configuration interface to the ADC. The channelizer can switch to different FFT sizes easily, ensuring future upgrade paths and potential design reuse. de

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Power Dividers Run 0.5 to 6.0 GHz

THE WMPDXX-0.5-6-Y series of power dividers includes two-, three-, four-, six-, and eight-way dividers with continuous frequency coverage of 500 MHz to 6 GHz. Available with Type-N or SMA connectors, these power dividers measure just 6.500 × 4.000 × 0.800 in. As an example, model 4PN325 is a four-way power divider/combiner that operates from 0.5 to 6.0 GHz with 1.7-dB typical insertion loss and 1.60:1 VSWR. It achieves isolation between ports of 17 dB and can handle power levels to 50 W. The power divider/combiner boasts amplitude balance within 0.5 dB and phase balance of ±4 deg. The component is actually usable to 250 MHz with some degradation of performance.

WERBEL MICROWAVE LLC,
51 Chestnut St., Livingston, NJ 07039; (973) 900-2480, FAX: (973) 716-9430, e-mail: Sales@werbelmicrowave.com, *www.werbelmicrowave.com*

LDMOS Amp IC Aids Avionic Designs

MODEL AFIC10275N is a wideband LDMOS-based integrated power amplifier from Freescale, including support from Richardson RFPD, that is designed for avionics applications from 978 to 1090 MHz. It integrates two amplification stages in a plastic package and achieves 250-W output power across its frequency range, with 31-dB gain and 64% drain efficiency. The single-ended amplifier also incorporates RF and temperature sensors to reduce the need for those external components. Available in 14-lead and 14-lead gull-wing plastic packages, the amplifier operates on +50-V dc supplies and can be supplied with a reference circuit that reduces cycle time and development costs. The compact plastic package makes it possible to trim weight in avionics systems.

RICHARDSON RFPD,
1950 S. Batavia Ave., Ste. 100, Geneva, IL 60134; (630) 262-6800, FAX: (630) 262-6950, *www.richardsonrfpd.com*

Surface-Mount Shields Help Curb EMI

THE SMS series of printed-circuit-board (PCB) electromagnetic-interference (EMI) shields has been expanded with the addition of 30 new shielding styles and sizes. The expanded shielding structures are constructed of tin-plated steel or Alloy 770 materials as a cost-effective shielding option for many automated pick-and-place circuit-assembly processes and large-volume manufacturing processes. The EMI shields provide as much as 60-dB shielding effectiveness (SE) for circuit boards that do not require ventilation holes in the shielding covers. Samples of the unvented shields are available for shipment in as little as 24 hours.

LEADER TECH,
2420 Race Track Rd., Tampa, FL 33626; (866) TECH-EMI (832-4364), (813) 855-6921, FAX: (813) 855-3291, *www.leadertechinc.com*

Amplifier Cuts Noise from 100 MHz to 18 GHz

OFFERING A wide bandwidth from 100 MHz to 18 GHz, model AF0118273A is a broadband low-noise amplifier (LNA) that can be used in a multitude of commercial and military applications. It features 27-dB gain across the frequency range, with gain variations reaching a maximum of ±1.2 dB. The noise figure is a respectable 2.8 dB even at 18 GHz, while the VSWR is 2.0:1 across the full frequency range. The output power at 1-dB compression is +10 dBm. The amplifier, which draws 100 mA current from a +50-V dc supply, is designed for operating temperatures from –55 to +85ºC.

HEROTEK INC.,
155 Baytech Dr., San Jose, CA 95134; (408) 941-8399, FAX: (408) 941-8388, e-mail: info@herotek.com, *www.herotek.com*

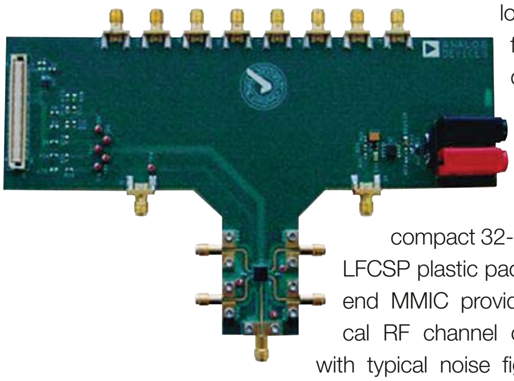
Isolators Channel Signals to 35.5 GHz

A PAIR OF microstrip isolators has been developed for applications through 35 GHz. Model T001110 operates from 29.6 to 30.6 GHz while model T001111 runs from 34.5 to 35.5 GHz. These components integrate ferrite circulator/isolator substrates on printed-circuit-board (PCB) materials to provide high performance at practical cost. Typical insertion loss for these isolators is 0.8 dB across their respective frequency ranges, with isolation between ports of 20 dB and return loss of 20 dB. The isolators handle the power levels required for typical applications in phased-array radar systems and satellite-communications (satcom) tracking antenna systems. Typical power levels are 20 W (average) and 500 W or more (peak power).

TRAK MICROWAVE CORP.,
4726 Eisenhower Blvd., Tampa, FL 33634; (888) 901-7200, (813) 901-7200, FAX: (813) 901-7491, e-mail: sales@trak.com, *www.trak.com*

Downconverter IC Receives 24 GHz

SUITABLE FOR both commercial and military applications, including automotive-radar and military-radar sensors, model ADF5904 is an integrated, four-channel receiver downconverter monolithic microwave integrated circuit (MMIC) with 250-MHz RF signal bandwidth at 24 GHz. Each channel contains a single-channel RF input signal path with on-chip balun, differential low-noise amplifier (LNA), and downconverter mixer with differential output buffers. Supplied in a compact 32-lead, 5- × 5-mm LFCSP plastic package, the front-end MMIC provides 22-dB typical RF channel conversion gain with typical noise figure of 10 dB. The MMIC, which easily connects to a high-speed analog-to-digital converter (ADC) for straightforward receiver front-end design, also contains an integrated temperature sensor to simplify calibration over wide operating temperature ranges. The LO-to-RF isolation and RF-to-intermediate-frequency (IF) isolation levels are typically 30 dB or better.



ANALOG DEVICES INC.,

One Technology Way, P.O. Box 9106, Norwood, MA 92062; (781) 329-4700, (800) 262-5643, *www.analog.com*

Pulsed TWTA Powers 32 to 36 GHz

MODEL DB-3861 is a high-power traveling-wave-tube amplifier (TWTA) for pulsed Ka-band applications from 32 to 36 GHz. Well-suited for such applications as radar and electronic-warfare (EW) systems, the amplifier delivers 400-W peak output power with 56-dB minimum gain at a 25% duty cycle. It is designed for 0.2- to 50.0-μs pulse widths at maximum pulse repetition frequency (PRF) of 300 kHz. Harmonic levels are –20 dBc or better, while spurious levels are –50 dBc or better. The TWTA uses a wideband periodic-permanent-magnet (PPM) focused, conduction-cooled TWT for power amplification. It is designed for altitudes to 10,000 ft. and operating temperatures from –20 to +55ºC. Provided in a 19-in. rack-mount configuration with integral forced-air cooling, the TWTA is equipped with WR-28 waveguide input and output ports and runs on 115/200-V ac supplies. It measures 24.5 × 19.0 × 7.0 in.

dB CONTROL,

1120 Auburn St., Fremont, CA 94538; (510) 656-2325, FAX: (510) 656-3214, *www.dBControl.com*

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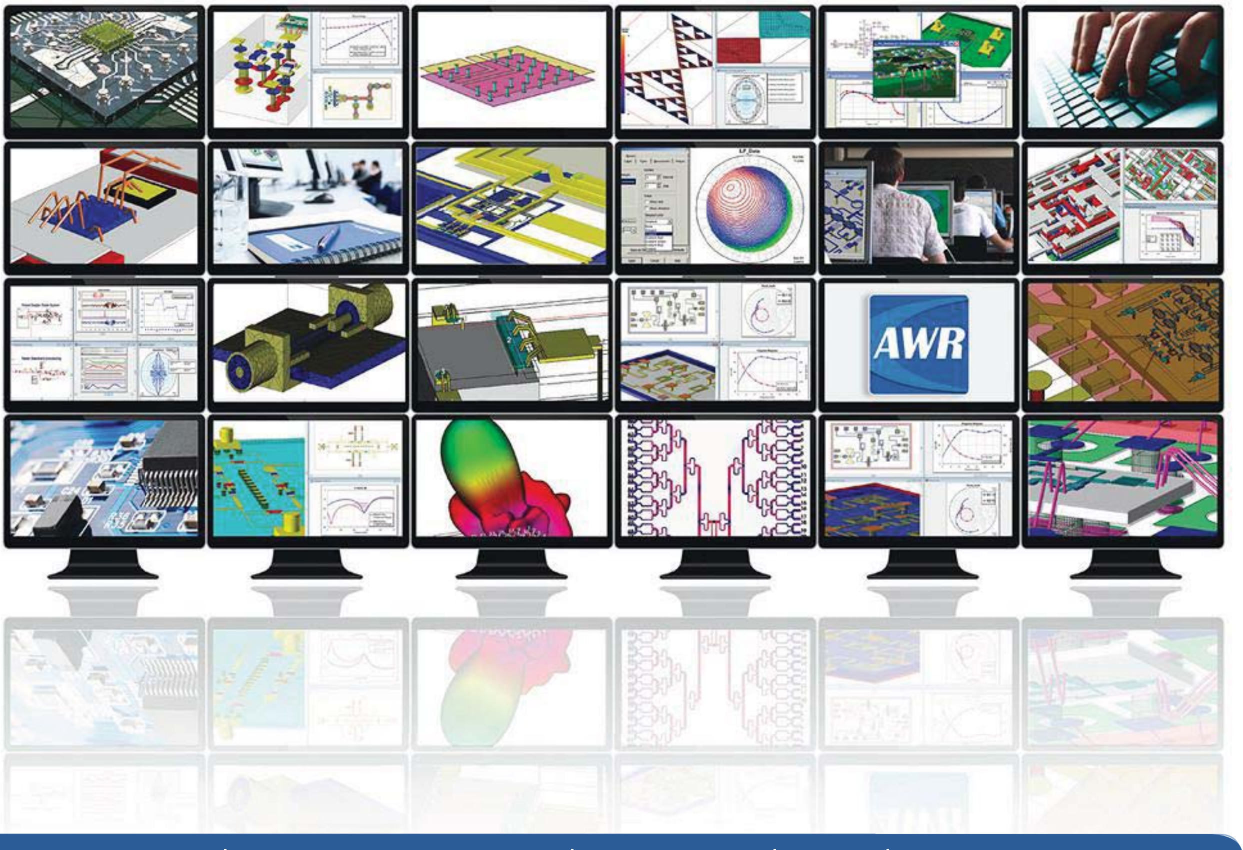
VADATECH s19

Space-Qualified Divider Handles 50 W to 2.4 GHz

RUGGED MODEL 10A4NAJ-2S-S is a high-power, S-band, two-channel power divider that has been space-qualified for use in remote applications. With a frequency range of 2.1 to 2.4 GHz, the two-way power divider limits insertion loss to just 0.4 dB while providing at least 20-dB isolation between ports. It features amplitude balance of 0.2 dB for the divided signals and VSWR that is maintained at 1.20:1 or less. The space-qualified power divider can be used in transmit as well as receive applications. It handles 50-W average input power. It measures 1.86 × 1.10 × 0.417 in. and works over an operating-temperature range of –30 to +70ºC.

RENAISSANCE ELECTRONICS & COMMUNICATIONS LLC,

12 Lancaster County Rd., Harvard, MA 01451; (978) 772-7774, FAX: (978) 772-7775, *www.rec-usa.com*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