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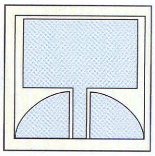

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Model	Bands	Step Size	BW (GHz)	Typical Phase Noise 10	100	1K	10K	100K	1M	Output Frequency	Output Power (dBm, Min.)
BTE	L - Ku	1 kHz	2.2	-73	-80	-96	-96	-97	-123	12.72 GHz	13
MFS	L - K	1 kHz	2	-60	-75	-90	-95	-95	-120	5.3 GHz	13
CFS	L - K	1 Hz	2	-62	-75	-85	-89	-97	-110	14.84 GHz	13
Ku3LS	X - Ku	1 kHz	2.2	-62	-70	-75	-85	-97	-115	12.50 GHz	13
C3LS	C	1 kHz	1.1	-63	-88	-90	-100	-100	-115	5.50 GHz	13
UWB	S - K	1 kHz	Multioctave	-60	-71	-80	-90	-96	-105	12 GHz	13
MOS	VHF - K	1 kHz	Multioctave	-55	-65	-75	-85	-90	-100	20 GHz	13
SLS	L - Ku	125 kHz	1	-70	-80	-86	-88	-105	-115	3.3 GHz	13
SLFS	VHF - Ku	100 kHz	2	-70	-75	-80	-90	-115	-125	5 GHz	13
LFTS	VHF - Ku	100 Hz	1	-78	-88	-98	-98	-110	-130	350 MHz	13
VFS	L - Ku	>25 MHz	1.5	-60	-80	-110	-115	-115	-130	12.5 GHz	13

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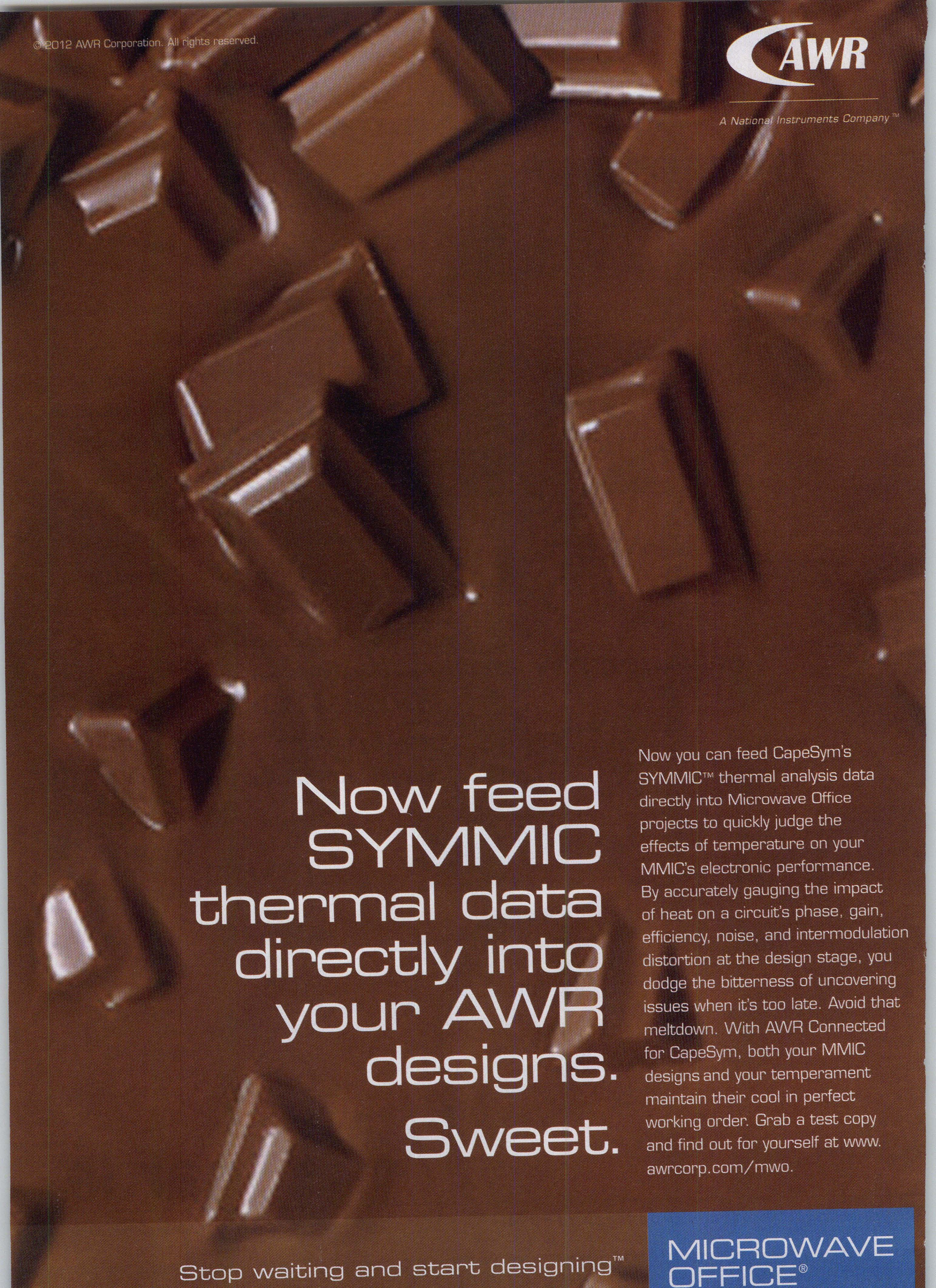
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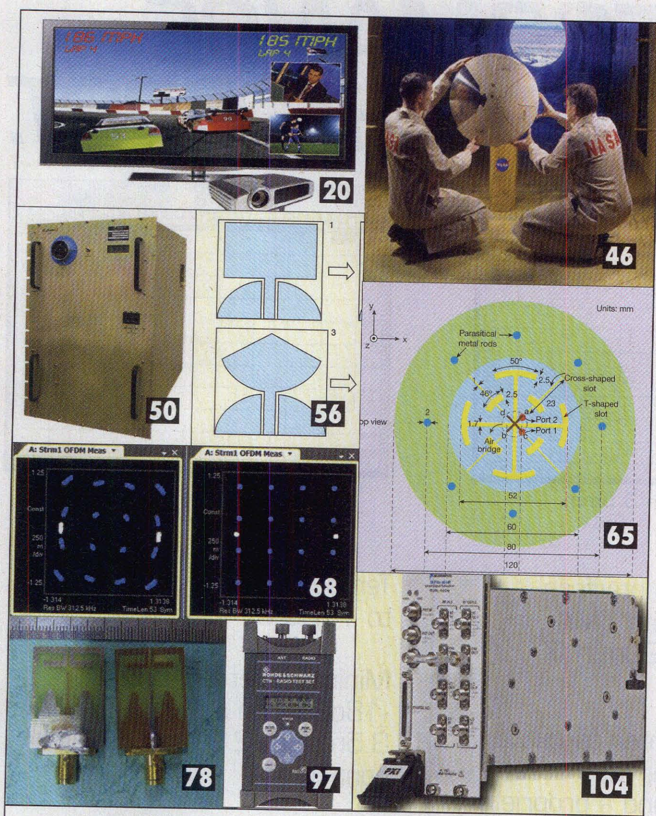

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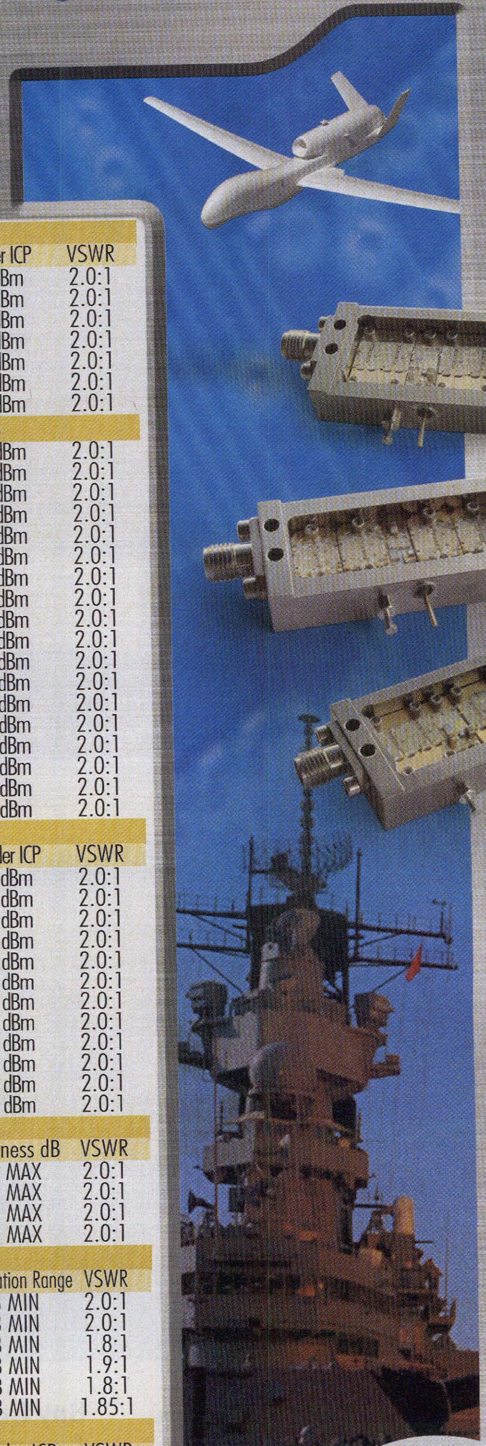

OCTAVE BAND LOW NOISE AMPLIFIERS

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB)	Power-out @ P1-dB	3rd Order ICP	VSWR
CA01-2110	0.5-1.0	28	1.0 MAX, 0.7 TYP	+10 MIN	+20 dBm	2.0:1
CA12-2110	1.0-2.0	30	1.0 MAX, 0.7 TYP	+10 MIN	+20 dBm	2.0:1
CA24-2111	2.0-4.0	29	1.1 MAX, 0.95 TYP	+10 MIN	+20 dBm	2.0:1
CA48-2111	4.0-8.0	29	1.3 MAX, 1.0 TYP	+10 MIN	+20 dBm	2.0:1
CA812-3111	8.0-12.0	27	1.6 MAX, 1.4 TYP	+10 MIN	+20 dBm	2.0:1
CA1218-4111	12.0-18.0	25	1.9 MAX, 1.7 TYP	+10 MIN	+20 dBm	2.0:1
CA1826-2110	18.0-26.5	32	3.0 MAX, 2.5 TYP	+10 MIN	+20 dBm	2.0:1

NARROW BAND LOW NOISE AND MEDIUM POWER AMPLIFIERS

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB)	Power-out @ P1-dB	3rd Order ICP	VSWR
CA01-2111	0.4 - 0.5	28	0.6 MAX, 0.4 TYP	+10 MIN	+20 dBm	2.0:1
CA01-2113	0.8 - 1.0	28	0.6 MAX, 0.4 TYP	+10 MIN	+20 dBm	2.0:1
CA12-3117	1.2 - 1.6	25	0.6 MAX, 0.4 TYP	+10 MIN	+20 dBm	2.0:1
CA23-3111	2.2 - 2.4	30	0.6 MAX, 0.45 TYP	+10 MIN	+20 dBm	2.0:1
CA23-3116	2.7 - 2.9	29	0.7 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA34-2110	3.7 - 4.2	28	1.0 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA56-3110	5.4 - 5.9	40	1.0 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA78-4110	7.25 - 7.75	32	1.2 MAX, 1.0 TYP	+10 MIN	+20 dBm	2.0:1
CA910-3110	9.0 - 10.6	25	1.4 MAX, 1.2 TYP	+10 MIN	+20 dBm	2.0:1
CA1315-3110	13.75 - 15.4	25	1.6 MAX, 1.4 TYP	+10 MIN	+20 dBm	2.0:1
CA12-3114	1.35 - 1.85	30	4.0 MAX, 3.0 TYP	+33 MIN	+41 dBm	2.0:1
CA34-6116	3.1 - 3.5	40	4.5 MAX, 3.5 TYP	+35 MIN	+43 dBm	2.0:1
CA56-5114	5.9 - 6.4	30	5.0 MAX, 4.0 TYP	+30 MIN	+40 dBm	2.0:1
CA812-6115	8.0 - 12.0	30	4.5 MAX, 3.5 TYP	+30 MIN	+40 dBm	2.0:1
CA812-6116	8.0 - 12.0	30	5.0 MAX, 4.0 TYP	+33 MIN	+41 dBm	2.0:1
CA1213-7110	12.2 - 13.25	28	6.0 MAX, 5.5 TYP	+33 MIN	+42 dBm	2.0:1
CA1415-7110	14.0 - 15.0	30	5.0 MAX, 4.0 TYP	+30 MIN	+40 dBm	2.0:1
CA1722-4110	17.0 - 22.0	25	3.5 MAX, 2.8 TYP	+21 MIN	+31 dBm	2.0:1

ULTRA-BROADBAND & MULTI-OCTAVE BAND AMPLIFIERS

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB)	Power-out @ P1-dB	3rd Order ICP	VSWR
CA0102-3111	0.1-2.0	28	1.6 Max, 1.2 TYP	+10 MIN	+20 dBm	2.0:1
CA0106-3111	0.1-6.0	28	1.9 Max, 1.5 TYP	+10 MIN	+20 dBm	2.0:1
CA0108-3110	0.1-8.0	26	2.2 Max, 1.8 TYP	+10 MIN	+20 dBm	2.0:1
CA0108-4112	0.1-8.0	32	3.0 MAX, 1.8 TYP	+22 MIN	+32 dBm	2.0:1
CA02-3112	0.5-2.0	36	4.5 MAX, 2.5 TYP	+30 MIN	+40 dBm	2.0:1
CA26-3110	2.0-6.0	26	2.0 MAX, 1.5 TYP	+10 MIN	+20 dBm	2.0:1
CA26-4114	2.0-6.0	22	5.0 MAX, 3.5 TYP	+30 MIN	+40 dBm	2.0:1
CA618-4112	6.0-18.0	25	5.0 MAX, 3.5 TYP	+23 MIN	+33 dBm	2.0:1
CA618-6114	6.0-18.0	35	5.0 MAX, 3.5 TYP	+30 MIN	+40 dBm	2.0:1
CA218-4116	2.0-18.0	30	3.5 MAX, 2.8 TYP	+10 MIN	+20 dBm	2.0:1
CA218-4110	2.0-18.0	30	5.0 MAX, 3.5 TYP	+20 MIN	+30 dBm	2.0:1
CA218-4112	2.0-18.0	29	5.0 MAX, 3.5 TYP	+24 MIN	+34 dBm	2.0:1

LIMITING AMPLIFIERS

Model No.	Freq (GHz)	Input Dynamic Range	Output Power Range Psat	Power Flatness dB	VSWR
CLA24-4001	2.0 - 4.0	-28 to +10 dBm	+7 to +11 dBm	+/- 1.5 MAX	2.0:1
CLA26-8001	2.0 - 6.0	-50 to +20 dBm	+14 to +18 dBm	+/- 1.5 MAX	2.0:1
CLA712-5001	7.0 - 12.4	-21 to +10 dBm	+14 to +19 dBm	+/- 1.5 MAX	2.0:1
CLA618-1201	6.0 - 18.0	-50 to +20 dBm	+14 to +19 dBm	+/- 1.5 MAX	2.0:1

AMPLIFIERS WITH INTEGRATED GAIN ATTENUATION

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB)	Power-out @ P1-dB	Gain Attenuation Range	VSWR
CA001-2511A	0.025-0.150	21	5.0 MAX, 3.5 TYP	+12 MIN	30 dB MIN	2.0:1
CA05-3110A	0.5-5.5	23	2.5 MAX, 1.5 TYP	+18 MIN	20 dB MIN	2.0:1
CA56-3110A	5.85-6.425	28	2.5 MAX, 1.5 TYP	+16 MIN	22 dB MIN	1.8:1
CA612-4110A	6.0-12.0	24	2.5 MAX, 1.5 TYP	+12 MIN	15 dB MIN	1.9:1
CA1315-4110A	13.75-15.4	25	2.2 MAX, 1.6 TYP	+16 MIN	20 dB MIN	1.8:1
CA1518-4110A	15.0-18.0	30	3.0 MAX, 2.0 TYP	+18 MIN	20 dB MIN	1.85:1

LOW FREQUENCY AMPLIFIERS

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure dB	Power-out @ P1-dB	3rd Order ICP	VSWR
CA001-2110	0.01-0.10	18	4.0 MAX, 2.2 TYP	+10 MIN	+20 dBm	2.0:1
CA001-2211	0.04-0.15	24	3.5 MAX, 2.2 TYP	+13 MIN	+23 dBm	2.0:1
CA001-2215	0.04-0.15	23	4.0 MAX, 2.2 TYP	+23 MIN	+33 dBm	2.0:1
CA001-3113	0.01-1.0	28	4.0 MAX, 2.8 TYP	+17 MIN	+27 dBm	2.0:1
CA002-3114	0.01-2.0	27	4.0 MAX, 2.8 TYP	+20 MIN	+30 dBm	2.0:1
CA003-3116	0.01-3.0	18	4.0 MAX, 2.8 TYP	+25 MIN	+35 dBm	2.0:1
CA004-3112	0.01-4.0	32	4.0 MAX, 2.8 TYP	+15 MIN	+25 dBm	2.0:1

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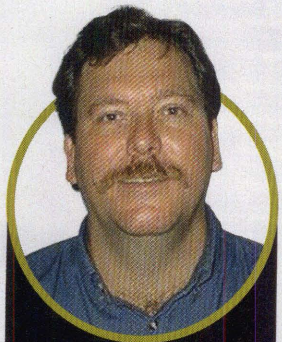

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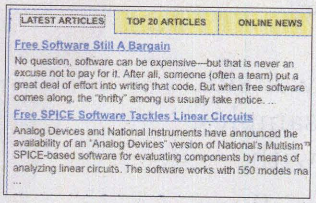
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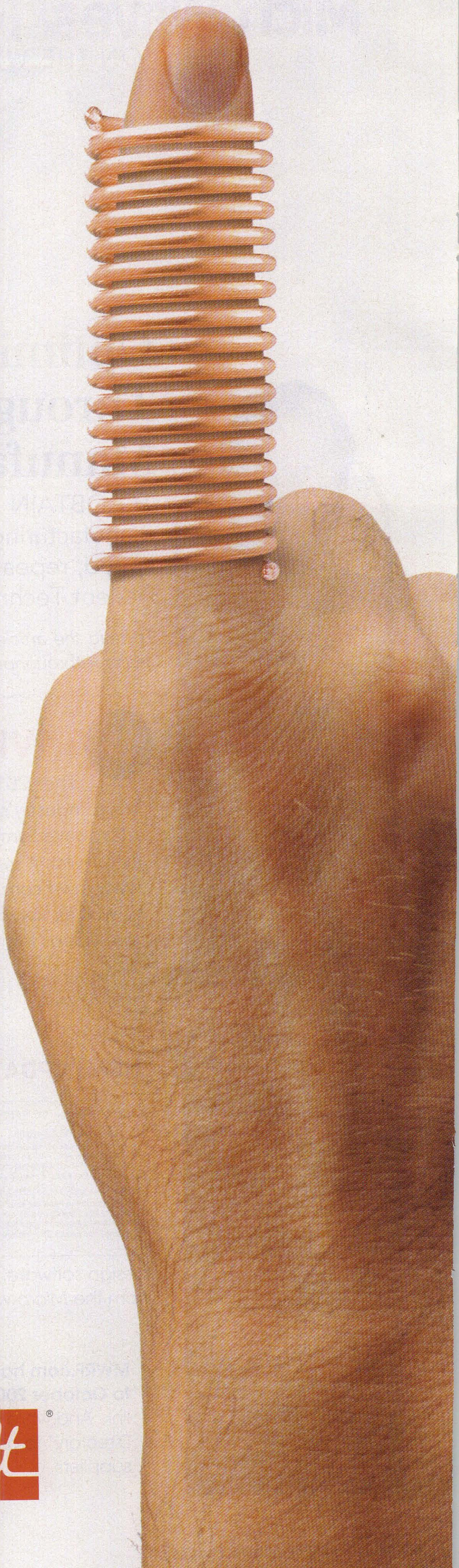

From the Editor

Cities Seek Sustainability

ENERGY-EFFICIENT HOMES ARE becoming more commonplace, thanks to affordable energy-conserving light bulbs and appliances. With the advent of products like the Nest "smart" thermostat (www.nest.com), they also are conserving energy more intelligently. The Nest thermostat "learns" the behavior patterns of a residence's occupants—for example, if a home occupant turns up the heat upon coming home in the evening, but turns it back down the next morning before leaving for work. The thermostat then incorporates such practices into a program that efficiently and cost effectively moderates the residence's temperature. While the resulting energy savings is obviously beneficial, today's extensive communications backbone and technical advantages make one wonder if such energy-conservation efforts can be rolled out on a grander scale.

In the microwave and RF industry, for example, there has been a lot of buzz about smart-grid applications—and by and large, those applications extend far beyond smart meters. By relying on wireless communications ranging from ZigBee to fourth-generation (4G) technologies, energy-monitoring devices can communicate back to a central point for billing, customer service, and more. And there's no reason that such capabilities cannot be leveraged across a grid or beyond. According to the Worldwatch Institute (www.worldwatch.org), the use of information and communication technology (ICT) could help cities achieve higher levels of safety, cleanliness, and sustainability.

In a report titled, "Worldwatch Institute's State of the World 2012: Moving Toward Sustainable Prosperity," the institute notes that often, cities are partnering directly with businesses to boost urban sustainability. In The Netherlands, for example, the city of Rotterdam is working with General Electric (GE) to reduce carbon-dioxide emissions by 50% compared with 1990 levels. GE will use technologies like data visualizations and smart meters to both optimize energy efficiency and improve water management.

To achieve success, Diana Lind, a Contributing Author for the Worldwatch report, recommends that communities use ICT to promote sustainability in three specific ways: by providing open access to data, mapping all of a city's neighborhoods and regions, and enabling a "Community Watch" (which comprises both low-tech monitoring and web sites where problems and issues can be reported). The goals are to ensure that diverse perspectives are included in the city's plans and to solve problems with ICT—not just identify them. Although ICT is largely a technical solution to a problem, it will not succeed unless the right information is gathered. Only then can the best plan be implemented.

Effective communications is a key to these sustainability efforts. Any city designed or modified for efficient energy use will require a strong communications backbone to process and respond to changing requirements and conditions. Most likely, this will also mean another layer of wireless-communications networking to connect in-building wireless systems, the Internet, cellular networks, point-to-point radios, and other forms of wired and wireless-communications systems now in use. Once again, RF/microwave engineers will be at the heart of a global technological evolution. MWRF

Nancy K. Friedrich

Editor-In-Chief


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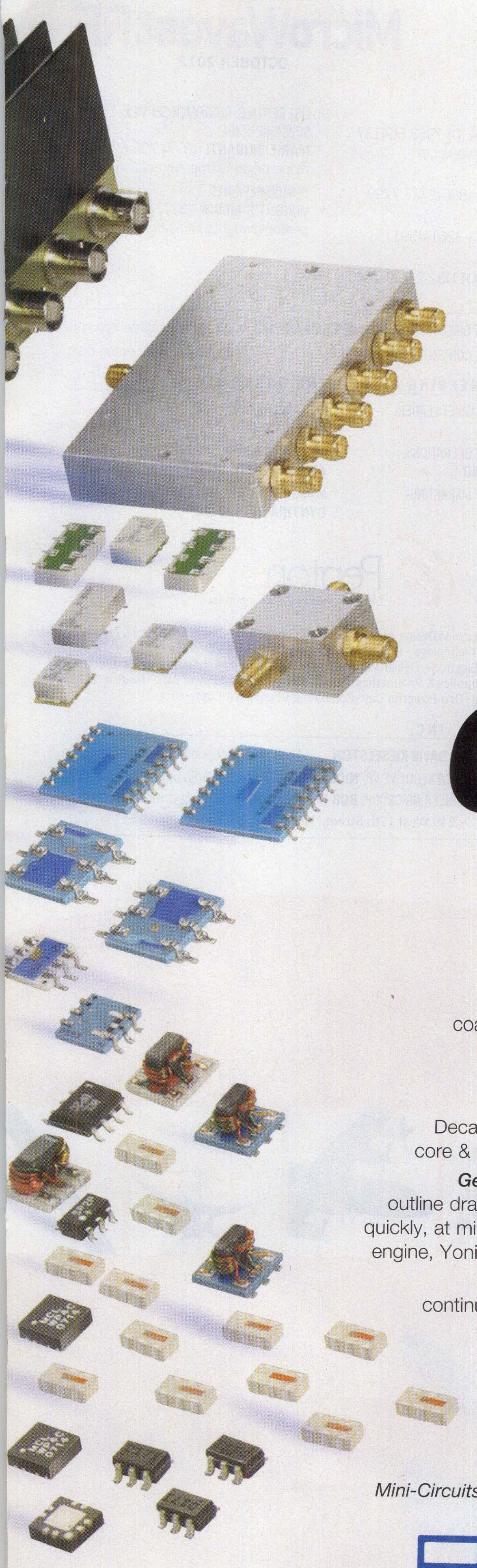

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EDITOR'S NOTE

Our apologies to Mr. Bierng-Chearl Ahn and the many others who have submitted technical articles for publication in *Microwaves & RF* during this past year, and have waited for some time to receive a response on the status of their article. Many of the articles submitted to this magazine are excellent in their format, and may cover a wide range of topics, from RF/microwave amplifiers to the design of complete radar and electronic-warfare (EW) systems. Unfortunately, *Microwaves & RF* is currently receiving better than one full contributed article for publication each working day, or more than 30 technical articles for publication each month. Many of these articles are well done, and covering excellent topics—including the design of antennas, filters, and other key components for high-frequency systems.

But given that each monthly issue carries about five or six contributed articles, along with the other magazine sections—including staff-written news and product reviews—the waiting list is long for many of these submitted articles. We plead with those submitting technical articles to be patient in hearing from us, and to understand that only a small percentage of submitted articles can find room in each issue.

Please feel free to send us reminder e-mails as necessary, and we will do our very best to bring you up to date on the status of your article, and if and when we can find a publication date for it in *Microwaves & RF.*

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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Video Travels Easily Between Devices

SMARTPHONES HAVE BECOME essential tools to many consumers—acting as a phone, camera, and social-media enabler, among other things. Given that consumers are increasingly using their smartphones to take photos and videos, it is only natural that they should be enabled to easily share them with an audience via a bigger screen. Fulfilling this need is Miracast, the Wi-Fi Alliance's (www.wi-fi.org) Wi-Fi CERTIFIED certification program. Miracast makes it possible for users to instantly display video, pictures, and applications between certified devices from any brand—wherever they are.

Miracast relies on the Wi-Fi medium-access-control (MAC) and physical (PHY) layers. The vendor-specific user interface (UI) is used to manage the user inputs and preferences. Vendor-session policy management plays a key role as well—initiating device discovery and selection, authorizing the link between the source and display devices, storing the user profile, and managing traffic.

Because Miracast connections are formed using Wi-Fi Certified Wi-Fi Direct, access to a Wi-Fi network is not needed. The ability to connect rests inside the Miracast-certified devices. Those devices also provide simplified discovery and setup, which facilitates the sharing process. After initially pairing two Wi-Fi devices, users simply choose to stream content or mirror a display from one device (the source) to a second device (the display).

Because Miracast supports protected content streaming, devices can stream feature films and other copy-protected materials. To protect premium content, Miracast uses a wireless adaptation of content-protection mechanisms that are widely used for cabled interfaces, such as HDMI and DisplayPort. In addition, the latest WPA2 security protections are automatically enabled on every device. The transport of all mul-

With Miracast-certified devices, users can view pictures from a smartphone on a big-screen television, share a laptop screen with the conference-room projector in real time, watch live programs from a home cable box on a tablet, and more.

timedia content is therefore kept private.

The Miracast certification program was developed with the support of an ecosystem of silicon, mobile-device, and consumer-electronics (CE) vendors. The first products to be designated Wi-Fi Certified Miracast (which also form the test suite for the certification program) are the following: Broadcom dual-band 11n Wi-Fi; Intel WiDi; Marvell Avastar USB-8782 802.11n 1x1 dual-band reference design; MediaTek a/b/g/n dual-band mobile-phone client, MT662X_v1 and DTV Sink, MV0690; Ralink 802.11n wireless adapter, RT3592; and the Realtek dual-band 2x2 RTL8192DE HM92D01 PCIe half-mini card and RTD1185 RealShare smart display adapter. The first consumer products certified since testing opened to vendors include the LG Optimus G smartphone, Samsung Galaxy S III smartphone, and Samsung Echo-P Series TV.

Industry analysts predict annual shipments of Miracast-certified devices to exceed ONE BILLION units within the next four years.

Texas Instruments (www.ti.com) is already providing an end-to-end Miracast solution to deliver Wi-Fi-enabled digital-content streaming from mobile devices to other screens **(see figure)**. The TI system, which comprises source and display (sink) solutions, is based on the multicore OMAP 4 processors, DaVinci video processors, and WiLink 6.0 and 7.0 connectivity solutions. It will soon be extended, however, to the OMAP 5 platform and WiLink 8.0 family. As an integrated near-field-communications (NFC) controller with Bluetooth v4.0, Global Navigation Satellite System (GNSS), and IEEE 802.11a/b/g/n, the WiLink 8.0 family promises to support all Wi-Fi throughput ranges using 2x2 multiple-input, multiple-output (MIMO) or single-input, single-output (SISO) at 40 MHz. It also will provide simple and quick NFC pairing to further simplify the setup process.

Missile Defense Succeeds From Sea

MISSILE DEFENSE SYSTEMS must identify and respond to incoming threats in a short amount of time. Although they have reached great heights, US missile-defense efforts have thus far been contained to land. Recently, however, a US Army and Navy test demonstrated that Raytheon Co.'s (www.raytheon.com) Joint Land Attack/Cruise Missile Defense Elevated Netted Sensors (JLENS) can integrate with the defensive systems currently in the Navy's inventory. In doing so, they can provide overland cruise-missile defense from the sea.

A test relying on this JLENS sensor system recently proved that the US can successfully provide overland cruise-missile defense from the sea.

During this test, a JLENS fire-control radar acquired and tracked a surrogate anti-ship cruise-missile target. That information was passed to sailors via the Raytheon-made Cooperative Engagement Capability (CEC) sensor-netting system. [CEC nets battleforce sensors together to provide a single, distributed Anti-Air Warfare (AAW) defense capability.] The sailors then fired a Raytheon-made Standard Missile-6 at the target. Initial SM-6 guidance used targeting information provided by the JLENS via CEC to the Aegis Weapon System (AWS) until the SM-6's on-board radar was able to acquire and track the target.

JLENS is an elevated, persistent, over-the-horizon sensor system. It uses an integrated radar system to detect, track, and target a variety of threats. A JLENS system, which is referred to as an orbit, consists of two tethered, 74-m, helium-filled aerostats connected to both mobile mooring stations and communications and processing groups **(see photo)**. The aerostats fly as high as 10,000 feet and can remain aloft and operational for up to 30 days. One aerostat carries a surveillance radar with 360-deg. surveillance capability while the other carries a fire-control radar.

MARKET*QUOTE*

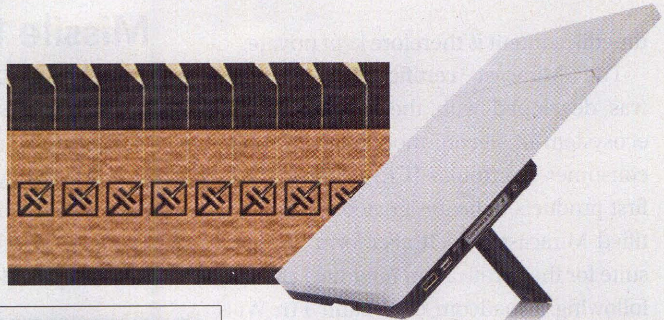
Smart meters will be shipped between 2012 and 2016, forecasts IMS Research (http://imsresearch.com/).

A third of those meters will include an integrated RF home-area-network (HAN) gateway, which typically uses ZigBee to enable connectivity between the back-haul AMI (typically powerline or RF mesh) and in-home devices, such as in-home displays (IHDs).

In contrast, the past three years have seen almost 60 million smart meters deployed—with 20 million including a HAN gateway.

Metamaterials-Based Approach Promises Satellite Connection

Imagine that a new antenna technology truly made "broadband everywhere" possible. As the most recent spinout from Intellectual Ventures (IV; www.intellectualventures.com), Kymeta (www.kymetacorp.com) just closed a $12-million funding round to develop and bring to market IV's Metamaterials Surface Antenna Technology (MSA-T). Backed by investments from Bill Gates, Liberty Global, and Lux Capital, Kymeta's mTenna product line promises to simplify the satellite-communications (satcom) connection needed for broadband Internet on the go.



1. Shown is an example of a metamaterial structure (above left).
2. This satellite-hotspot product, which is based on advances in materials, could be rapidly deployed to enable satellite-broadband connectivity (above right).

With the mTenna products, users are expected to be able to access a variety of mobile, portable, and fixed-satellite services. The key is their use of metamaterials, which can manipulate electromagnetic (EM) radiation **(Fig. 1)**. mTenna uses this capability to electronically point and steer a radio signal toward a satellite. A continuous broadband link is thereby created between a satellite and a moving platform—such as an aircraft, car, or boat—by dynamically manipulating the antenna material's characteristics. Kymeta claims that its metamaterials-based approach allows its antennas to be thinner, lighter, more efficient, and less expensive than traditional satcom antenna technology.

Kymeta also plans to develop a portable satellite-hotspot product for individual users **(Fig. 2)**. The laptop-sized antenna will open the door for high-speed Internet and other satellite-broadband services wherever they are needed. This device could benefit everyone from emergency responders to average consumers looking to untether from public Wi-Fi. Kymeta's mTenna products are currently in development at the company's Redmond, WA headquarters. Commercial availability is expected by 2015.

KUDOS

BIRD TECHNOLOGIES—Is celebrating its 70th year in business. The Solon, OH-based supplier of RF communications products was founded in 1942 by J. Raymond Bird. The firm, which boasts approximately 50 patents and installations in more than 130 countries, originally gained prominence in the early 1950s for its Model 43 Thruline Directional Wattmeter. In recent decades, Bird has expanded its product offerings (through the acquisitions of X-COM Systems and TX RX) to include RF data-capture and storage products; signal-generation and software-analysis tools; and communications products and services for the public-safety sector.

SYMMETRICOM—Chief Scientist Dr. Robert Lutwak has been awarded the 2012 GNSS Leadership Product Award, which recognizes his leadership and contributions in the development of the Quantum SA.45s Chip Scale Atomic Clock (CSAC). The annual GNSS Leadership Awards honor four individuals for significant recent achievement in the categories of Satellites, Signals, Services, and Products.

L-COM—Has received six Stevie awards at the 2012 International Business Awards (IBA). Among them is a gold award for Best New Product or Service of the Year - Telecommunications Hardware.

TELIASONERA INTERNATIONAL CARRIER (TSIC)—Has been shortlisted for two separate honors at the 2012 World Communications Awards: Best Wholesale Carrier and Best Project. TSIC has won the former category on three previous occasions (2007, 2009, and 2011). The Best Project nomination references the carrier's initiative to update its optical network in both the US and Europe.

REDPINE SIGNALS—Has received the 2012 Frost & Sullivan Global Wireless Solutions and RTLS Technology Innovation Award. The company's Quali-Fi technology incorporates the provisioned features of the draft IEEE 802.11ac standard in the 5-GHz band. In addition, its WiSeMote RTLS products feature standards-compliant operation in the 5-GHz band.

RFEL—The United Kingdom-based firm has been presented with The Queen's Award for Enterprise 2012, Innovation category, in recognition of its digital-signal-processing technologies. This is RFEL's second Queen's Award (the UK's most prestigious award for business performance) as it previously received one in 2009.

COMPRION—Is celebrating its 10th anniversary. The Paderborn, Germany-based company develops, manufactures, and markets test and measurement equipment for smart-card vendors, smart-card issuers, and terminal manufacturers.

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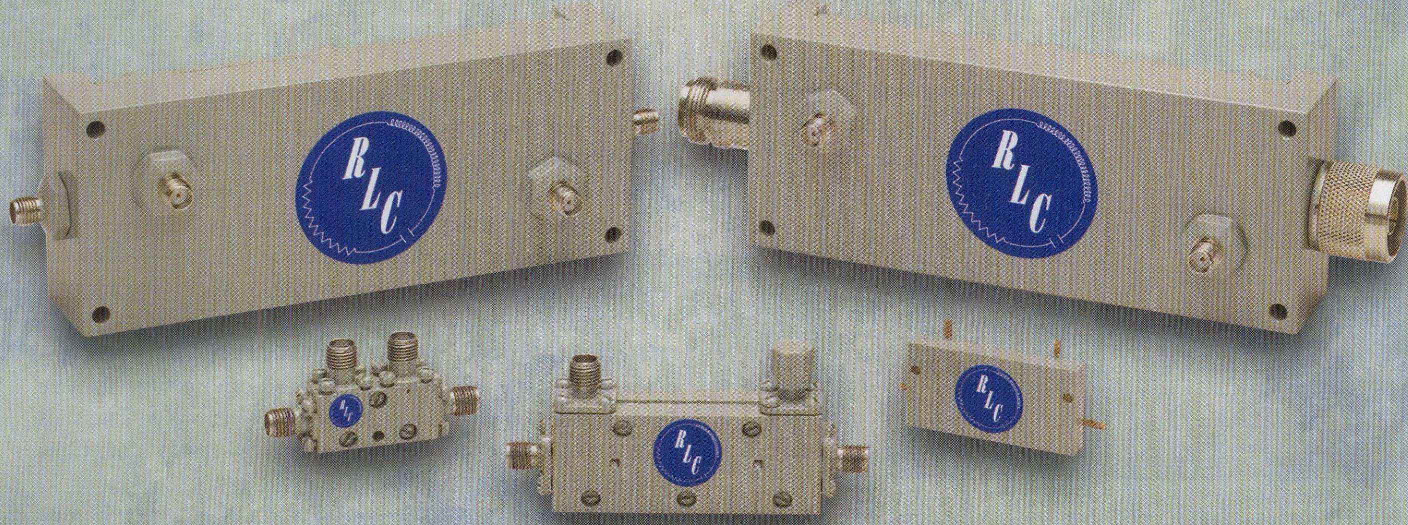

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Broadcast Services Are Demonstrated Over LTE

USING EVOLVED MULTIMEDIA BROADCAST MULTICAST SERVICE (eMBMS) technology, it is possible for Long-Term-Evolution (LTE) network infrastructure to be used for the delivery of broadcast services, such as television. This capability, if utilized, could certainly impact how LTE services are offered. To first prove that this prospect is viable, Samsung Electronics Co. Ltd. (www.samsung.com) has successfully demonstrated the clear reception capabilities of LTE broadcast services.

This demonstration made use of eMBMS technology, which enables carriers to adjust coverage and capacity as needed. Network resources are therefore used more efficiently. The demonstration relied on Anritsu's (www.anritsu.com) Rapid Test Designer (RTD) and MD8430A to simulate the LTE network environment. The Samsung engineers were able to create the eMBMS demonstration using RTD's graphical script design. It drove the execution of the test simulation on an Anritsu MD8430A LTE signaling tester.

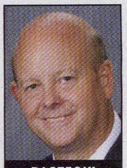
By simulating the LTE network environment, the reception capabilities of LTE broadcast services were recently touted.

PEOPLE

SPARRER KRAUSE

LPKF—Has announced two new additions to its product-management team. SEBASTIAN SPARRER is overseeing technical development of the company's laser-direct-structuring systems. STEPHAN KRAUSE is responsible for coordinating technical product management, external partners, and customer requirements.

GLOBAL SEMICONDUCTOR ALLIANCE (GSA)—Has added three new members to the GSA Asia-Pacific Leadership Council, which serves as advisors to the organization's board of directors on regional issues. The new members are DR. JACKSON HU, Chairman and Chief Executive Officer of NeoEnergy Microelectronics; DR. QIANG LIU, Chairman and Chief Executive Officer of Ingenic Semiconductor; and VINCENT TAI, Co-Founder, Chairman, and Chief Executive Officer of RDA Microelectronics.



BASTECKI

INDIUM CORP.—CHRIS BASTECKI has been named Associate Director of Electronics Assembly Materials. Basteki has nearly 20 years of experience in electronic-materials marketing, sales, and business management. He is based out the company's headquarters in Clinton, NY.

TELECOMMUNICATIONS INDUSTRY ASSOCIATION (TIA)—Has appointed two new members to its board of directors. TREVOR PUTRAH is the current Chief Operating Officer of KGP Logistics while CHUCK SHAUGHNESSY serves as Vice President of Public Safety LTE at Harris Corp.

ENTROPIC COMMUNICATIONS—VAHID MANIAN has been named Senior Vice President of Global Operations. Manian was previously Vice Chairman of the Global Semiconductor Alliance (GSA), where he served on the board of directors.

GEORGIA TELECOMMUNICATIONS ASSOCIATION (GTA)—DURAND STANDARD has been named President of the industry group for 2012-2013. Standard is Vice President and General Manager for CenturyLink's Georgia and South Carolina operations.

AMETEK—ROBERT J. VOGEL has been appointed Vice President and General Manager, Thermal Management Systems, within AMETEK Aerospace & Defense. Vogel joins the firm from Aeroflex, where he most recently served as President of Aeroflex Test Solutions.

MINIATURE FOOTPRINT

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Model	Frequency Range (MHz)	Tuning Voltage (VDC)	DC Bias VDC @ I [Typ.]	Phase Noise @ 10 kHz (dBc/Hz) [Typ.]	Size (Inch)
DCO Series					
DCO50100-5	500 - 1000	0.5 - 15	+5 @ 34 mA	-100	0.3 x 0.3 x 0.08
DCO6080-3	600 - 800	0 - 3	+3 @ 15 mA	-105	0.3 x 0.3 x 0.08
DCO7075-3	700 - 750	0.5 - 3	+3 @ 12 mA	-108	0.3 x 0.3 x 0.08
DCO80100-5	800 - 1000	0.5 - 8	+5 @ 26 mA	-111	0.3 x 0.3 x 0.08
DCO8190-5	810 - 900	0.5 - 16	+5 @ 34 mA	-118	0.3 x 0.3 x 0.08
DCO100200-5	1000 - 2000	0.5 - 24	+5 @ 36 mA	-95	0.3 x 0.3 x 0.08
DCO1198-8	1195 - 1205	0.5 - 8	+8 @ 30 mA	-115	0.3 x 0.3 x 0.08
DCO170340-5	1700 - 3400	0.5 - 24	+5 @ 29 mA	-90	0.3 x 0.3 x 0.08
DCO200400-5 DCO200400-3	2000 - 4000	0.5 - 18	+5 @ 46 mA +3 @ 46 mA	-90 -89	0.3 x 0.3 x 0.08
DCO300600-5 DCO300600-3	3000 - 6000	0.5 - 18	+5 @ 35 mA +3 @ 35 mA	-80 -78	0.3 x 0.3 x 0.08
DCO400800-5 DCO400800-3	4000 - 8000	0.5 - 18	+5 @ 20 mA +3 @ 20 mA	-78 -76	0.3 x 0.3 x 0.08
DCO432493-5 DCO432493-3	4325 - 4950	0.5 - 11	+5 @ 22 mA +3 @ 22 mA	-88 -86	0.3 x 0.3 x 0.08
DCO450900-5 DCO450900-3	4500 - 9000	0.5 - 18	+5 @ 20 mA +3 @ 20 mA	-76 -74	0.3 x 0.3 x 0.08
DCO473542-5 DCO473542-3	4730 - 5420	0.5 - 22	+5 @ 20 mA +3 @ 20 mA	-88 -86	0.3 x 0.3 x 0.08
DCO490517-5 DCO490517-3	4900 - 5175	0.5 - 5	+5 @ 22 mA +3 @ 22 mA	-88 -86	0.3 x 0.3 x 0.08
DCO495550-5 DCO495550-3	4950 - 5500	0.5 - 12	+5 @ 22 mA +3 @ 22 mA	-83 -85	0.3 x 0.3 x 0.08
DCO5001000-5 DCO5001000-3	5000 - 10000	0.5 - 18	+5 @ 20 mA +3 @ 20 mA	-75 -73	0.3 x 0.3 x 0.08
DCO579582-5	5780 - 5880	0.5 - 10	+5 @ 20 mA	-90	0.3 x 0.3 x 0.08
DCO608634-5 DCO608634-3	6080 - 6340	0.5 - 5	+5 @ 20 mA +3 @ 26 mA	-85 -86	0.3 x 0.3 x 0.08
DCO615712-5 DCO615712-3	6150 - 7120	0.5 - 18	+5 @ 22 mA +3 @ 22 mA	-85 -83	0.3 x 0.3 x 0.08

Model	Frequency Range (GHz)	Tuning Voltage (VDC)	DC Bias VDC @ I [Typ.]	Phase Noise @ 10 kHz (dBc/Hz) [Typ.]	Size (Inch)
DXO Series					
DXO810900-5 DXO810900-3	8.1 - 8.925	0.5 - 15	+5 @ 32 mA +3 @ 32 mA	-82 -80	0.3 x 0.3 x 0.08
DXO900965-5 DXO900965-3	9.0 - 9.65	0.5 - 12	+5 @ 27 mA +3 @ 27 mA	-80 -78	0.3 x 0.3 x 0.08
DXO10701095-5	10.70 - 10.95	0.5 - 15	+5 @ 25 mA	-82	0.3 x 0.3 x 0.08
DXO11441200-5	11.44 - 12.0	0.5 - 15	+5 @ 30 mA	-82	0.3 x 0.3 x 0.08
DXO11751220-5	11.75 - 12.2	0.5 - 15	+5 @ 30 mA	-80	0.3 x 0.3 x 0.08
DXO14851515-5	14.85 - 15.15	0.5 - 15	+5 @ 30 mA	-74	0.3 x 0.3 x 0.08

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FRESH STARTS

Qualcomm—Has completed previously announced plans to modify its corporate structure. The new hierarchy comprises parent company Qualcomm, Inc. and a wholly owned subsidiary, Qualcomm Technologies, Inc. (QTI). Along with its subsidiaries, QTI now operates a substantial portion of Qualcomm's R&D activities as well as product and services businesses. The latter includes semiconductor business QCT.

Anritsu Co.—Has announced the opening of its Microwave Technology Center (MTC Fab), which offers thin-film fabrication services. The MTC Fab will manufacture circuits for microwave applications, multi-layer systems (MCM-D), thin-film sensors, resistor networks, attenuator circuits, hybrid circuits, and power hybrids. Anritsu also is offering customer-specific services including thin-film depositions, resistor laser trimming, substrate laser drilling, photolithography patterning, and device singulation.

Constant Wave—The developer and provider of measurement-analysis software has teamed with Agilent Technologies as an Agilent Solutions Partner. This program provides access to specialized Agilent training events, collaborative marketing activity, and other joint business opportunities.

Lockheed Martin—Is implementing new global environmental goals with the intent of decreasing its use of natural resources at all stages of product development and business operations. By 2020, the company is targeting absolute reductions in carbon emissions (35%), facility energy use (20%), waste to landfills (35%), and water use (10%).

everything RF—Has added a parametric search tool for test and measurement equipment to its product-search website.

Emirates Telecommunications Corporation (Etisalat)—Has finalized the sale of a 9.1% stake in XL Axiata, an Indonesian mobile telecommunications provider. Some 775 million shares were purchased by institutional investors, resulting in gross proceeds of AED 1870 million to Etisalat.

Nujira—Has filed its 175th patent related to Envelope Tracking (ET) technology. The firm's patents cover the key technical aspects enabling the Coolteq ET modulator ICs as well as wider system elements, such as system architectures and timing alignment.

RFMW—Has announced a distribution agreement with EMC Technology/Florida RF Labs. The deal adds Europe, the Middle East, and Africa (EMEA) to franchised RFMW territories.

Peregrine Semiconductor—Has expanded its European operations with the opening of a design, manufacturing, and sales facility in Reading, UK. Multiple product families will be developed at the new facility including digital step attenuators, phase-locked-loop (PLL) frequency synthesizers, and RF switches.

Gowanda Electronics—Has achieved failure-rate Level R for its MIL-PRF-39010 RF inductors (ER10M and ER17S series). Both series meet the US military's Qualified Product List (QPL) requirements for Established Reliability (ER). Each has exceeded 10 million unit hours of life testing to date.

Aeroflex and MagnaChip Semiconductor—Aeroflex's Colorado Springs, CO division has received QML-V qualification from the US Defense Logistics Agency (DLA), Land and Maritime. The company's mixed-signal products are manufactured by MagnaChip.

Rohde & Schwarz—Has entered into a partnership with Albatross Projects Group. Rohde & Schwarz will take over the sales of Albatross Projects' anechoic chambers and shielded rooms in the US and Canada.

Export-Import Bank of the United States (Ex-Im Bank)—Has approved two separate transactions, totaling more than $1.2 billion, to finance the export of American-made telecommunications satellites to Mexico and Australia.

TeleCommunication Systems (TCS)—Has been issued eight new patents by the US Patent and Trademark Office. These patents reflect intellectual property in the areas of public safety, mobile location, messaging, and secure communications.

CONTRACTS

Agilent Technologies— STMicroelectronics will use Agilent's Electromagnetic Professional (EMPro) simulation software in the development of electrostatic-discharge (ESD) structures based on CMOS process technology. **Lockheed Martin**—Has received a $218-million contract from the US Coast Guard for three additional HC-130J surveillance aircraft. This order will increase the Coast Guard's fleet of HC-130Js from six to nine. The contract also includes funding for two mission suites, which will support search and rescue operations. The new aircraft are scheduled to be delivered in early 2015.

HUGHES Snares three-year CS2 contract

LOCKHEED MARTIN Receives $218-million aircraft order

Hughes—Has been awarded a Custom Satellite Communications Solutions (CS2) contract by the US General Services Administration (GSA). Hughes will provide commercial-satellite end-to-end communications to government customers. The contract covers a base period of three years plus two one-year options.

Raytheon Co.—Has received an $8.7-million modification to a previously awarded US Navy production contract. Raytheon will provide the Navy with Joint Tactical Terminal Senior (JTT-Sr) radios that are compatible with the new Common Interactive Broadcast (CIB) waveform. The radios receive and broadcast near-real-time threat data to joint-service host platforms.

TeleCommunication Systems, Inc. (TCS)—The company's In-Building Wireless (IBW) program has received a $2.9-million order from the US Department of Defense (DoD). TCS is designing and installing a distributed antenna system for a DoD medical campus comprising 15 buildings.

Pasternack Enterprises—Has appointed Spur Microwave as its exclusive distributor for India. Pasternack's full product catalog is now available through Spur.

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Model Family	Freq. (GHz)	Connectors (male)	Lengths† (ft)	Temp (°C)
Performance Test (CBL)	DC-18	SMA‡, N	1.6-25	-55/+105
Quick Lock (QBL)	DC-18	SMA	1.0-6.6	-55/+105
Armored (APC)	DC-18	N	6.0-15	-55/+105
Low Loss (KBL-xx-LOW)	DC-40	2.92	1.5-6.6	-55/+85
Phase Stable (KBL-xx-PHS)	DC-40	2.92	1.5-6.6	-55/+85

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† *Custom lengths available by special order.*

‡ *SMA female connectors featured on some models, or via special order.*

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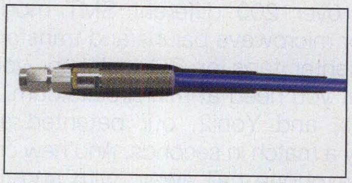

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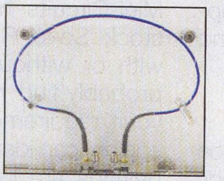

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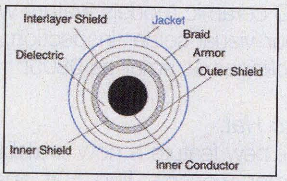

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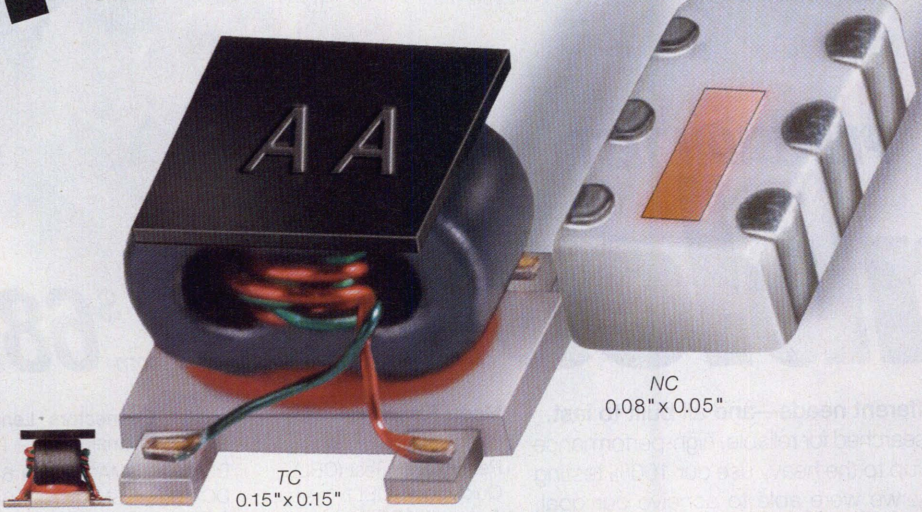

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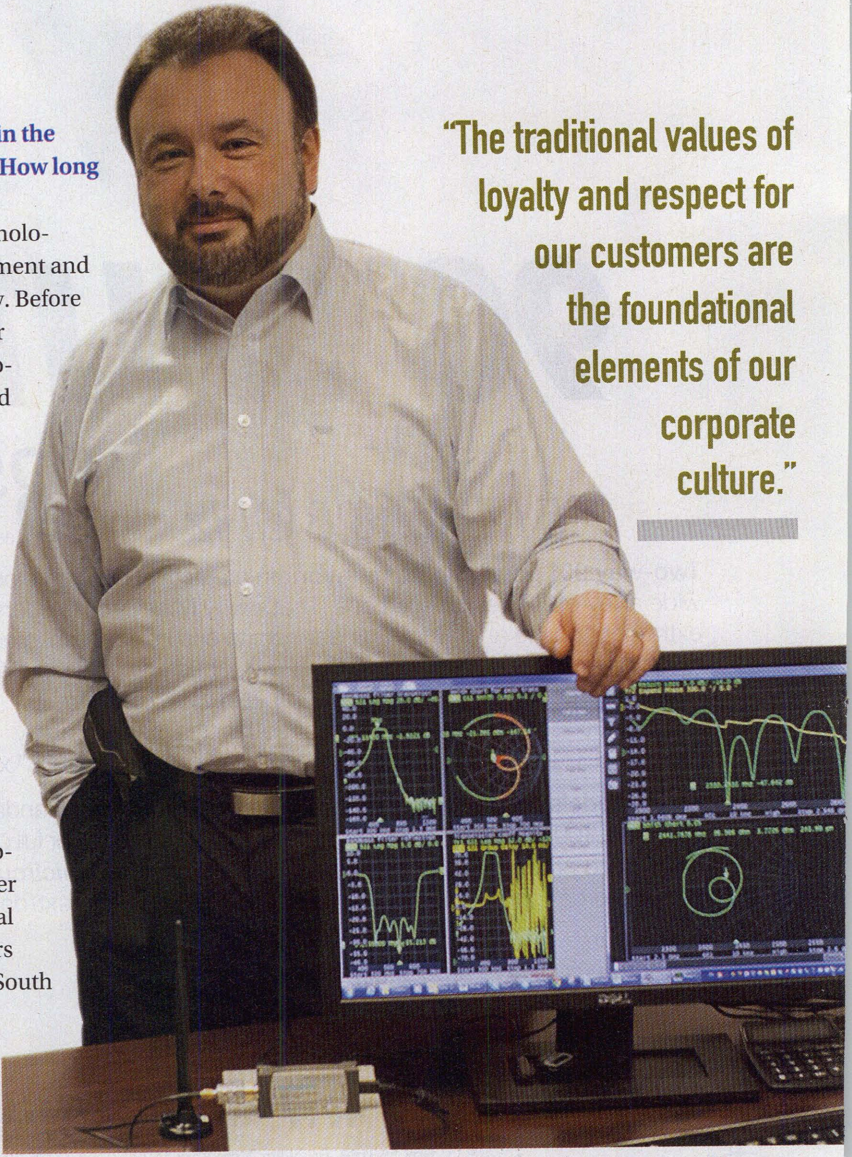
IF/RF MICROWAVE COMPONENTS

377 rev Y

Inside Track with Alex Goloschokin,

MANAGING DIRECTOR, COPPER MOUNTAIN TECHNOLOGIES

Interview by NANCY FRIEDRICH



"The traditional values of loyalty and respect for our customers are the foundational elements of our corporate culture."

NF: Copper Mountain Technologies is a fresh face in the microwave and RF test and measurement market. How long has the company been around?

AG: In its current structure, Copper Mountain Technologies has existed for one year. However, our development and production team just celebrated its 20th anniversary. Before rebranding and reorganizing in October of 2011, our company made telecom, RF, and microwave components and test instrumentation for the European and Asian markets.

NF: The best-known Copper Mountain in this country is in Colorado. Why did you name the firm "Copper Mountain Technologies?" And who came up with the name?

AG: Yes, we've received inquiries about ski passes more than a few times! Unfortunately for those callers, our expertise is... ice hockey. Just kidding, it is actually in microwave and RF test equipment. Our company is named after a different Copper Mountain, which is located in the South Ural Mountain Ridge [in central Russia]. Chelyabinsk, home to our manufacturing facility, is located in this region. Our company's name is a tribute to the rich history of the region. It brings together old-world craftsmanship with modern technological advancements (created by highly talented engineers and researchers—many of whom are graduates of South Ural University, a well-known engineering school).

The Mistress of the Copper Mountain is a well-known Russian sorceress from the tales of writer Pavel Bazhov. Drawing on the mining folklore of the South Ural Mountain region, Bazhov wrote several stories (*The Mistress of the Copper Mountain, The Malachite Casket,* and *The Stone Flower*) about the mineral-rich mountains and their mysterious spirit. The mythical "mistress," who could change into a lizard, was a guiding force for the hard-working miners of the mountain. She protected them in exchange for their complete loyalty and respect for the land. The traditional values of loyalty and respect for our customers are the foundational elements of Copper Mountain Technologies' corporate culture.

NF: How many employees do you have? And how many of those are engineers?

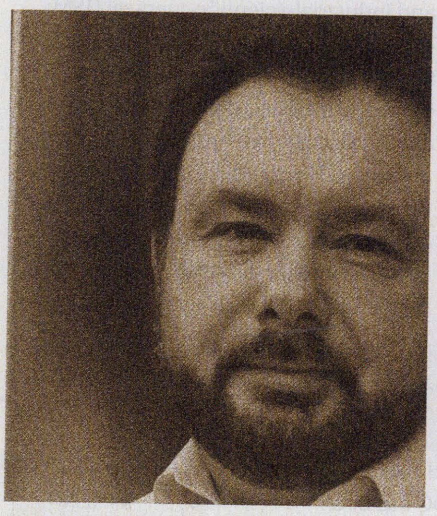
AG: Our vector-network-analyzer (VNA) development team counts 15 engineers. And there are over 70 highly qualified technicians in the VNA production line and quality control. Our Indianapolis facility conducts global business development and sales activities. Customer support is also provided by two of our engineers in Indianapolis.

NF: What challenges have you had getting started as a company?

AG: The VNA market is dominated by several well-known and highly respected providers. Our biggest challenge is overcoming our customers' brand loyalty to those manufacturers. However, at less than one-half the price, dimensions, and weight—accompanied by equal or better performance—our VNAs sell themselves once engineers get a chance to use them. We also have been fortunate to develop relationships with highly reputable and respected manufacturers' reps in the microwave and RF industry. They have done an outstanding job introducing their customers to our solutions.

NF: You are incorporated in Indianapolis. What made you choose Indiana over, say, Silicon Valley in California?

AG: Indianapolis has been my home for the past 22 years—many of which were spent working in international sales and business development at the Commtest Division of JDSU (formerly Wavetek/WWG/Acterna). It offers a lot of advantages. Indiana is rapidly gaining the reputation of being a viable alternative to the cutthroat coasts and their exorbitant cost of doing business. The rise of Indiana's tech sector also has been nurtured by high-profile initial public offerings; several Indiana-based technology firms breaking into national "Best Of" and "Fastest Growing" lists; and the efforts of organizations like TechPoint, IEDC, Verge, and numerous university-outreach initiatives. Indianapolis offers a fast-growing high-tech community, a world-class airport, and Lucas Oil Stadium—the location for the professional football championship, Super Bowl 2012. Go Colts!



"The biggest benefits of virtual VNAs are much lower price point, smaller footprint, light weight, and operation from any external PC."

NF: Copper Mountain offers a "virtual vector network analyzer." Please define this virtual instrumentation.

AG: By the definition first introduced by National Instruments, a virtual instrument is an instrument that consists of a hardware RF measurement module, the external processing module (a PC), and a software package that operates the measurement module and provides users with the user interface (UI).

NF: What advantages would you say a virtual VNA has over a traditional instrument?

AG: The biggest benefit of the virtual VNA is that users can take advantage of the processing power, bigger display, and more reliable performance of an external PC, while simplifying maintenance of the analyzer. Virtual VNAs are flexible. They can be easily adapted to multiple users and are well-suited for lab, production, field, and secure testing environments. Not to mention that they are significantly less expensive!

NF: How do you expect this virtual instrumentation to change the test and measurement market, if at all?

AG: As previously discussed, the biggest benefits of the virtual format are much lower price point, smaller footprint, light weight, and operation from any external PC. All of these aspects will make our VNAs very attractive to both development labs and production environments. For example, our small R54 reflectometer (patent currently pending) can be easily introduced to every workstation at any manufacturing facility that produces RF cables, antennas, connectors, etc.—no matter how limited those workstations are in terms of space. We hope that, by virtue of introducing the VNA en masse to production and quality control, RF and microwave equipment manufacturers will be able to significantly improve their manufacturing processes.

NF: What's next for Copper Mountain Technologies in terms of product development?

AG: Our short-term (next few months) plans include releasing a 2x8 4-GHz port extender for our current line of two-port VNAs. In the December/January timeframe, we are planning on launching a four-port, 8-GHz model as well as a new series of small and lightweight analyzers, which will include 50-Ω, 20-kHz-through-4.8-GHz and 75-Ω, 20-kHz-through-3.0-GHz VNAs. Both the 50- and 75-Ω analyzers in this series will be available in one-path (TR) and full two-path iterations. We are also planning to deliver revisions to our software. They will include additional features and functionality in addition to implementing our customers' recommendations on UI improvement in 2013. MWRF

Methodology Optimizes Design Of SCALP-IMPLANTABLE ANTENNAS

IN THE AREA of implanted medical devices, antenna-enabled biotelemetry is gaining attention for its potential to overcome the limitations of inductive biotelemetry. Such issues include low data rate, a restricted communication range, and sensitivity to inter-coil misalignment. At Greece's National Technical University of Athens, two researchers have developed a two-step design methodology for implantable planar inverted-F antennas (PIFAs). Asimina Kiourti and Konstantina S. Nikita proposed miniature, scalp-implantable PIFAs at 402, 433, 868, and 915 MHz. Their antennas exhibit identical volume of $\pi \times 6^2 \times 1.8$ mm^3 and 10-dB bandwidths of 27, 28, 38, and 40 MHz.

The researchers studied the design and radiation performance of miniature antennas for integration in head-implanted medical devices operating in both the medical-implant-communication-service (MICS; 402.0 to 405.0 MHz) and industrial-scientific-medical (ISM; 433.1 to 434.8, 868.0 to 868.6, and 902.8 to 928.0 MHz) bands. They then created a parametric model of a skin-implantable antenna and both fabricated and tested a prototype. To speed the design process, the researchers suggest a two-step methodology: approximate antenna design inside a simplified model geometry and then perform Quasi-Newton optimization inside a canonical model of the intended implantation site. The antennas are further analyzed inside an anatomical model of a human head.

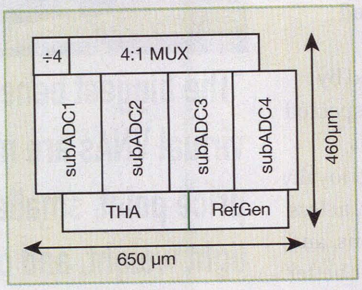
The results reveal that the exhibited radiation performance greatly depends on design parameters and operating frequency. The researchers tackle the choice of canonical versus anatomical tissue models for design purposes while addressing patient safety and link budget at various frequencies. For the different stages of antenna design and analysis, both finite-element (FE) and finite-difference-time-domain (FDTD) numerical solvers were used. See "Miniature Scalp-Implantable Antennas for Telemetry in the MICS and ISM Bands: Design, Safety Considerations and Link Budget Analysis," *IEEE Transactions On Antennas And Propagation*, Aug. 2012, p. 3568.

TIME-INTERLEAVED ADC Benefits 60-GHz Transceiver

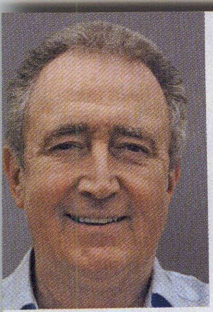
A NUMBER OF standards have sprung up in the 57-to-64-GHz band, such as IEEE 802.15.3c, IEEE 802.11ad, and WirelessHD. All have one common goal: to speed the realization of integrated circuits (ICs) that can support large wireless data transfers at those millimeter-wave frequencies. Due to these ICs' wide applicable bandwidth and modest circuit-implementation complexity, low-order data modulation approaches like binary phase shift keying (BPSK) and quadrature phase shift keying (QPSK) are often chosen. To provide power-efficient, low-cost system-on-a-chip (SoC) solutions for such applications, medium-resolution (6 to 8 b), CMOS analog-to-digital converters (ADCs) with speeds beyond 1 GSample/s are needed. At the University of California, a 7-b, 2.2-GSamples/s, time-interleaved subranging CMOS ADC has been presented for low-power gigabit-wireless-communications SoCs by I-Ning Ku, Zhiwei Xu, Yen-Cheng Kuan, Yen-Hsiang Wang, and Mau-Chung Frank Chang.

The time-interleaved ADC combines multiple sub-ADCs to deliver the required high sampling rate. But the time-interleaved architecture suffers from channel mismatches in timing, offset, and gain among individual sub-ADCs. Because the total area increases as the number of channels rises, the routing of multiple-phase clock signals and digital outputs also becomes complicated.

To achieve high power efficiency and performance, a time-interleaved ADC design thus requires the proper sub-ADC architecture and a strategy for alleviating channel mismatches. To boost the speed of individual ADC channels, for example, this team invented a time-splitting subranging architecture. It raises the speed of individual ADC channels while reducing the total number of interleaved channels to four. In addition, the researchers proposed a low-power and fast-settling distributed resistor array for reference voltages to mitigate gain mismatches within channels. The channel offset mismatches are calibrated through the digital-controlled corrective current sources, which are embedded in the track-and-hold (T/H) amplifiers of each sub-ADC.



Ultimately, the team created a prototype in 65-nm CMOS that occupies only 0.3 mm^2 of chip area. It consumes 40 mW at 2.2 GSamples/s from a 1-V supply. The ADC boasts measured signal-to-noise and distortion ratio (SNDR) and spurious-free dynamic range (SFDR) of 38 and 46 dB, respectively, with a 1.08-GHz input at the 2.2-GSamples/s sampling rate. The effective number of bits (ENOB) is 6.0 b at Nyquist rate while the figure of merit (FOM) is 0.28 pJ/conv.-step. The researchers were able to integrate the ADC into a self-healing wireless-transceiver SoC. See "A 40-mW 7-bit 2.2-GS/s Time-Interleaved Subranging CMOS ADC for Low-Power Gigabit Wireless Communications," *IEEE Journal Of Solid State Circuits*, Aug. 2012, p. 1854.

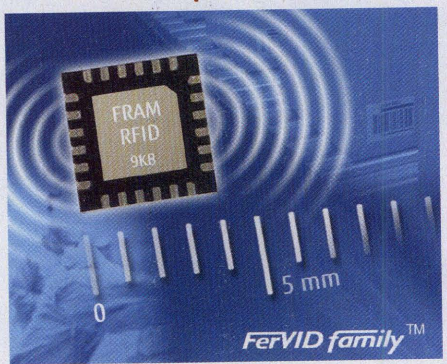


Microwaves in Europe

PAUL WHYTOCK, *European Editor*

Memory Infusion Allows Chip To Further RFID's Reach

LANGEN, GERMANY: RF identification (RFID) has been a major success for the wireless industry, helping manufacturers keep track of parts and products in a multitude of markets. Now, RFID may have the capacity to expand its scope by invading new markets. The key to these new opportunities is enhanced memory. The European division of Japanese company Fujitsu (www.fujitsu.com) has developed a new device for its FerVID chip family, which is used in RFID tagging applications. In addition to increased memory capacity, Fujitsu Semiconductor Europe notes that this device boasts a serial interface that could expand the applications for RFID tagging **(see figure)**.



With 9 kB of FRAM, this device claims to offer the highest density available in an RFID chip operating in the HF band (as defined in ISO/IEC 15693).

Like all members of the FerVID family, the MB89R112 series employs ferroelectric random-access memory (FRAM). FRAM is touted for providing fast write speeds, high-frequency re-writing, and a good level of radiation tolerance—all while being conservative in terms of power consumption. With 9 kB of FRAM, the company claims that its product provides the greatest density available in an RFID chip operating in the high-frequency (HF) band as defined in ISO/IEC 15693.

A total of 8 kB of this capacity is provided as user memory, enabling access by read/write operations as defined in ISO/IEC 15693. The series will be offered in two variants with 24- and 96-pF input capacitance. Writing 8 kB of data takes about 4 s, which is 6X faster than the time it takes E2PROM products.

With these memory devices, the increased available data volume on RFID tags would enable greater operating characteristics in applications like product-lifecycle traceability management and equipment maintenance records. According to Fujitsu, these memory devices can provide solutions spanning embedded, industrial, and medical applications.

WHAT ENGINEERS WANT

For engineers, the higher-capacity memory—combined with the RFID connectivity to sensors and microcontrollers—can enable the wireless modification of product operating parameters or the logging of environmental factors during distribution. These features would benefit production control in automotive and electronics manufacturing. They also would aid maintenance applications in aviation, construction, and civil engineering.

The MB89R112QN products enable these features by supplementing the HF RFID interface with an additional Serial Peripheral Interface (SPI) for microcontroller connectivity. Because the 8 kB of user memory in FRAM can be accessed from the microcontroller via SPI, shared memory regions can be used both for data logging and as a parametric area for changing the microcontroller's operating parameters.

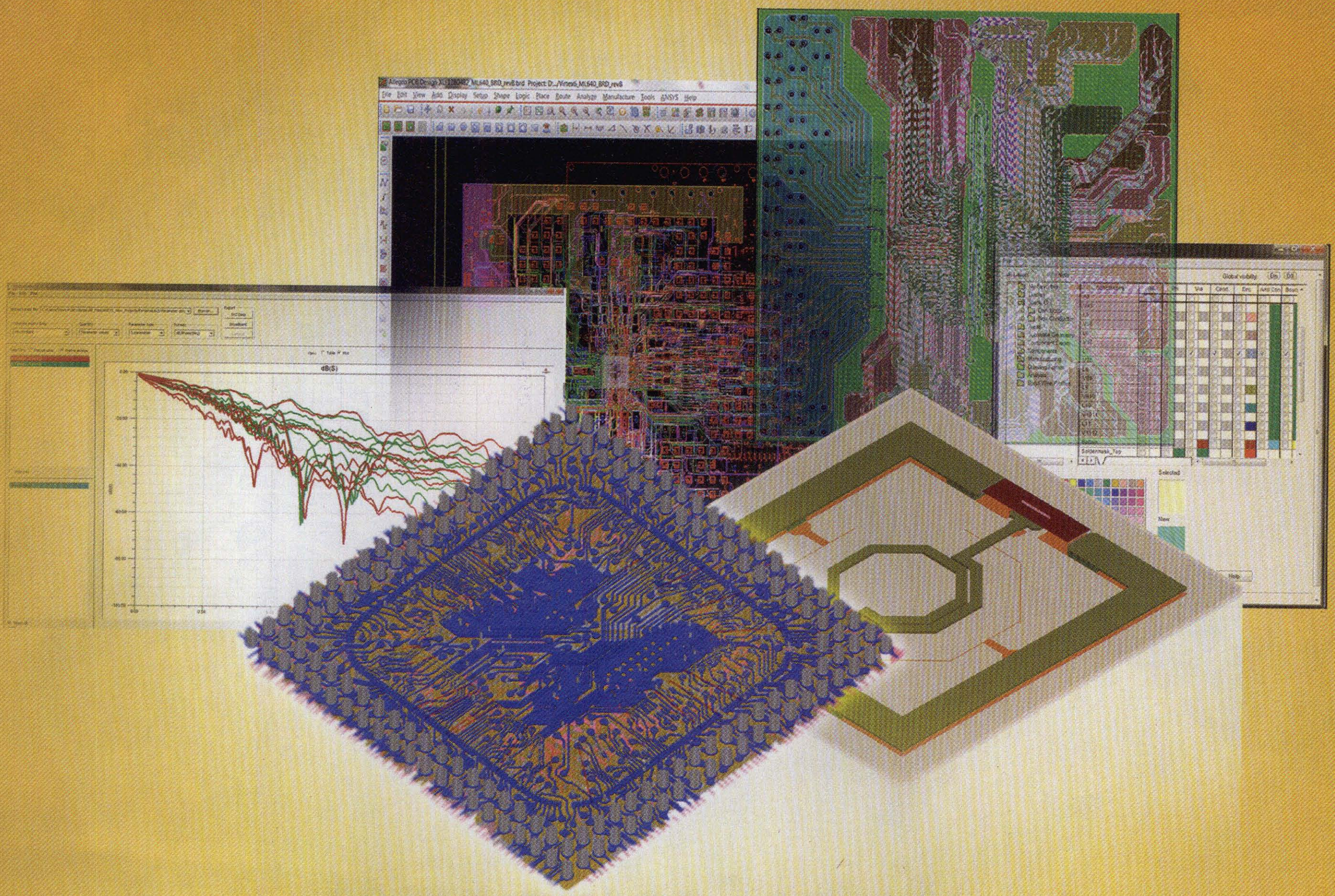
DEVELOPMENT BACKSTORY

For eight years, Fujitsu has been developing FRAM products as part of the FerVID family. The firm uses two frequency bands for the chips integrated in high-functionality RFID tags operating in the HF band from 3 to 30 MHz. Also known as the decameter band or decameter wave [as the wavelengths range from one to ten decameters (10 to 100 m)], Fujitsu's designs operate at 13.56 MHz and an ultra-high-frequency (UHF) band covering 860 to 960 MHz. As a result, these products serve a wide range of chips including those used in data-carrier tags in factory automation and maintenance, those that can withstand gamma radiation or electron beams for the medical and pharmaceutical sectors, and chips with serial interfaces for embedded applications.

WHAT IS FRAM?

FERROELECTRIC RANDOM-ACCESS MEMORY (FRAM) is a nonvolatile form of memory that uses ferroelectric film as a capacitor. Possessing characteristics of both read-only-memory (ROM) and RAM devices, FRAM features high-speed access, high endurance in write mode, low power consumption, and nonvolatility. It also is very tamper-resistant. Consequently, it is used in smart cards and mobile phones, where high security and low power consumption are critical.

Ferroelectric thin films with a perovskite crystalline structure are suitable for a range of applications, such as nonvolatile memories, dynamic random-access memories (DRAMs), solid-state displays, infrared detectors, pyroelectric and piezoelectric sensors, and microwave devices. Thus, PZT [Pb (ZrTi)O3] material is widely used as a ferroelectric material. When it is subjected to an electric field, the Zr/Ti atom shifts up or down. This polarization remains when the electric field is removed, providing nonvolatility while keeping power consumption low.



JACK BROWNE | Technical Contributor

Tracking Trends in Wireless Infrastructure

THE INFRASTRUCTURE NEEDED TO PROVIDE A GROWING NUMBER OF WIRELESS FIXED AND MOBILE SERVICES TO A CONSTANTLY GROWING AUDIENCE **MUST EXPAND FOR WIDER COVERAGE, USING SMALLER CELL SITES WHERE NECESSARY.**

WIRELESS COMMUNICATIONS has evolved through four generations of technology to its current state: a hybrid vehicle for voice, video, and data using handheld and stationary electronic devices. It is the infrastructure—the towers, antennas, and associated hardware and software—that make all this possible, and it is the infrastructure that has driven a good part of the commercial RF/microwave market for the past 20 years. Although it is impossible to see the future, some of the technology advances that lead to the Fourth Generation (4G) of wireless communications may provide some insight into what will be needed for the next generation of wireless infrastructure equipment, and some of the technology evolution to come.

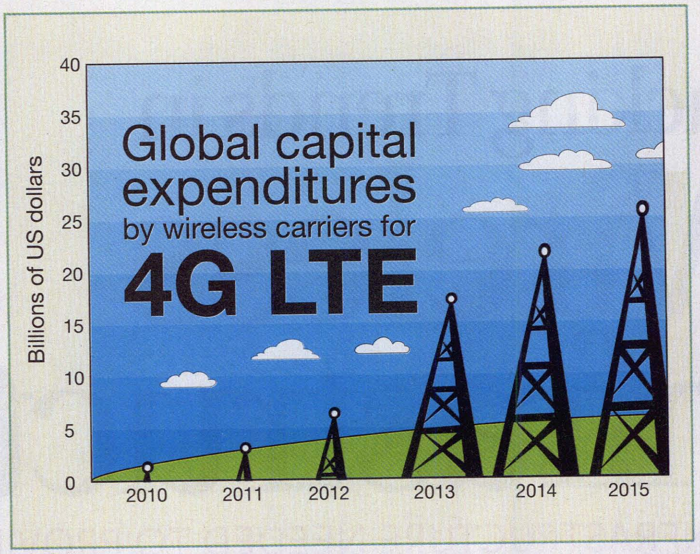
Wireless technology has been embraced worldwide as it continues to expand in a growing number of applications, both indoors and outdoors. Wireless communications customers continue to demand increased services in terms of voice, video, and data communications. These growing demands are driving cellular/wireless carriers and service providers to expand their wireless infrastructure to achieve higher data rates and increased capacity to serve the increased requirements of a growing customer base.

"Wireless infrastructure" is a term generally associated with the equipment and buildings needed to make cellular communications possible **(Fig. 1)**, beginning with the erection of towers, antennas, and associated electronic equipment with the expansion of analog first-generation (1G) cellular communications systems in the 1980s. Successive generations of cellular equipment employed digital technology and modulation formats, with 3.5G cellular infrastructure currently the most dominant technology in use. However, fourth-generation (4G) cellular formats—such as WiMAX and Long Term Evolution (LTE) cellular technologies—are rapidly gaining ground.

Although the transmission/reception technologies change, the need for towers and the associated infrastructure still exists. Typically, the infrastructure represents a considerable investment in a cellular network, and existing towers will support multiple generations of cellular technologies; service providers will try to make the most efficient use of (possibly) 2G, 3G, and 4G equipment, all on the same tower.

1. Large towers with their cellular antennas are an ever-present reminder of the infrastructure needed to support wireless communications networks. [Photo courtesy of Huber + Suhner (www.hubersuhner.com).]

Some general trends that are driving the expansion of wireless infrastructure include the growing number of mobile wireless communications users and the increasing amount of data being communicated via mobile networks. Cellular customers are even starting to use near-field-communications (NFC) technology to make on-site bill payments, adding to the amount of data on a cellular network. For their part, cellular service providers must find ways to accommodate the growing demands for data and bandwidth, while at the same time manage their own infrastructure operating expenses. The latter consist of capital equipment expenses (CAPEX), such as the cost of the cellular towers and wireless transceiver equipment, and operating expenses (OPEX), such as the electricity needed to run the cellular towers.



2. Market studies project strong growth in the use of LTE technology in wireless base stations in the next several years. [Plot courtesy of IHS iSuppli Wireless Communications (www.isuppli.com).]

In some cases, increased wireless coverage can be increased through the use of smaller cell sites, known as femtocells, which can be installed in buildings and within public gathering places (e.g., shopping centers). They must also adopt "green" strategies for their wireless networks, since many service providers are managing heterogeneous networks consisting of a variety of different technologies (such as 2G, 3G, and 4G) together. A major OPEX is the electrical power needed to maintain the wireless network. Any green strategies that can save operating power can also result in significant savings in OPEX. In addition, improvements in spectrum efficiency, the use of advanced antenna techniques, such as multiple-input, multiple-output (MIMO) antenna configurations, and the use of smaller cells to expand coverage can all contribute to lower OPEX.

Clearly, LTE technology has captured the fancy of wireless service providers and will be the wireless standard of choice for expanding infrastructure in the next few years. According to a recent report by market research firm IHS iSuppli Wireless Communications (www.isuppli.com), LTE will capture the majority of wireless infrastructure capital spending over the next several years as mobile service providers and carriers seek to provide their customers with the combination of coverage and services that is often difficult to support with earlier generations of cellular technology. According to the IHS iSuppli market study **(Fig. 2)**, global capital spending on LTE technology is projected to reach $24.3 billion (USD) in 2013, or almost triple the level of spending on LTE technology in 2012.

The expected size and growth rate of 4G LTE technology has spurred its share of market research and positive expectations, including a study by Reportlinker (www.reportlinker.com), "The Wireless Infrastructure Market 2012-2017: Wi-Fi, WiMAX, 3G, HSPA+ and LTE," which examines the projected market shares for a number of different technologies vying to support cellular communications. This report sets the value of the global wireless infrastructure market at $43 billion (USD) by the end of 2012. The report also makes some important points about how network operators must assess both their CAPEX and OPEX when installing and maintaining wireless infrastructure. The backhaul connections could be a limiting factor in terms of the number of subscribers that can be served by a specific infrastructure configuration. Put simply, when a cellular subscriber connects to a cellular antenna tower, the backhaul equipment connects them to the rest of the world.

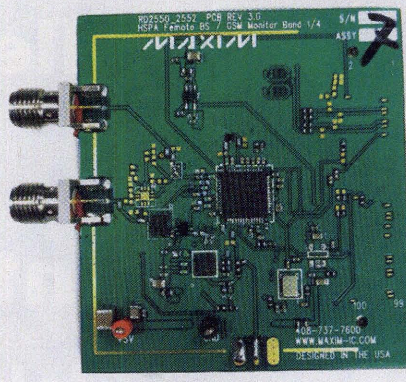
Among the firms that are contributing to that expanding wireless infrastructure is the Swiss company Huber + Suhner (www.hubersuhner.com), perhaps best known for its wide range of connectivity solutions. Sprint, one of the largest telecommunications companies in the US, is upgrading its 4G LTE towers to Huber + Suhner's fiber-to-the-antenna (FTTA) for added bandwidth in its wireless infrastructure equipment, including in the backhaul portion of its networks. Huber + Suhner is now the leading supplier for 4G LTE installation systems in North America, helping to upgrade equipment for numerous large telecommunications companies [including Sprint, T-Mobile, Bell Mobility, SaskTel, and Telus (in Canada)], all with more than 10 million subscribers. According to a Huber + Suhner report, Sprint plans to upgrade around 15,000 cell sites within the next three years, while T-Mobile alone will upgrade more than 14,000 antenna masts in the US over the next 12 months. With the FTTA connectivity, the cellular transceiver electronics can be mounted near the antennas (on the mast), rather than as remote radio heads (RRHs) in cabinets on the ground, helping to speed and simplify installations.

Increasingly, carriers are viewing the maintenance and operation of their cellular infrastructure as an additional business, on top of serving their wireless communications subscribers. This has created opportunities for third-party companies to serve as wireless tower/

equipment installers and maintainers, providing turnkey wireless infrastructure solutions for cellular/wireless carriers. As an example, Multiband Corp. (www.multibandusa.com) offers an extensive list of wireless-infrastructure-related capabilities, including communications site construction with both RF/microwave and digital design and installation, site surveys, inspections, repair and maintenance, and even necessary preparation for Federal-Communications-Commission (FCC) site licensing. These third-party companies run the wireless infrastructure as a business, thereby freeing cellular carriers to focus on their primary responsibilities.

Large cell sites are beginning to share wireless communications traffic, with much smaller sites in the years to come—many within buildings, malls, and other public gathering places. In a market study by Maravedis-Rethink (www.maravedis-rethink.com), "Transforming the Mobile Data Network: Operator Strategies for Profitable Small Cell Networks 2012-216," which is based on a global survey of mobile wireless communications operators, two-thirds of smaller cellular base stations will be operating in bands above 2.2 GHz by 2016. This projects to several years of strong growth for smaller cell sites from 2013, when the number of small sites in bands above 2.2 GHz is less than 40%. Both 3G and 4G equipment will be used in the smaller cells, in spectrum of 2.3 GHz and above. According to the report, the deployment of public-access small cells for 3G/4G services will rise from less than 30,000 in 2011 to about 11.3 million by 2016, or CAPEX investment of about $4 billion. The smaller cells enable additional mobile communications capacity in the short-distance areas that they cover, such as in and around shopping malls, which will generate new revenue streams for the carriers. Of course, securing locations for these smaller cells, managing the cells, and making effective backhaul connections will add to the complexity of adding smaller cells to existing cellular network infrastructure.

In support of smaller cell sites, a number of companies have developed integrated-circuit (IC) or system-on-chip (SoC) solutions that essentially incorporate most of the radio components and many of the digital components needed for a complete cellular base station. For example, the MAX2550 transceiver IC from Maxim Integrated Circuits (www.maxim-ic.com) can be supplied as part of a package with a reference design **(Fig. 3)** and operating software for installing a cellular femtocell. The package includes additional power amplifiers, duplexers, a temperature-controlled



3. This reference design can be supplied for a number of different WCDMA and cdma2000 frequency bands for quick development of a wireless base station. [Photo courtesy of Maxim Integrated Circuits (www.maxim-ic.com).]

crystal oscillator (TCXO), software drivers, and all necessary passive circuit elements. The package even includes a performance report on how the radio design complies with the Third-Generation-Partnership-Program (3GPP) TS25.104 home-area base-station standard. The transceiver IC and reference design operate over a base-transceiver-station (BTS) receive band of 1920 to 1980 MHz and BTS transmit band of 2110 to 2170 MHz. It also supports downlink monitoring of surrounding cells. In addition, the company offers radio transceivers and reference designs for additional cellular bands, including full wideband-code-division-multiple-access (WCDMA) and cdma2000® coverage.

On the digital side, Texas Instruments (www.ti.com) offers its model TMS320TCI6616 SoC, which combines cellular physical-layer (PHY) technology with high-speed packet processing capability. It features multiple TMS320C66x digital-signal-processing (DSP) cores, combining for essentially 4.8 GHz of equivalent DSP signal-processing capability. The SoC, which includes generous on-chip memory, can perform up to 76 billion floating-point operations per second (76 GFLOPS). It is ideal for use in smaller base stations, and provides the digital processing power without need of additional external components, such as field-programmable gate arrays (FPGAs).

Recently, Broadcom (www.broadcom.com) announced a universal digital front end which essentially could serve any number of different wireless platforms and standards with a single-chip solution. The single-chip model BCM51030 is designed to adapt automatically to any signal combination, including CDMA, WCDMA, and LTE signals. Ideal for smaller cell sites, it boasts improved efficiency with external amplifiers by means of the company's VersaLine™ digital predistortion technology. It can work with any power amplifier technology, including with silicon LDMOS, GaAs, and GaN amplifiers.

These few devices are just a sampling of the radio and digital solutions to come, with an eye for operating at lower power levels in support of smaller, "greener" cell sites. The number of large sites with towers will be expanding, but that growth will be unmatched by the increase in smaller, mainly in-building wireless base stations. MWRF

JACK BROWNE | Technical Contributor

Preparing RF/MW Parts For Space

Companies seeking to sell their RF and microwave electronic products into space must meet a rigid set of requirements, ensuring the highest reliability for prolonged periods of service.

SPACE HAS BEEN called "the final frontier" in both fiction and reality, and it does represent a challenging market for many RF/microwave companies. Components built for use on orbiting satellites as part of communications links (to give one example) simply cannot fail during the intended lifetime of the satellite, which is typically 10 years or longer. After all, there is no luxury of "making a house call" for maintenance. Along with high reliability, there is also the expectation that performance remains at the highest levels, with minimal degradation, for at least a decade **(see figure)**.

NASA technicians evaluate the temperature effects of atmospheric re-entry on electronic materials. [Photo courtesy of NASA (www.nasa.gov).]

Ensuring reliability is an essential step in preparing any RF/microwave component or subsystem for an application in space, but it is only one of many requirements that must be met before an electronic device can be considered a "space-qualified" part. Companies pursuing sales in space must first ensure that their manufacturing facilities meet the requirements for producing space-qualified components—typically through a set of guidelines as detailed in the MIL-PRF-38534 Class K standards for commercial and government spaceflight equipment. The MIL-PRF-38534 Class K documentation applies to military specification for microcircuits and multichip modules (MCMs) for use by the US Department of Defense (DoD) and other government agencies.

However, MIL-PRF-38534 Class K is only one such document or guideline for companies interested in pursuing space-grade components. Since it is generally true that most companies selling into space-based applications are also designing and manufacturing parts for military and aerospace applications, firms that intend to serve both markets will usually comply with a number of different specification guidelines. These include military documents MIL-STD-202, MIL-STD-883, MIL-STD-790, and MIL-STD-1344, as well as several NASA (www.nasa.gov) documents.

The MIL-STD-202 documentation, for example, covers guidelines for vibration, thermal shock, and mechanical shock, while MIL-STD-883 provides details on salt spray testing, temperature cycling, immersion, barometric pressure, and shock. In truth, many of these may be more appropriate for maritime applications. But because the reliability requirements for space applications are so demanding, a combination of military standards is typically needed to ensure that a component or assembly is "ready" for deep space use.

As an example, SV Microwave (www.svmicro.com) is a supplier of space-qualified RF/microwave connectors and components. The company has processes and systems for MIL-STD-202, MIL-STD-790, and MIL-STD-1344 requirements, and performs high-reliability (hi-rel) screening for a number of parameters that can impact reliability in space or even in critical ground-based requirements. Among these are screening for contact stresses, separating forces, solderability, and plating adhesion in components and assemblies. In addition, the company has an approved destructive physical analysis (DPA) laboratory for evaluating its space-

qualified products. Prior to shipment, the firm can provide documented verification of any number of key reliability parameters, including adhesion, axial contact retention, contact engaging and separation forces, solderability, joint destruct torque, epoxy captivation, and full design review and verification.

Numerous military standards are typically applied to ensure deep-space readiness.

For any company, selling into space requires a considerable investment in laboratory equipment and training to use that equipment properly. For example, satcom component and assembly supplier MITEQ (www.miteq.com) relies on five Class 100,000 clean rooms and two Class 10,000 clean rooms to support manufacturing of components and assemblies for its military and hi-rel space businesses. In addition to electrical and environmental test equipment, every circuit element that goes into an RF/microwave component intended for use in space must be carefully considered. Parts that are needed for an oscillator, for instance, must meet the requirements as set forth by the governments Qualified Products List (QPL). Alternately, when specific circuit elements are not available with the proper screened designation, they must be up-screened through the use of a specification-controlled drawing (SCD).

Military-grade parts may be adequate for some space applications. By way of example: For an oscillator, chip resistors screened to MIL-PRF-55342 military requirements and chip capacitors screened to MIL-PRF-55681 requirements are readily available for use in military circuits; they can also provide high reliability for space-based designs. But when space customers demand it, the highest-reliability parts, such as Class T for resistors and Class S for capacitors must be used.

Although the reliability required of space-based components is easily associated with the performance needed in military electronic systems, many space-based applications are actually commercial. Think of the many satellite-communications (satcom) systems used for commercial broadcast television services, telephone services, computer networking, and other high-speed digital services, not to mention the Global Positioning System (GPS) satellites so often used for position information. To give an idea of the many thousands of satellites currently in orbit around the Earth, either active or decaying, EchoStar XVII was launched this past summer.

Manufacturing a component such as an oscillator for space requires using the proper materials and following the proper guidelines. Using standardized circuit elements and parts—from such lists as the QPL, the NASA Parts Selection List, and the NASA Goddard Space Flight Center (GSFC) Preferred Parts Lists (which are screened for the effects of radiation in space)—can help the overall process of documenting reliability, but it will also add to manufacturing costs. And the costs of components for space far outweigh the costs of those for terrestrial use.

An RF/microwave component that has been readied for space use has been through extensive testing and inspections. It must be made with space-approved materials, and even the circuit elements within the component must be qualified for use in space. As an example of a space-qualified oven-controlled crystal oscillator (OCXO), model OSC029 from TRAK Microwave Corp. (www.trak.com) has been space qualified for at least 10 years of in-orbit operating life. The S-level OCXO, which operates at 10.3 GHz, exhibits long-term stability of ±1.2 ppm over 10 years, with outstanding spurious performance of typically –95 dBc. The phase noise is a mere –95 dBc/Hz offset 2 kHz from the carrier. Designed for a space environment, it is rated for baseplate operating temperatures from –15 to +65°C.

Many suppliers of space-grade components and assemblies refer to their track record of success in space as an assurance that its products will be 100% reliable when put to work. Dow-Key Microwave (www.dowkey.com), for example, refers to its 42-year heritage and its use of a dedicated group for its space products, with zero failures in its past. Similarly, Teledyne Cougar (www.teledyne-cougar.com) points to its 22-year legacy of supplying components for space missions—as well as its MIL-PRF-38534 Class K certification. Suppliers of miniature passive components and waveguide assemblies, respectively, Anaren Microwave (www.anaren.com) and ARRA, Inc. (www.arra.com) have also built strong reputations as space-level component manufacturers.

W.L. Gore & Associates (www.gore.com) has provided its cable assemblies to more than 70 satellite programs since 1976, with a 100% failure-free flight record. EMC Technology (www.emc-rflabs.com) has even gone as far as creating a space-level product working reference sheet, available for free download on their website, by which customers can review different options for screening their component orders for space-level requirements.

Finally, given the high price of space-grade components and assemblies, some companies have considered ways to cut costs for their space-level customers without sacrificing reliability. Merrimac Industries (www.merrimacind.com), which has supplied everything from power dividers to complete beam-forming networks for space platforms, has developed a program called Merrimac Space Qualified Products (MSQP). The MSQP program was created to reduce the complexity of procuring RF/microwave components for space. It builds on Merrimac's heritage of designing and shipping hi-rel military and space-qualified components for a large number of systems and already having documentation and screening levels set for those components; in effect, the company has created a list of "standard" components that are already qualified for use in space. Customers can select a part from the MSQP list, or have Merrimac create a specification for the component they need based on the MSQP design, process, qualification, and screening guidelines. MWRF

JACK BROWNE | Technical Contributor

Crows Fly High At 49th Annual AOC

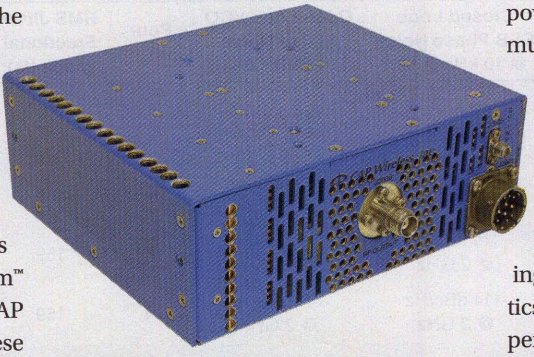
The 2012 Edition of the Association of Old Crows (AOC) International Symposium and Convention offered a diversified educational program—along with an energetic exhibit hall—for fans of military electronics.

EVERY YEAR, the Association of Old Crows (AOC; www.crows.org) gathers in a different city. This professional organization is comprised of past, present, and future soldiers, along with the electronics manufacturers hoping to supply their battlefield needs. This year, the 49th Annual International AOC Symposium & Convention took place Sept. 23-26 at the Phoenix Convention Center (Phoenix, AZ).

Keynote addresses included a talk on the evolution of the National Security Agency (NSA; www.nsa.gov) by Dr. Eric Haseltine, the agency's former Director of Research. Also featured was a discussion on the future needs for small-signal detection on the battlefield presented by Jeff Jones, Fellow and Chief Scientist of the IBM Analytics Group (www.ibm.com). In addition, the exhibition floor was filled with a large number of company representatives and their visitors.

In terms of emerging RF/microwave technology, the relatively small exhibition floor was bustling with points of interest, including the show of Spatium™ power amplifier technology from CAP Wireless (www.capwireless.com). These are reliable solid-state amplifiers based on gallium arsenide (GaAs) or gallium nitride (GaN) device technologies, using quasi-optical combining to sum the outputs of individual solid-state devices or amplifiers in free space, rather than through a stripline or microstrip power combiner with much greater loss (and loss of output power). By combining the contributions of individual monolithic-microwave-integrated-circuit (MMIC) amplifiers, the company has developed Spatium power amplifiers operating through 40 GHz.

The Spatium technology appeals to various branches of the US military for its capability of delivering high output-power levels in much smaller and lighter packages than the technology it replaces, traveling-wave-tube amplifiers (TWTAs). Another positive aspect of the Spatium amplifiers is that they undergo what is known as a "soft" failure mode. Even if one or more of the solid-state amplifiers in a Spatium enclosure fail, the amplifier will continue operating, albeit with reduced gain and output power.



1. This compact solid-state amplifier delivers as much as 100 W in a single channel at X-band frequencies and can replace much larger, heavier TWT amplifiers. [Photo courtesy of CAP Wireless (www.capwireless.com).]

CAP Wireless brought several examples of this technology to the AOC exhibition, notably an X-band amplifier developed for electronic-warfare (EW) applications **(Fig. 1)**. Available as a single-channel design with 100 W output power, or a dual-channel amplifier with 50 W output power per channel, the X-band amplifier is a direct bolt-in replacement for TWTAs in EW systems. From 8 to 11 GHz, a model XS259900 dual-channel X-band amplifier provides better than 30% drain efficiency.

For a look at the alternative technology, visitors to the dB Control (www.dbcontrol.com) booth could size up the dB-3902 power-combined TWTA **(Fig. 2)** with as much as 8 kW peak output power at 6% duty cycle from 4 to 8 GHz. It employs two periodic-permanent-magnet (PPM) -focused traveling-wave tubes (TWTs) to achieve its rates output power. The firm minimizes losses through the power combiners, carefully matching the amplitude and phase characteristics of the two TWTs for optimum amplifier performance. The C-band model dB-3902 provides 60-dB minimum gain from 4 to 8 GHz with better than –10 dBc harmonics and –50 dBc spurious levels. It includes numerous protection functions, including against TWT over-temperature and TWT helix over-current conditions.

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The next generation air and missile defense radars demand effectiveness, reliability, power efficiency and affordability. You can count on CTT's twenty-five years of experience in microwave amplification and subsystem integration to meet these demands.

CTT offers not only form, fit, function of microwave amplifier replacements for many mature systems, but also incorporates leading-edge technology components such as GaN and GaAs.

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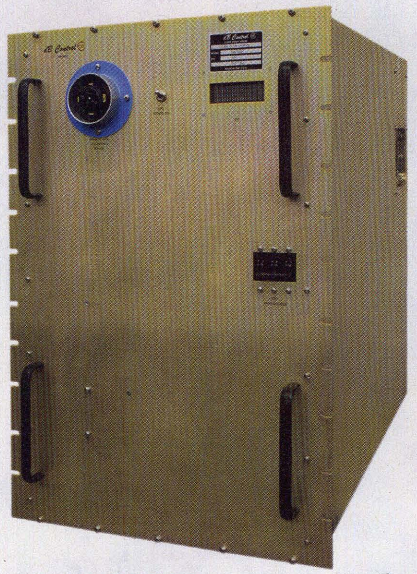
Communications & Power Industries (www.cpii.com) was also on hand at the 49th AOC with an example of its high-power vacuum-tube capability in tow: the model VTX-5682A pulsed coupled-cavity TWT, with 30 kW peak output power (at 1% pulsed duty cycle) from 9.0 to 9.5 GHz. It is designed for use with 0.25-W input power and 50-μs pulse widths. The tube provides 48-dB gain, and is equipped with WR-90 waveguide input and output ports to handle the high power levels.

Micro Lambda Wireless (www.microlambdawireless.com) showed several examples of its YIG-based technology, including its lines of tunable filters and oscillators. The firm also displayed the capabilities of its frequency synthesizers, including the MLSP Series sources for frequency bands of 2 to 18 GHz and 2 to 20 GHz. These YIG-based synthesizers include models MLSP-2018 (with a frequency range from 2 to 18 GHz) and MLSP02020 (which runs from 2 to 20 GHz). The synthesizers tune with 1-kHz resolution and can switch frequencies as fast as 1 ms. Typical spurious levels are –60 dBc; phase noise is typically –93 dBc/Hz offset 10 kHz from the carrier and –114 dBc/Hz offset 100 kHz from the carrier.

FEI-Elcom Tech (www.elcom-tech.com) also showed its frequency synthesizers at the AOC exhibition hall, although with slightly faster switching speeds. The firm's UFS line of ultrawideband frequency synthesizers includes models covering 0.3 to 3.0 GHz (model UFS-3), 0.3 to 4.0 GHz (model UFS-4), and 0.3 to 18.0 GHz (model UFS-18) with +10-dBm typical output power across their frequency ranges. These synthesizers shift frequencies in about 250 ns for a full-band switch, and tune with 1-Hz frequency resolution. Harmonic levels are only –50 dBc while spurious levels are –65 dBc. The frequency synthesizers boast a low phase-noise floor of –147 dBc/Hz through 18 GHz and phase noise of only –135 dBc/Hz offset 1 MHz from a 10-GHz carrier. The sources are ideal for applications in EW systems,



2. Model dB-3902 is a power-combined TWTA with as much as 8 kW peak output power from 4 to 8 GHz. [Photo courtesy of dB Control (www.dbcontrol.com).]

in signal-intelligence (SIGINT) systems, automatic-test-equipment (ATE) systems, and for frequency-agile radar systems.

At the system level, ITT Exelis (www.exelisinc.com) announced its Exelis GPS Interference, Detection, and Geolocation (IDG) system for near real-time geolocation of intentional and unintentional GPS jamming sources; it operates through a network of sensors and advanced geolocation technology. IDG technology is based upon a network of threat-detection sensors networked to a centralized server running Exelis geolocation algorithms. The IDG system can detect, analyze, and geolocate any hostile signal sources and send the captured intelligence through a secure network.

During the AOC event, BAE Systems (www.baesystems.com) announced several items of good news. The firm's Australian arm had been awarded a contract from the New Air Combat Capability (NACC) Program to develop an operational model to integrate the Joint Strike Fighter (JSF) into the Australian Defense Environment. Also, the company had been selected by major defense contractor Raytheon Co. (www.raytheon.com) to help develop the US Air Force's Dismount Detection Radar (DDR). The company will lead the development of the DDR's radar command, control, processing, exploitation, dissemination, and mission-planning modules. The radar will be mounted under the wings of MQ-9 Reaper aircraft; it is intended to provide information for Air Force intelligence, surveillance, and reconnaissance (ISR) missions.

Also during the AOC exhibition, Mercury Computer Systems (www.mc.com/microwave-rf) announced its Echotek® Series SCFE-V6-4QSFP-OVPX OpenVPX™ fiber-optic input/output (I/O) module, which has the capability to transfer and process data across 16 channels in a single OpenVPX slot. Ideal for EW applications, the module combines 16 high-speed channels with three powerful Virtex®-6 field-programmable gate arrays (FPGAs) from Xilinx (www.xilinx.com).

On the AOC exhibition floor, X-COM Systems, LLC (www.xcomsystems.com), a subsidiary of Bird Technologies, demonstrated Version 3.0 of its RF Editor Graphical RF Editor software. The program supports the creation and modification of custom RF signal waveform files for use in defense, commercial, and system verification applications. It is suitable for modifying captured radar, jammer, and communications signals to create simulated threat scenarios. The software can work with files from spectrum and signal analyzer, in addition to waveform segments created in MATLAB and other third-party scientific programming languages. MWRF

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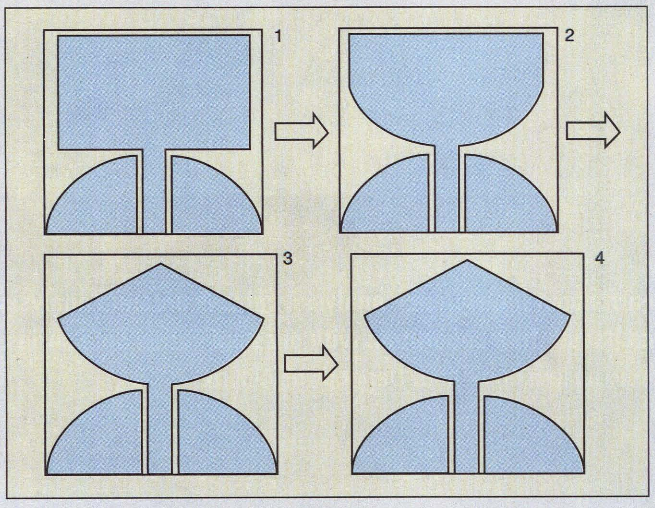
Arming Antennas With Dual Bandstops

Building a notch into an UWB antenna eliminates the need for the notch filter that would normally prevent interference with WLAN systems at 5 GHz.

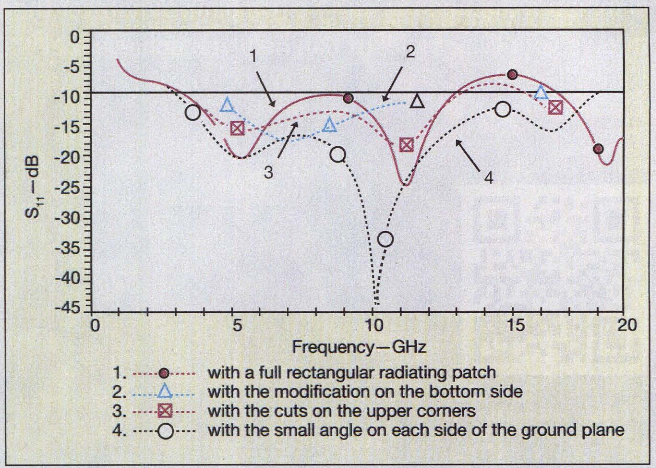
ANTENNAS WITH multiple bandstop characteristics can be useful for multiple-network applications. By inserting C-shaped slots in various antenna configurations, it has proven possible to create a desired frequency stopband. Such antennas have value for selected bands within the US Federal Communications Commission's (FCC's) approved ultrawideband (UWB) frequency range from 3.1 to 10.6 GHz.[1] Antennas are critical components in UWB systems that must be carefully designed for stable radiation patterns and polarization as well as good matching and low dispersion. The current researchers discovered that by etching a C-shaped slot in the radiating element, a compact UWB antenna can be fabricated with strong band-notched characteristic from 5 to 6 GHz.

In recent antenna developments, planar printed antennas fed with microstrip or coplanar-waveguide (CPW) transmission lines have received a great deal of attention for their high radiation efficiencies in compact sizes, as well as their ease of integration with other circuits. CPW-fed antennas are appealing because their feed lines and slots are on one side of the substrate.[2]

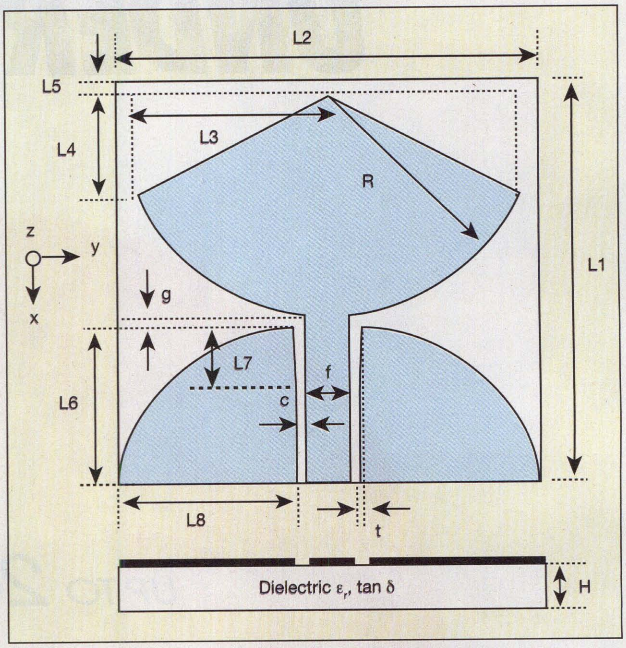
For wideband coverage, different patch geometries have been developed, including X-shaped,[3] fork-shaped,[4] square-shaped,[5] elliptical-shaped,[6] spade-shaped,[7] and circular-shaped[8] patches. Because the 5.150-to-5.825-GHz band is limited by IEEE 802.11a for wireless-local-area-network (WLAN) applications, any UWB



1. These steps show the process of improving a patch antenna with built-in notches.



2. These curves represent simulated reflection coefficients for different shapes of the radiation patch and the ground plane.



3. This diagram shows the configuration of proposed antenna A.

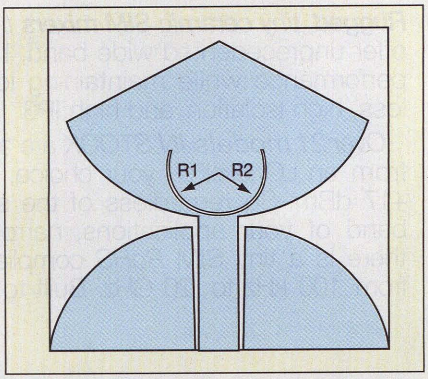
system must use a band-notch filter to prevent interference with WLAN systems. Of course, adding a filter increases UWB system complexity; ideally, the notch can be included in the antenna.

Various methods can achieve an antenna with band-notched characteristics. Conventional approaches including cutting a slot (such as a U-, C-, or V-shaped slot) into the antenna patch.[9-11] While this technique typically achieves a notch for one band, it doesn't prevent interference on other narrow bands. More recently, antennas with two notched bands have been proposed.[12-15] But most of these notched antennas are large in size and not suitable for compact wireless designs.

As an alternative to these larger antenna designs, a compact UWB antenna was developed that measures just 28 x 30 mm. By etching a C-shaped slot in the radiating element, a single band-notched characteristic from 5 to 6 GHz was obtained. And by etching two nested C-shaped slots in the radiating patch, dual band-notched characteristics can be achieved for the compact UWB antenna.

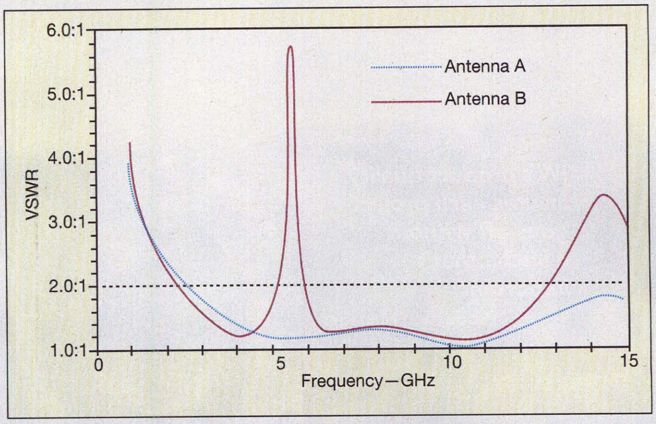
Rectangular patch antennas are typically known to provide narrowband characteristics. To improve the operating bandwidth, the authors shaped the bottom of the antenna patch into an arc. In practical applications, the size of ground plane is finite and the direction of maximum radiation tilts somewhat upward from the horizontal plane. To reduce this beam tilting, the ground plane of the proposed antenna was designed for a rounded rather than a rectangular shape. The arc-shaped patch and tapered ground plane make good broadband impedance matching of the antenna possible. To further expand the impedance bandwidth, several forms were etched from the patch: a right-angle triangle on the upper corners of the patch and a small fan angle on each side of the ground plane near the feed line.[16] These improvements are highlighted in **Fig. 1**.

Figure 2 shows a comparison of the simulated reflection coefficient (S_{11}) for an antenna with full rectangular radiating patch with an antenna modified on the bottom—with cuts on the upper corners and the small angle on each side of the ground plane—when all the dimensions are the same. The first line demonstrates the rectangular patch antenna has a narrowband characteristic. The second line shows the impedance bandwidth is broadened when the bottom of the patch is shaped into an



4. This diagram shows the configuration of proposed antenna B.

5. These curves compare the simulated VSWRs of antennas A and B.



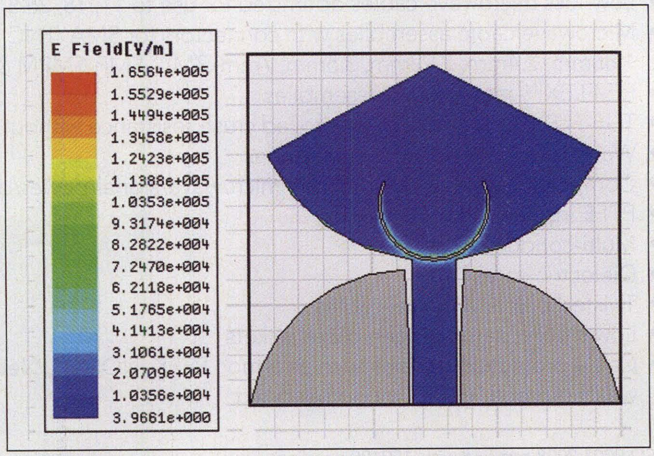
arc. On the basis of this, the third line about the upper corners modification indicates that the bandwidth has been further expanded compared with the second line (the main advantages that this modification is reducing the lowest frequency). The fourth line demonstrates the small angle on each side of the ground plane near the feed line will affect the characteristic impedance of the CPW line and also contribute to the modified antenna's very wide impedance bandwidth.[16]

Figure 3 shows the final geometry of the proposed antenna (referred to as antenna A),[16] which was measured 28 x 30 mm printed on FR-4 substrate. The circuit-board material has 1.6-mm thickness, relative permittivity of 4.4, and loss tangent (tan δ) of 0.02. The antenna is formed in the x-y plane with normal direction parallel to the z-axis. The center strip and gap of the CPW line are 3.6 and 0.3 mm, respectively, to achieve a 50-Ω characteristic port impedance. The improvement steps mentioned earlier contribute to good impedance matching across a wide bandwidth.

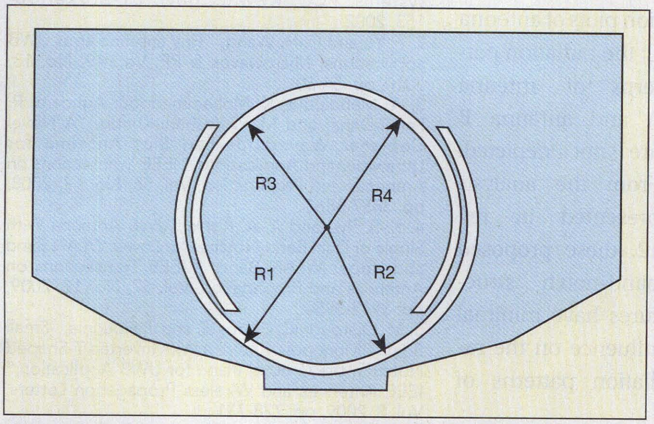
The antenna's geometric parameters were optimized for $S_{11} \leq -10$ dB across the full frequency range using ANSYS HFSS 11.0 electromagnetic (EM) simulation software from Ansys (www.ansys.com). The final antenna geometry parameters were obtained as L1 = 28 mm, L2 = 30 mm, L3 = 13.5 mm, L4 = 5 mm, L5 = 1.5 mm, L6 = 10.8 mm, L7 = 5.4 mm, L8 = 12.9 mm, R = 15 mm, g = 0.7 mm, f = 3.6 mm, c = 0.3 mm, t = 0.3 mm, and H = 1.6 mm. By selecting optimal parameters, the proposed antenna can be tuned to operate across the UWB band.

Since UWB radios share part of the spectrum with HIPERLAN/2 applications (5.15 to 5.35 GHz and 5.470 to 5.725 GHz) and WLAN applications using the IEEE 802.1la protocol (5.15 to 5.35 GHz and 5.725 to 5.825 GHz), an UWB antenna with reconfigurable band-rejection characteristic at WLAN frequencies is highly desirable. Several designs of UWB antennas with band-rejection characteristics have been investigated and successfully implemented in the past. The simple and commonly used approach is to incorporate slots into the antennas' main radiator. **Figure 4** shows a schematic diagram of the UWB planar antenna (referred to as antenna B) with filtering property operating in the 5-to-6-GHz band.

Band-notched operation is achieved by using a C-shaped slot in the radiat-



6. This diagram simulates current distributions at 5.5 GHz for antenna B.



7. This is the physical configuration of proposed antenna C.

ing patch of antenna A. When the band-notched design was applied to antenna A, no retuning work was required for the previously determined dimensions. A simple relationship shows the notch frequency (f_{notch}) for the dimensions of the band-notch feature:

$$f_{notch} = c/[2L(\varepsilon_{eff})^{0.5}] \quad (1)$$

where:

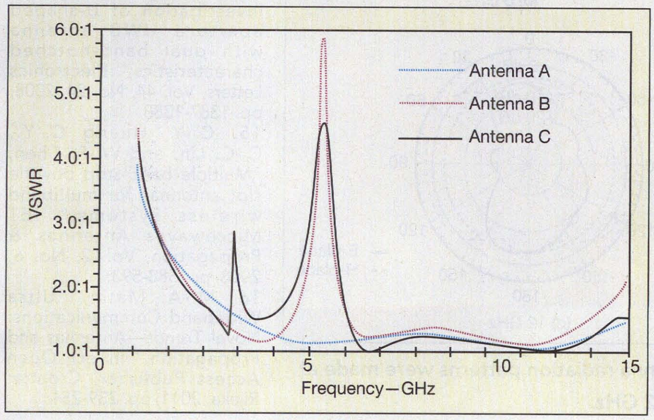
L = the total length of the C-shaped slot;
ε_{eff} = the effective dielectric constant of the substrate; and
c = the speed of light in free space.

In this design, the C-shaped slot was chosen to be nonresponsive close to about 0.33λ at the center frequency of the desired notched-band, where λ is the wavelength at the center frequency of the rejection band. The final design parameters of the C-shaped slot were chosen to be R1 = 4.3 mm and R2 = 4.5 mm.

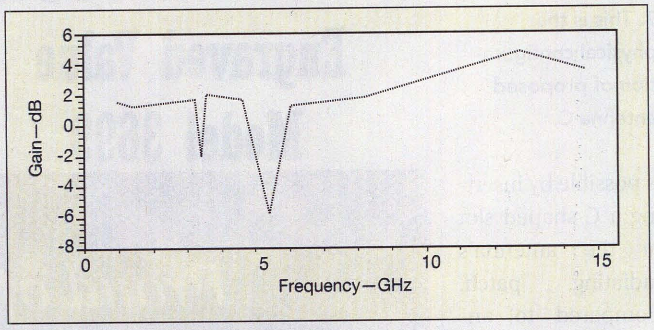
Figure 5 plots simulated VSWR for the antenna, illustrating that a sharp stopband is possible by inserting a C-shaped slot in the antenna's radiating patch. Compared to antenna A, this single band-notched UWB antenna (antenna B) successfully blocks out the 5-to-6-GHz band while maintaining good impedance matching at other frequencies across the UWB band.

Figure 6 shows the current distribution around the slot of antenna B at the 5.5-GHz notch frequency. At 5.5 GHz, the current flows mainly around the C-shaped slot. The impedance is nearly zero at the top of the slot and the impedance is very high near the antenna feed line. In this case, the high impedance at the feed point leads to the desired impedance mismatch near the 5.5-GHz notch frequency.

In addition to WLAN systems, WiMAX (3.3 to 3.6 GHz) and C-band communications systems (3.7 to 4.2 GHz) may interfere with UWB communications systems, prompting the need for antennas with multiple notched bands. Antennas with dual notched bands can be realized by using two nested C-shaped slots in the radiating patch (antenna A), which can yield band-notched characteristics centered at 3.4 and 5.5 GHz, respectively. **Figure 7** shows the geometry of the UWB antenna (referred to as antenna C) with dual notched-band characteristics. Since mutual coupling exists between the exterior and interior C-shaped slots, the HFSS simulated values did not match



8. These curves compare the simulated VSWRs of antennas A, B, and C.



9. This plot shows the simulated gain of proposed antenna C.

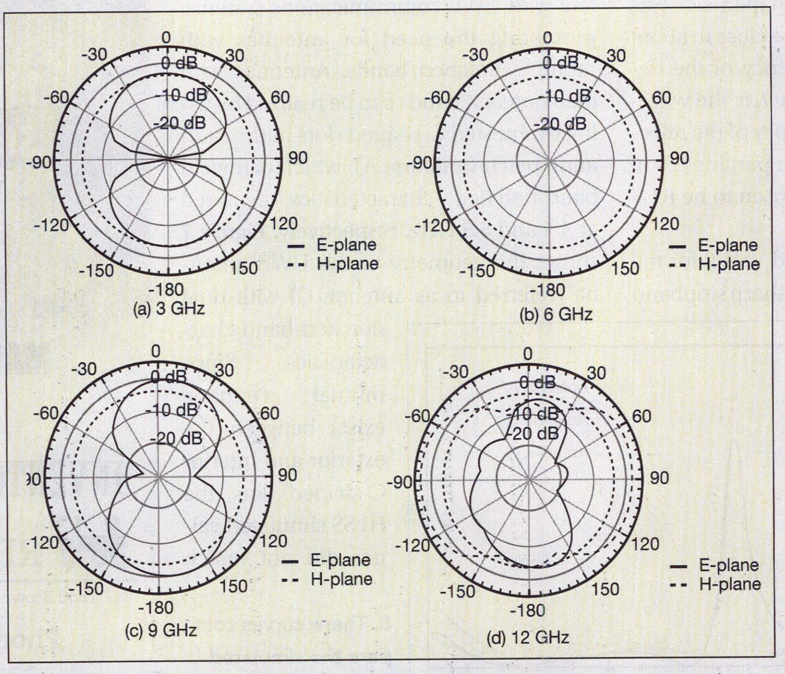
the predicted values. The optimized design parameters are R1 =4.5 mm, R2 = 4.2 mm, R3 = 4.0 mm, and R4 = 3.7 mm.

Figure 8 shows simulated VSWR as a function of frequency for proposed antenna C. Results of the reference antennas without band-notched characteristics and with single band-notched characteristic are also shown for comparison. Antenna C, with its two notched bands, exhibits notched bands of 3.3 to 3.6 and 5 to 6 GHz, while maintaining wideband performance from 2.2 to 13 GHz for VSWR ≤ 2.0:1, covering the entire UWB frequency range.

The proposed antenna design features two strong notched bands, created by the two nested C-shaped slots. **Figure 9** shows simulated gain. As expected, sharp gain decreases occur in both the 3.3-to-3.6-GHz and 5-to-6-GHz bands. However, for other frequencies outside the rejected bands, the antenna gain is nearly constant across the entire UWB band.

Figure 10 shows the simulated radiation patterns for the proposed antenna, at 3 GHz, 6 GHz, 9 GHz and 12 GHz for E- and H-plane patterns. The greatly distorted radiation pattern at 12 GHz [Fig. 10(d)] is caused by seriously unequal phase distribution on the antenna aperture and increased magnitudes of higher-order modes. The four plots show the radiation plots of antenna C; the radiation patterns of antenna A and antenna B are not depicted. From the analysis presented in ref. 12, these proposed band-notch structures have minimal influence on the radiation patterns of an UWB antenna.

In summary, the structural modifications detailed for patch antennas successfully achieve sharp notches where needed across the frequency ranges of UWB antennas. As was shown, by inserting two nested C-shaped slots in the radiating patch, notches of 3.3 to 3.6 GHz and 5 to 6 GHz (representing WiMAX and WLAN frequencies, respectively) can be obtained. Owing to the simple structure and ease of impedance matching, the proposed antennas should be profitable for multiband applications. MWRF



10. These simulated H- and E-plane antenna radiation patterns were made at (a) 3 GHz, (b) 6 GHz, (c) 9 GHz, and (d) 12 GHz.

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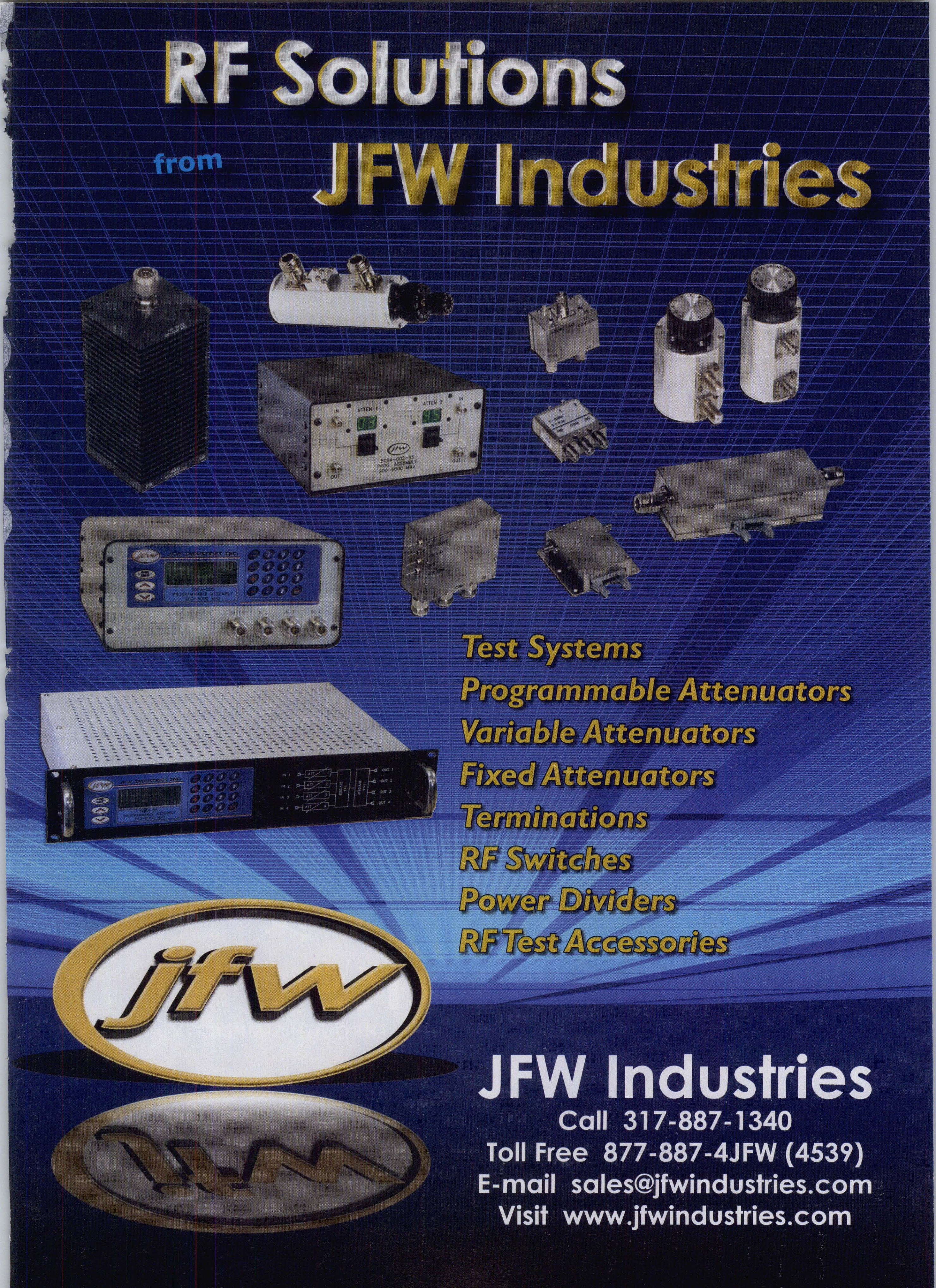
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Slot Antenna Uses Dual Polarization

This novel, compact dual-polarized antenna achieves low cross polarization and broad beamwidths across a wide frequency range, even when fabricated on low-cost FR-4 PCB material.

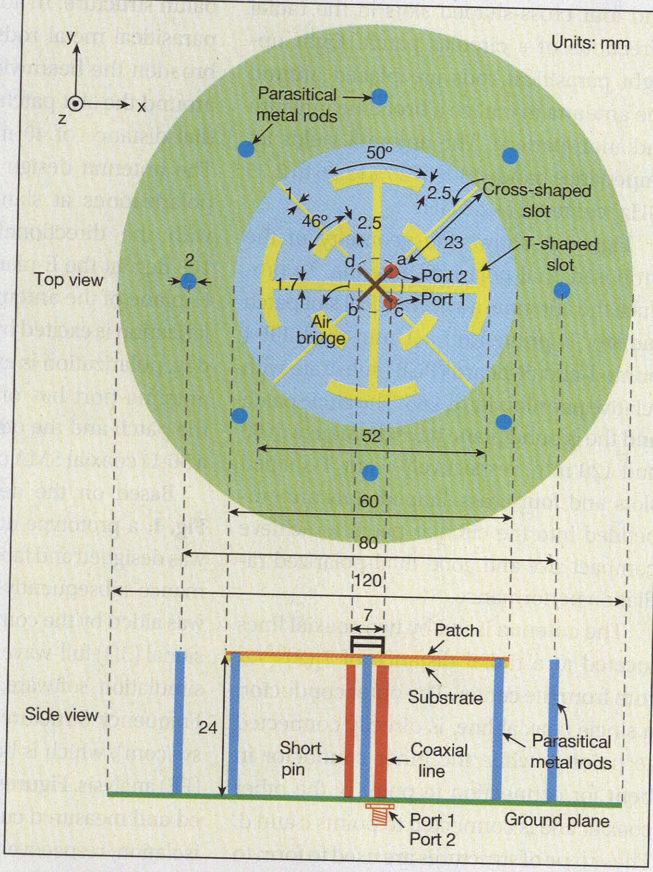
DUAL-POLARIZED ANTENNAS have often brought exceptional performance to wireless communications systems, at the same time reducing occupied space in wireless base stations. While a variety of dual-polarized antenna designs have been developed for this purpose,[1-12] there is always room for improvement. With that goal in mind, the current researchers developed a novel dual-polarized broad beamwidth slot antenna with low cross-polarization and high isolation.

This design features special T-shaped and cross-shaped slots to achieve symmetrical radiation patterns at slanted ±45-deg. polarization angles, and with low cross-polarization between the radiation patterns. High isolation between the two feeding ports is accomplished by means of two shorting pings, and the beamwidth is broadened by placing eight upright parasitical metal rods around the antenna. The antenna's frequency coverage of 2.26 to 2.75 GHz makes it suitable for WiMAX applications.

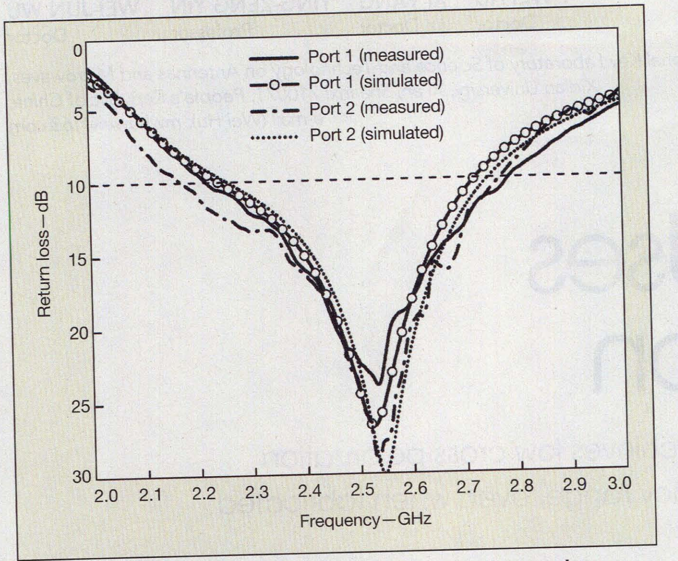
Dual-polarized antennas are often used in wireless communications systems to enhance signal reception quality. Compared with the use of space diversity, a dual-polarized antenna can help effectively reduce the space occupied by the antenna systems in a wireless base station. Dual-polarized antennas have been realized by means of several different design approaches—for example, achieving high input-port isolation and wide bandwidth when using aperture coupling feeds.[1-6] But this type of antenna suffers from obvious cross-polarization radiation caused by higher-order-mode transverse currents.

To reduce cross-polarization, a number of other feed types have been reported.[7-12] It has been found that higher-order modes can be suppressed when the antenna is symmetrically excited by a dual-feed system with a phase difference of 180 deg.[7-10] If a meandering probe[11,12] is employed instead of a straight probe, the probe radiation can be further reduced. Unfortunately, while these antennas exhibit lower cross-polarization than the aperture coupling types, they require much more complex structures and may not be practical for all engineering applications.

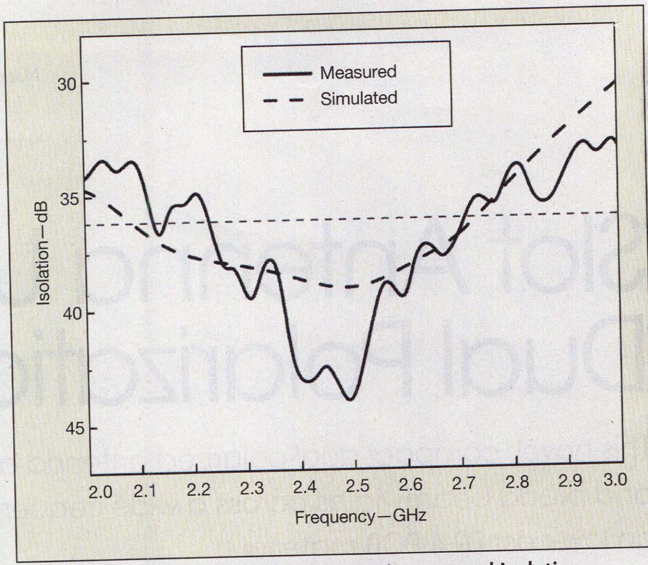
Some wireless applications, such as WiMAX, pose rigorous requirements in terms of broad bandwidth, along with the need for the system antennas to provide a uniform response over approximately the entire upper hemisphere and stable gain at a low angle. These demands call for tight control of radiation characteristics, and a number of design methods have been documented accordingly. These include the use of loading gaps and stubs,[13] incorporating a corner reflector,[14] and applying a microstrip dielectric structure.[15] But broad-bandwidth techniques have seldom been associated with dual-polarized-antenna designs.



1. This diagram shows the geometry of the proposed dual-polarized antenna, as well as how the T-shaped and cross-shaped slots are formed. The antenna is fabricated from low-cost FR-4 PCB substrate material.



2. These plots show the simulated and measured return-loss characteristics at antenna ports 1 and 2 from 2 to 3 GHz.



3. These plots show the simulated and measured isolation characteristics at antenna ports 1 and 2 from 2 to 3 GHz.

As will be shown, however, it is possible to obtain broadband frequency operation with a dual-polarized-antenna design. The antenna, excited by two coaxial-line feeds, is composed of four T-shaped slots and four cross-shaped slots in the radial directions of a circular patch. Eight upright parasitical rods are placed around the antenna to realize a broad beamwidth radiation pattern. The antenna yields an impedance bandwidth of 20% (2.26 to 2.75 GHz) centered at 2.5 GHz.

Figure 1 shows the geometry of the proposed dual-polarized antenna. To produce the antenna, a symmetrical slot patch radiator is printed on a 1-mm-thick FR-4 printed-circuit-board (PCB) substrate with relative permittivity of 4.65. The circle patch and the ground plane have diameters of 60 and 120 mm, respectively. Four T-shaped slots and four cross-shaped slots are embedded into the circular patch to achieve compact size and good dual-polarized radiation performance.

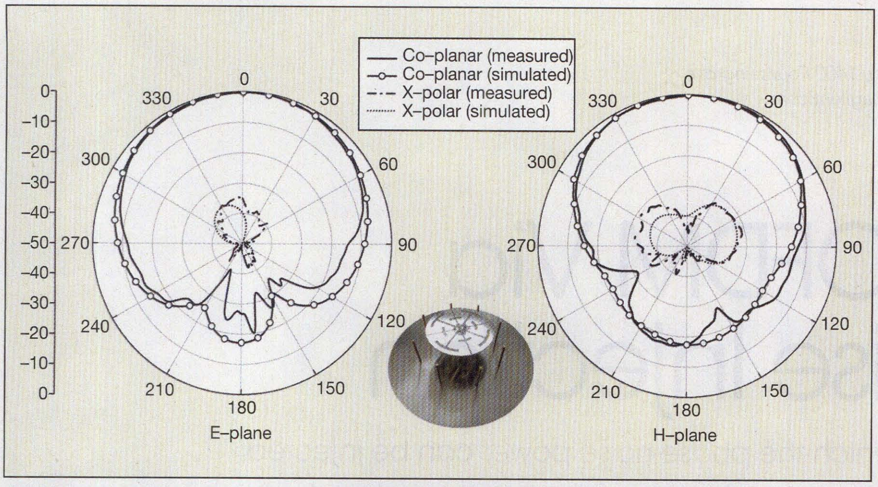
The antenna is fed by two coaxial lines located at a radial distance of $7[(2)^{0.5}/2]$ mm from the center. The outer conductor, a single coaxial line, is directly connected to point a, while the inner conductor in bent for connection to point b; the other coaxial line is connected to points c and d. These type of structures are used to form to air crossover bridges. The two linear polarizations at the two antenna ports are along these two air crossover bridges. To improve the isolation between the two input ports, two short pins connected to points b and d have been added.

The height from the ground to the patch is 24 mm, used for high gains and excitation of the balanced mode without a balun structure. In addition, eight upright parasitical metal rods were employed to broaden the beamwidth; they are placed around the slot patch and located at a radial distance of 40 mm from the center. The antenna design exhibits dual linear polarizations at slanted ±45-deg. angles with the directional beamwidth about 108 deg. at the E-plane and 92 deg. at the H-plane of the antenna. The –45-deg. polarization is excited by port 1, while the 45-deg. polarization is excited by port 2. Each antenna port has one end connected to the patch and the other end connected to a 50-Ω coaxial SMA connector.

Based on the detailed dimensions of **Fig. 1**, a prototype dual-polarized antenna was designed and fabricated, and its performance subsequently evaluated. The design was aided by the commercial three-dimensional (3D) full-wave electromagnetic (EM) simulation software, ANSYS HFSS (High-Frequency Structure Simulator) (www.ansys.com), which is based on finite-element (FE) analysis. **Figures 2 and 3** show simulated and measured curves of return loss and isolation, respectively, for the proposed antenna. As the results show, fair agreement was obtained between the measured and simulated data. The resonant mode was activated to achieve good impedance matching for a bandwidth of 490 MHz (from 2.26 to 2.75 GHz), based on a criterion of better than 10-dB return loss to successfully cover the 2.5-GHz band used for WiMAX applications. Measured isolation between the two antenna ports was better than 36 dB across the full desired bandwidth.

The dual-polarized slot-antenna design was also tested in a far-field chamber. **Figure 4** shows the measured normalized radiations in the E-plane (slanted –45-deg. vertical cross-section) and H-plane (slanted 45-deg. vertical cross-section) at a test frequency of 2.5 GHz. The antenna radiates in a broadside direction and features almost symmetrical radiation patterns in both the E- and H-plane directions. As **Fig. 4** shows, the antenna's cross-polarization remains under –35 Db; the front-to-back ratio is less than 18 dB; and the half-power beamwidth is about 108 deg. in the E-plane and 92 deg. in the H-plane. Peak gains for the antenna were also measured at several discrete frequencies across its operating bandwidth. For that bandwidth, the average gain was about 6.3 dBi.

In summary, a novel dual-polarized slot antenna with two coaxial feed lines was designed and fabricated. The measured results of the fabricated antenna prototype show good agreement with computer-aided-engineering (CAE) software simulations using a commercial program. The novel antenna design is extremely compact, making it suitable for WiMAX applications. MWRF



4. These plots show the simulated and measured E-plane (left) and H-plane (right) radiation patterns for the novel dual-polarized antenna.

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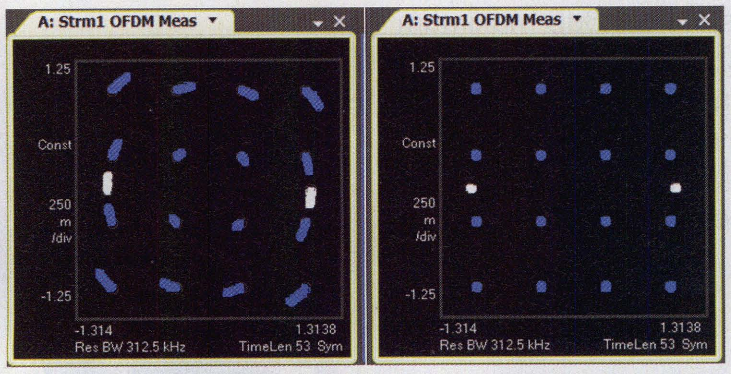
Optimize OFDM Via Phase-Noise Injection

By using a signal generator in which the phase-noise power can be injected and controlled at known levels, it is possible to "exercise" radio designs for the effects of different-quality radio signals.

ORTHOGONAL FREQUENCY division multiplexing (OFDM) is a favored transmission scheme for many RF/microwave communications systems. It is both efficient and robust, even within a signal environment laden with interference and multipath signals, and is readily scalable in terms of number of users and bandwidth. Given the capabilities of modern application-specific integrated circuits (ASICs) and field-programmable gate arrays (FPGAs), the digital signal processing (DSP) needed to make OFDM work is not a barrier.

However, the analog technologies required for OFDM radios can still pose serious design challenges, especially when application requirements call for large numbers of OFDM radios within small enclosures at low cost and power consumption. Analog approaches cannot be upgraded as readily or quickly as digital technologies and, as a result, many basic performance parameters still present complex engineering tradeoffs. One of the more critical analog performance parameters, for example, is phase noise. It is especially relevant in OFDM radios due to the large number of closely spaced subcarriers. These subcarriers overlap in the frequency domain, with spectral peaks and nulls arranged to maintain orthogonality. Phase noise spreads the subcarrier energy—reducing orthogonality—and the resulting intercarrier interference impairs multiplexing and demodulation.



1. These displays show the impact of I/Q correction on an OFDM constellation, before (left) and after (right) being applied to correct pilot and payload symbols. Both plots are shown with 312.5-kHz resolution bandwidth.

Signal generators perform multiple roles in OFDM system design, and optimizing their use speeds the design process. Modern signal generators can produce modulated and fully coded signals to test receivers, as well as continuous-wave (CW) signals to substitute for frequency references and synthesizers. In both cases, they provide the biggest benefit when they can generate both ideal signals and those which have specific imperfections. Ideal signals provide a reference to isolate and quantify the performance of other elements in the system, while deliberately imperfect signals allow the engineer to evaluate system performance in a "just good enough" scenario or a situation with known operating margins in terms of performance. Quickly and reliably arriving at performance that is "just good enough" is the designer's goal, meeting system specifications while minimizing multiple cost factors.

The phase-noise performance levels of sources in OFDM systems can be qualified in terms of close-in phase noise through far-from-the-carrier phase-noise characteristics. The phase noise close to the carrier is always the lowest number for a source and can be characterized by various different offset frequencies, depending upon the signal source supplier. Close-in barriers for evaluating single-sideband (SSB) phase noise for a given signal source can range from as close as 10 to 100 Hz to 1 kHz or more. The phase-noise floor for an OFDM signal source is typically at a distance of 1 or 10 MHz from the carrier, and this phase noise level will reflect the lowest noise level possible for the signal source.

System architects are aware of the phase-noise challenges of OFDM and, accordingly, structure signals to minimize the problem. The primary mechanism is known as pilot tracking, where selected subcarriers at some (but not necessarily all) symbol times transmit reference signals instead of payload data. The transmitted values of the pilot signals, such as their amplitude/

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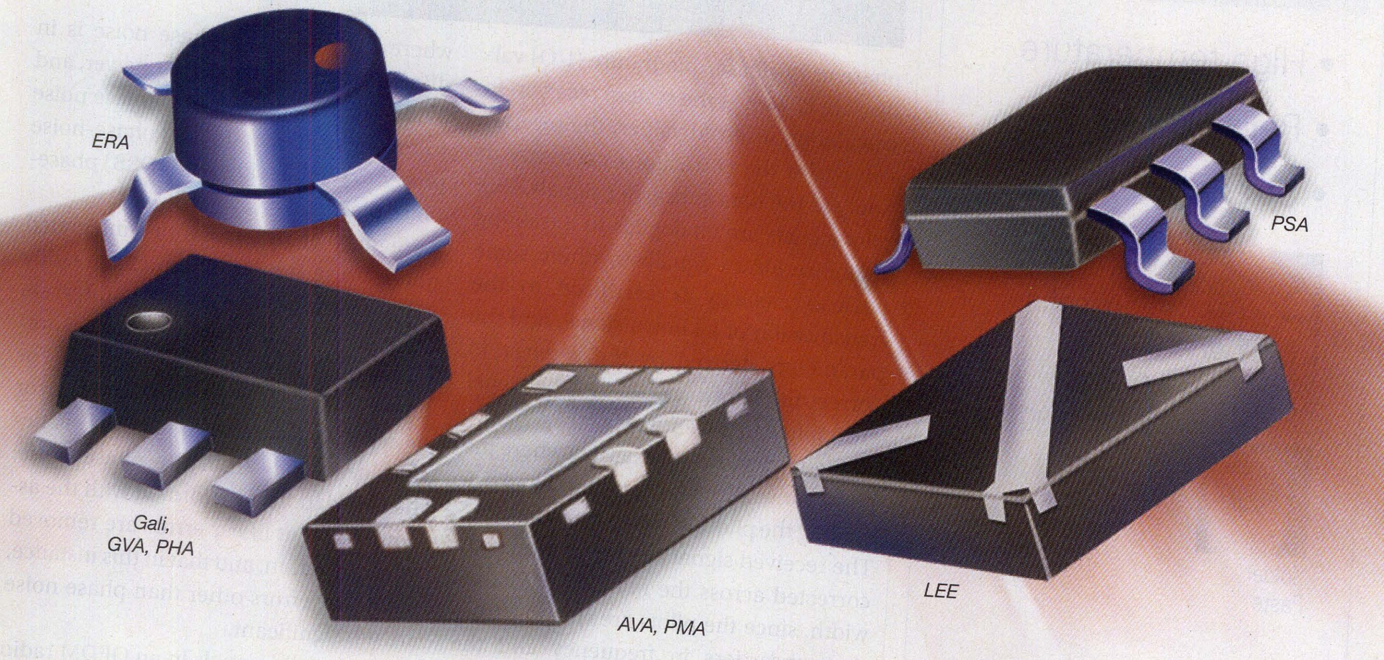

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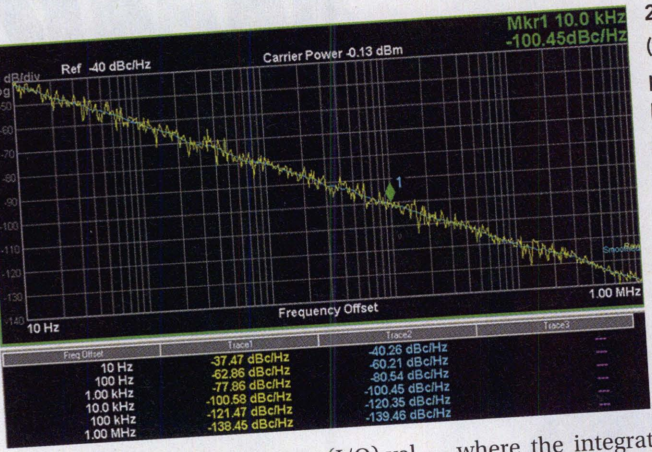

2. Using random (white) noise to phase-modulate an RF signal generator produces phase-noise sidebands with a constant slope of –20 dB/decade, although such a slope is not representative of real-world signal sources.

phase or in-phase/quadrature (I/Q) values, are known at the system receiver. In calculating received values, the receiver will derive the corrections necessary to apply to the data subcarrier signals. The pilot signals are analogous to a training sequence for an equalizer, where some payload capacity is sacrificed to the transmission of a known signal, and the parameters derived by the receiver to correct the known portion of the signal are applied to the entire signal.

Figure 1 shows an example where the phase noise in the transmitted signal (including the pilot signals) is "tracked out." The received signal can be continuously corrected across the full channel bandwidth, since the pilots are spread across the subcarriers in frequency and the symbols in time, allowing corrections to be applied. For example, a vector signal analyzer (VSA) can show the signal phase portion of "common pilot error," making it possible to isolate and remove a great deal of the phase-noise error power.

Of course, an engineer hoping to improve OFDM communications system performance needs to know which portion of the phase-noise power can and should be removed. A basic rule of thumb is that pilot tracking is effective for frequency offsets from 0% to about 10% of the subcarrier spacing. Assuming that the phase noise at frequency offsets wider than the channel will also be filtered out, the contribution of phase noise power to signal error can be given as:

EVM (dB) = [integrated SSB phase noise (0 to 100% of subcarrier spacing)] + [3 dB]

where the integrated phase noise is in dBc/Hz relative to the carrier power, and 3 dB is added to convert the phase noise from single-sideband (SSB) phase-noise power to double-sideband (DSB) phase-noise power.

Signal analyzers with integrated phase-noise applications can readily make SSB measurements and integrate the detected power from those measurements over a desired bandwidth. For this calculation, the modulation error or error vector magnitude (EVM) is determined solely from the phase noise; the calculation is performed with the assumption that linear errors are removed by equalization, and that in this instance, nonlinear errors other than phase noise are not significant.

Real-world signals in an OFDM radio (especially those from low-cost, low-power circuits) can suffer significant levels of phase noise. To help designers make reasonable tradeoffs, it is helpful to generate both CW and modulated signals with known amounts of phase noise and to use these signals to evaluate their impact on other circuits in the radio. The simplest approach to create signals with known amounts of phase noise is to use random noise to phase-modulate a signal generator. For the CW case, the approach produces a SSB phase-noise curve (L_f) with constant –20 dB/decade slope, as shown in **Fig. 2**. Any adjustments to frequency-modulation (FM) deviations will change the overall phase-noise level, but not the phase-noise slope. Where needed, this phase modulation can be added to digital modulat


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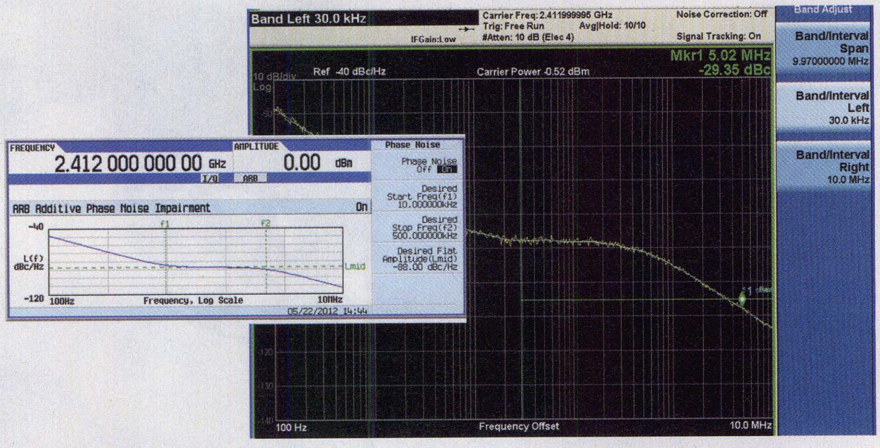
instead of CW signals, though the result will not be as readily verifiable as for the CW case shown above.

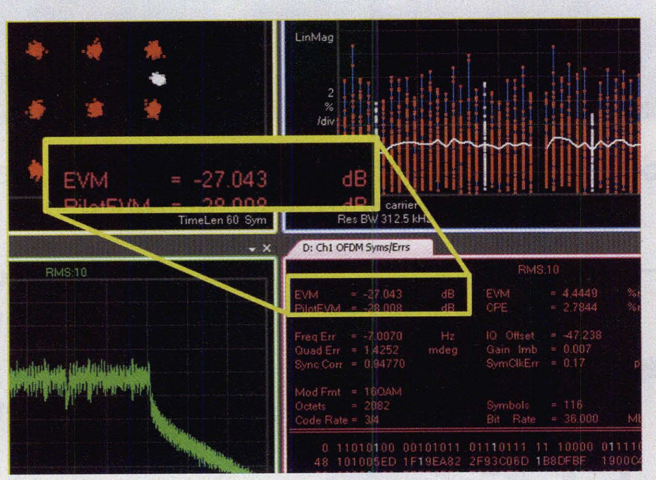
The uniform –20 dB/decade slope of the aforementioned example is not typical of phase-noise sidebands exhibited by high-frequency oscillators and frequency synthesizers typically found in OFDM systems. Because the frequency sensitivity of OFDM systems is not uniform as described above, a more realistic phase-noise generation technique is desirable for system design and verification.

Fortunately, the fast digital-signal-processing (DSP) capabilities provided by modern ASICs and FPGAs that make OFDM practical also make possible the generation of test signals with customized phase-noise performance. As an example, the N5182B MXG X-Series signal generator from Agilent Technologies (www.agilent.com) employs real-time baseband signal generation which provides "phase-noise-injection" capability. The inherent phase noise of this signal generator is extremely low, providing plenty of margin for generating signals with customized phase noise curves—even when the curves represent oscillators or synthesizers with relatively low phase noise.

The N5182B signal generator is avail-



3. Setting signal generator phase noise to a pedestal of –88 dBc/Hz between 10 and 500 kHz (left) produces integrated SSB phase noise (right) of –29.35 dBc over the relevant bandwidth of 30 kHz to 10 MHz. Integrating at offsets greater than 10 MHz would not result in appreciable additional power.



4. The measured EVM of the signal impaired by phase noise correlates well with the estimate of −26.35 dB (−29.35 dB + 3 dB). The "10% of subcarrier spacing" guideline is thought to be slightly conservative, as shown in this example.

able in several configurations, with frequency ranges of 9 kHz to 3 GHz or 9 kHz to 6 GHz. Both the continuous-wave (CW) and digital pilots are run at standard speeds of typically 5 ms and optional high-speed motions of better than 900 {LC MU}m for both CW and digital items.

The N5182B signal generators can be used for both linear or logarithmic step changes, with equally spaced frequency and amplitude studies or logarithmically spaced frequency steps. The signal generators can handle maximum output power of +16 dBm through frequencies of 3 and 6 GHz, using a step attenuation with 5-dB steps from 0 to 130 dB.

The phase-noise injection capability of the N5182B signal generator is designed to provide a variety of phase-noise curves while remaining simple to operate. Curves are configured as a close-in slope, a flat (with frequency) phase-noise pedestal, and resumption of a slope at wider offset frequencies descending to the signal generator's broadband noise floor. Accordingly, only three parameters need to be set by the user: the end of the initial slope (f_1), the beginning of the outer slope (f_2), and the level of the pedestal. A constant slope of −20 dB/decade is assumed below f_1 and above f_2. Adjustment of the levels and inflection points allow the performance of different oscillators and synthesizers to be easily simulated.

A basic IEEE 802.11g OFDM signal provides a good example of the effects of pilot tracking and the validity of calculating expected EVM from a customized phase-noise curve. The subcarrier spacing is the standard 312.5 kHz, and the 10% rule of thumb would suggest that phase noise within about 30 kHz of the carrier would be tracked out through demodulation relative to the pilot signals. In this example, the signal generator is programmed for a pedestal of −88 dBc/Hz between the 10- and 500-kHz inflection points, with the carrier set to 0 dBm for convenient calculations. An integrated SSB phase noise measurement of this signal produces a relevant phase-noise power of −29.35 dBc.

Figure 3 shows the signal generator's phase-noise configuration screen reflecting these three parameters and a corresponding phase noise measurement. In this measurement, the integration bandwidth extends to 10 MHz (the widest offset measured), but the integrated power is dominated by the phase noise at narrower offsets (generally below about 5 MHz). Since the phase-noise power declines with frequency at a rate of 20 dB/decade, it becomes insignificant well before offsets reach the receiver's nominal channel bandwidth of 20 MHz, or even the 10-MHz phase-noise measurement bandwidth.

The final step in calculating expected EVM due to phase noise is to double the SSB power, thus arriving at the total phase-noise power in the receiver's vulnerable bandwidth. Adding 3 dB to the measured −29.35-dBc phase-noise power suggests an EVM of −26.35 dBc, the result of the phase-noise contribution from the signal generator's phase-

noise injection.

To measure the actual EVM, a signal analyzer with Agilent 89600 vector signal analyzer (VSA) software from Agilent Technologies is configured for normal IEEE 802.11g demodulation. The default setup enables phase tracking essential to remove phase noise. In addition, the demodulator should be configured for equalizer training that includes both the preamble and data, both to optimize equalizer effectiveness and provide the most accurate modulation quality results. **Figure 4** shows the results.

The measured results closely match the calculated estimate, especially since the 10% rule of thumb is generally regarded as slightly conservative. Since the bandwidth of the demodulator pilot tracking has a finite rolloff and the signal generator phase noise curve transitions gradually between slopes and the pedestal, the precision of the estimate is limited. Nonetheless, for situations where phase noise is a significant concern, this approach to simulating and estimating EVM in OFDM systems holds up well.

The Agilent 89600 VSA software as been developed to evaluate a total of more than 70 signal standards and modulation types and helps when performing troubleshooting on a wide range of different wireless communications systems. It can be used to study cellular signals such as those found in Long-Term-Evolution (LTE) systems, in wideband code-division-multiple-access (W-CDMA) networks, and even in IEEE 802.11 wireless-local-area-network (WLAN) systems. It is suitable for analyzing signals in aerospace, defense, and satellite communications systems as well as in terrestrial communications systems. It has been developed to evaluate such features as multiple-input, multiple-output (MIMO) antenna technology within these systems.

The 64-b Agilent 89600 VSA software can define and store any number of pratical measurements in memory for instant recall, either separately or as combinations of multiple simultaneous measurements to check the performance of a wireless communications system, allowing the evaluation of a system in both the frequency and time domains. It provides signal capture and playback, with a wide range of standard analysis tools, such as constellation diagrams, in-phase/quadrature (I/Q) parameters, and EVM diagrams on pilot, resource signals, and preamble signals.

The software features a straightforward graphical user interface (GUI) that helps pinpoint different problems, each with its own marker. It allows a user to set up multiple instances of the same measurement to compare the performance of different channels in a multiple-channel system. This type of capability is particularly useful for evaluating the performance of wireless MIMO systems. The software's multiple-domain spectrogram capability allows simultaneous viewing of frequency- and time-domain signal characteristics on a single screen.

In summary, signal substitution is a proven approach for understanding and optimizing performance in complex RF systems. The use of signal substitution can help to speed the design process, reduce risk, and avoid the costs of producing an under- or over-performing radio. The capability to produce phase noise at specific levels and frequency distributions is beneficial for OFDM applications where frequency offsets matter.

Whether substituting for CW sources in the signal conversion chain or fully modulated signals at IF or RF, signal generators are a more powerful tool when they can produce both ideal and nonideal signals in which the imperfections are known and precisely controlled. Even for systems with complex tracking and correction capabilities, it's possible to simulate typical impairments and accurately estimate their consequences by using signal generators with controlled phase noise. MWRF

For additional reading

Bob Cutler, "Effects of Physical Layer Impairments on OFDM Systems," *RF Design*, May 2002, p. 36. http://rfdesign.com/images/archive/0502Cutler36.pdf.

HIGH POWER

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

◊ In excess of theoretical split loss of 3.0 dB
▫ With matched operating conditions

HYBRIDS RoHS

Model #	Frequency (MHz)	Insertion Loss (dB) [Typ./Max.] ◊	Amplitude Unbalance (dB) [Typ./Max.]	Phase Unbalance (Deg.) [Typ./Max.]	Isolation (dB) [Typ./Min.]	VSWR (Typ)	Input Power (Watts) [Max.]	Package
90º								
DQS-30-90	30 - 90	0.3 / 0.6	0.8 / 1.2	1 / 3	23 / 18	1.35:1	25	102SLF
DQS-3-11-10	30 - 110	0.5 / 0.8	0.6 / 0.9	1 / 3	30 / 20	1.30:1	10	102SLF
DQS-30-450	30 - 450	1.2 / 1.7	1 / 1.5	4 / 6	23 / 18	1.40:1	5	102SLF
CSDK3100S	30 - 1000	0.8 / 1.2	0.05 / 0.2	0.2 / 3	25 / 18	1.15:1	50	378
DQS-118-174	118 - 174	0.3 / 0.6	0.4 / 1	1 / 3	23 / 18	1.35:1	25	102SLF
DQK80300	800 - 3000	0.2 / 0.4	0.5 / 0.8	2 / 5	20 / 18	1.30:1	40	113LF
MSQ80300	800 - 3000	0.2 / 0.4	0.5 / 0.8	2 / 5	20 / 18	1.30:1	40	325
DQK100800	1000 - 8000	0.8 / 1.6	1 / 1.6	1 / 4	22 / 20	1.20:1	40	326
MSQ100800	1000 - 8000	0.8 / 1.6	1 / 1.6	1 / 4	22 / 20	1.20:1	40	346
MSQ-8012	800 - 1200	0.2 / 0.3	0.2 / 0.4	2 / 3	22 / 18	1.20:1	50	226
180º (4-PORTS)								
DJS-345	30 - 450	0.75 / 1.2	0.3 / 0.8	2.5 / 4	23 / 18	1.25:1	5	301LF-1

◊ In excess of theoretical coupling loss of 3.0 dB

COUPLERS RoHS

Model #	Frequency (MHz)	Coupling (dB) [Nom]	Coupling Flatness (dB)	Mainline Loss (dB) [Typ./Max.]	Directivity (dB) [Typ./Min.]	Input Power (Watts) [Max.] ▫	Package
KDS-30-30	30 - 512	27.5 ±0.8	±0.75	0.2 / 0.28	23 / 15	50	255 *
KFK-10-1200	10 - 1200	40 ±0.75	±1.0	0.4 / 0.5	22 / 15	150	376
KBS-10-225	225 - 400	10.5 ±1.0	±0.5	0.6 / 0.7	25 / 18	50	255 *
KDS-20-225	225 - 400	20 ±1.0	±0.5	0.2 / 0.4	25 / 18	50	255 *
KBK-10-225N	225 - 400	10.5 ±1.0	±0.5	0.6 / 0.7	25 / 18	50	110N *
KDK-20-225N	225 - 400	20 ±1.0	±0.5	0.2 / 0.4	25 / 18	50	110N *
KEK-704H	850 - 960	30 ±0.75	±0.25	0.08 / 0.2	38 / 30	500	207
SCS100800-10	1000 - 8000	10.5 ±1.5	±2.0	1.2 / 1.8	8 / 5	25	361
KBK100800-10	1000 - 8000	10.5 ±1.5	±2.0	1.2 / 1.8	8 / 5	25	322
SCS100800-16	1000 - 7800	16.8 ±1.5	±2.8	0.7 / 1	14 / 5	25	321
KDK100800-16	1000 - 7800	16.8 ±1.5	±2.8	0.7 / 1	14 / 5	25	322
SCS100800-20	1000 - 7800	20.5 ±2.0	±2.0	0.45 / 0.75	12 / 5	25	321
KDK100800-20	1000 - 7800	20.5 ±2.0	±2.0	0.45 / 0.75	14 / 5	25	322

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

Unless noted, products are RoHS compliant.

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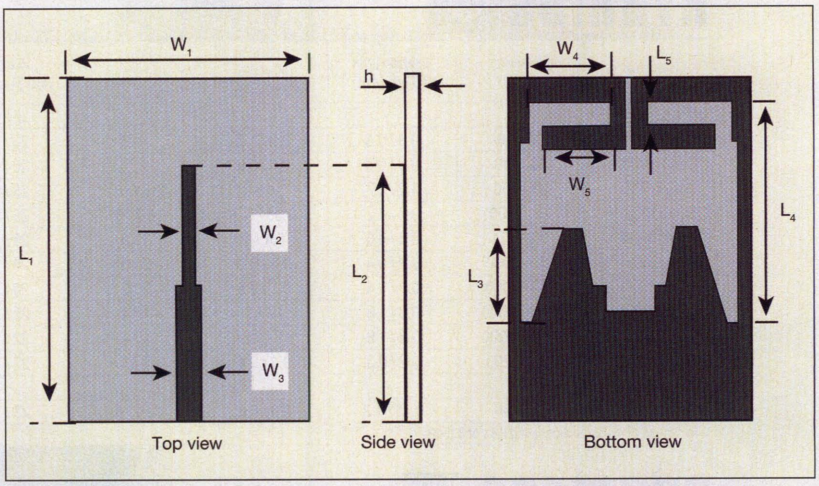
Antenna Aims At Dual Bands

By leveraging a modified ground structure, this antenna not only covers multiple frequency bands, but does so with enhanced bandwidths and very reasonable gains.

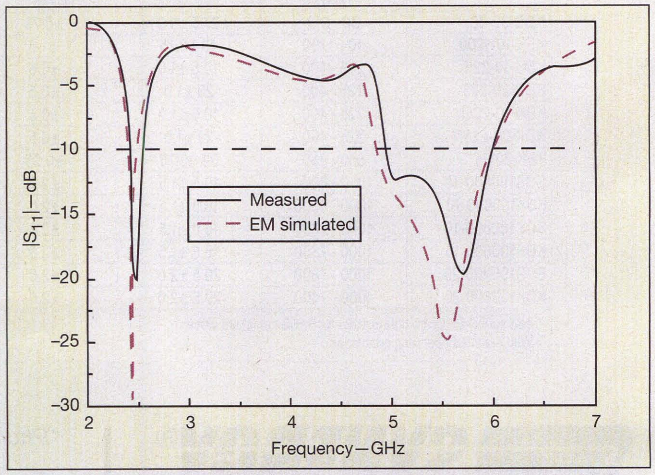
WIRELESS APPLICATIONS continue to spread across different bandwidths, with wireless local area networks (WLANs) alone occupying several frequency bands. To realize effective antenna designs for these applications, it is possible to use a modified ground structure (MGS) to achieve dual-band operation. To form the MGS, a rectangular ground plane is shorted with dual meandered side strips and dual tapering protruding stubs. Prototype antennas based on this design approach show dual operating bands centered at 2.4 and 5.5 GHz, with reflection coefficients ($|S_{11}|$) of better than –10 dB and frequency coverage for 2.4-, 5.2-, and 5.8-GHz WLAN standards. In addition, antenna designs using the MGS have achieved stable monopole-like radiation patterns and acceptable gain across the three WLAN operating bands.

Antennas are critical components in WLAN and other wireless systems. In the quest for designs that offered low profiles, light weight, low cost, and ease of integration with other circuits, planar printed antennas were extensively investigated. More recently, monopole antenna designs have been considered for these wireless applications, including a design with a G-shaped construction,[1]



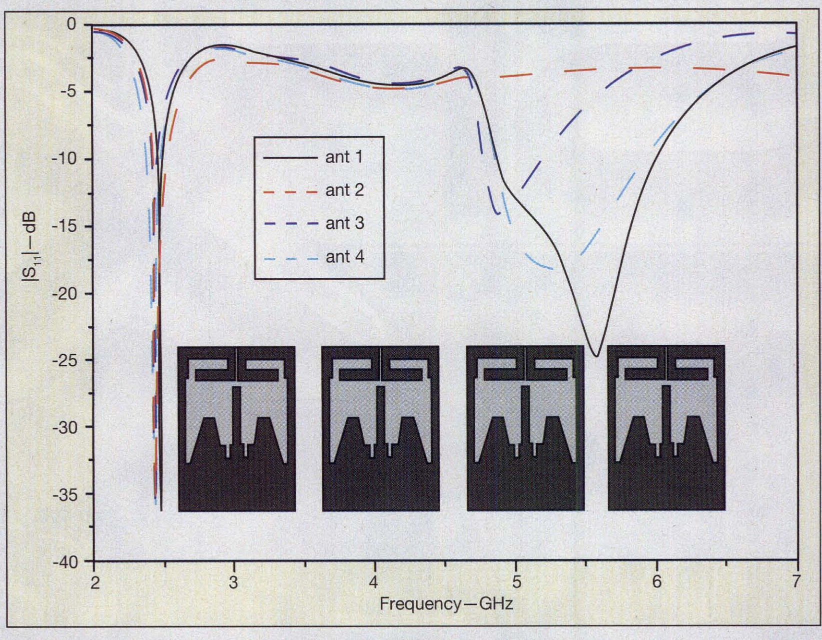
1. These diagrams show top, side, and bottom views of the proposed dual-band MGS antenna.

2. This photograph shows top (left) and bottom (right) views of the fabricated prototype MGS antenna.



3. These plots show the simulated and measured $|S_{11}|$ performance for the proposed MGS antenna as a function of frequency.

a double T-shaped design,[2] an antenna created by adding parasitic elements,[3] and a slotted monopole version.[4,5] These different approaches can provide two or three current paths to excite multiple resonant modes for multiple-frequency operation, although the majority of the design efforts have been on monopole structures. The use of MGS approaches is attractive because it has been widely employed in the form of defected ground structures (DGS) in many different microwave and wireless components.[6-9]



4. These plots show the differences in S_{11} performance for the proposed antenna with four different modifications to the ground structure (ant 1, 2, 3, and 4).

Reference 6, for example, details the use of a cross-shaped DGS to broaden the operating bandwidth and reduce the size of a conventional DC bias line. Dumbbell-shaped DGS shapes were applied under the feed line to suppress harmonics in the bandpass filter design of ref. 7. A DGS with U-shaped slot helped obtain a notched band to avoid interference in an ultrawideband (UWB) power divider in ref. 8 and an UWB antenna in ref. 9.

In multiband antenna design, the MGS is also a simple and effective way to excite additional resonance modes,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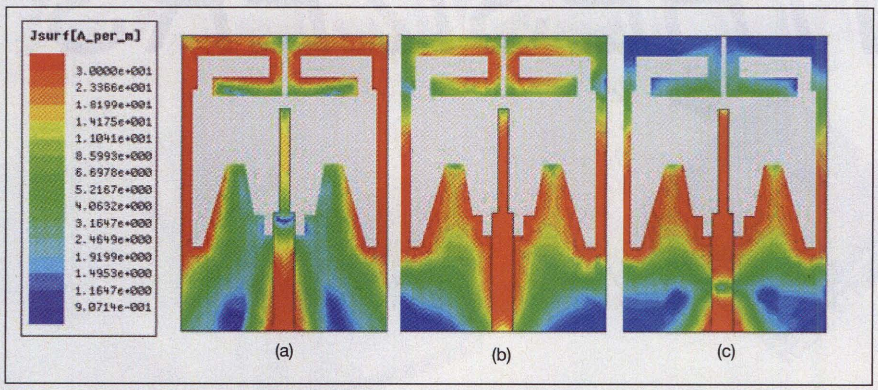


5. The surface current distributions on the novel MGS antenna are shown here at (a) 2.44 GHz, (b) 5.2 GHz, and (c) 5.8 GHz.

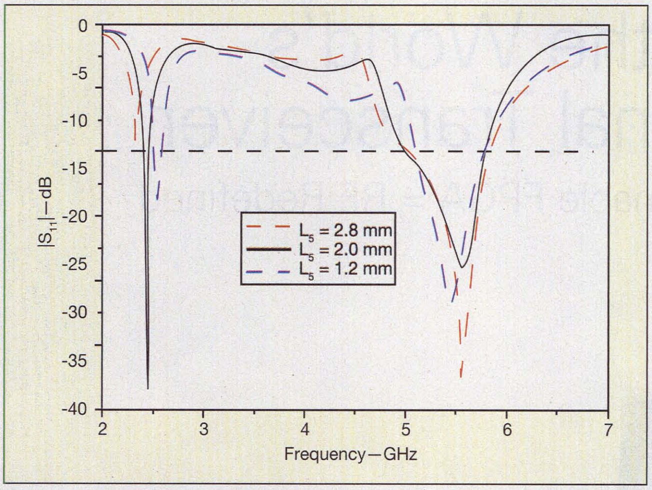
such as a rectangular ground with dual inverted L-shaped strips,[10] a cambered ground plane with an isosceles-triangle-shaped defect,[11] and an L-shaped slot cut out of the ground.[12] However, multiband performance relies on the hybrid combination of MGS and traditional monopole technologies: The MGS introduces a single resonance, with the other resonant modes excited by the traditional monopole antenna.

Figure 1 shows the geometry of the proposed dual-band antenna and its modified ground plane. The antenna is etched on the laminated sides of a 1-mm-thick FR-4 printed-circuit-board (PCB) substrate, which features relative dielectric constant of 4.6 and measures just 20 x 28 mm. Unlike a conventional microstrip-fed antenna with a solid ground plane, this design features a ground plane that was modified to form an MGS. Dual meandered side strips, with total length of $L_4 + W_4 + L_5 + W_5$ (which is about one-quarter wavelength at 2.4 GHz), are etched on the edge of the substrate to connect with the rectangular ground plane, achieving a resonance at 2.4 GHz in a relatively limited space.

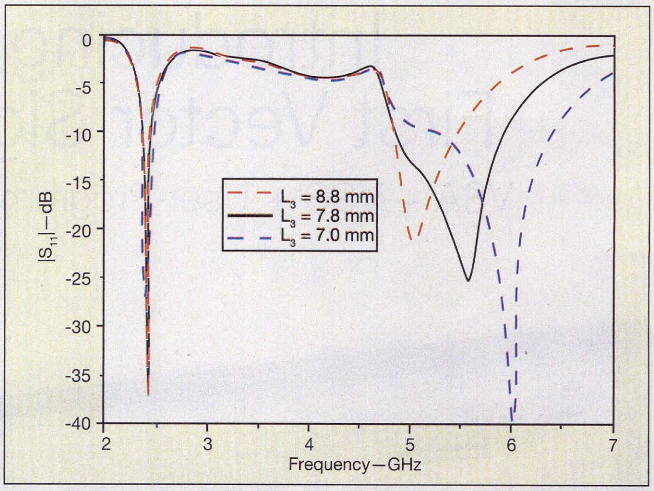
The ground plane's left and right sides protrude with dual tapering stubs of height L_3, providing another current path and achieving an additional resonant mode with good impedance bandwidth at around 5.5 GHz. The MGS is electromagnetically fed by a 50-Ω microstrip feed line, placed on the center of the antenna PCB. For improved lower-frequency impedance matching, the microstrip feedline is protruded with a thin line stub from the line's upper side.

A commercial electromagnetic (EM) computer-aided-engineering (CAE) software package was used for numerical analysis to examine the performance of the proposed antenna design. The software, the High-Frequency Structure Simulator (HFSS) from Ansoft (www.ansys.com), is based on finite-element-method (FEM) analysis. Via iterative trials, the final optimal dimensional values for the antenna were obtained and are listed in the **table**.

A prototype of the proposed antenna was experimentally fabricated and measured to support the EM simulation, and a 50-Ω SMA connector was used to feed the antenna, as shown in **Fig. 2**. The simulated and measured reflection coefficient magnitudes ($|S_{11}|$) of the proposed dual-band antenna based on MGS are illustrated in **Fig. 3**. As **Fig. 3** shows, the proposed antenna achieves dual-resonant modes over the frequency ranges of 2.40 to 2.52 GHz and 4.95 to 6.01 GHz for $|S_{11}| \leq -10$ dB, simultaneously covering the 2.4-, 5.2-, and 5.8-GHz WLAN frequency bands. The values from the simulations agreed closely with the measured results for the an-



6. The impact of changing the strip length, L_5, on $|S_{11}|$ performance is shown here.



7. The impact of changing slot length, L_3, on $|S_{11}|$ performance is shown here.

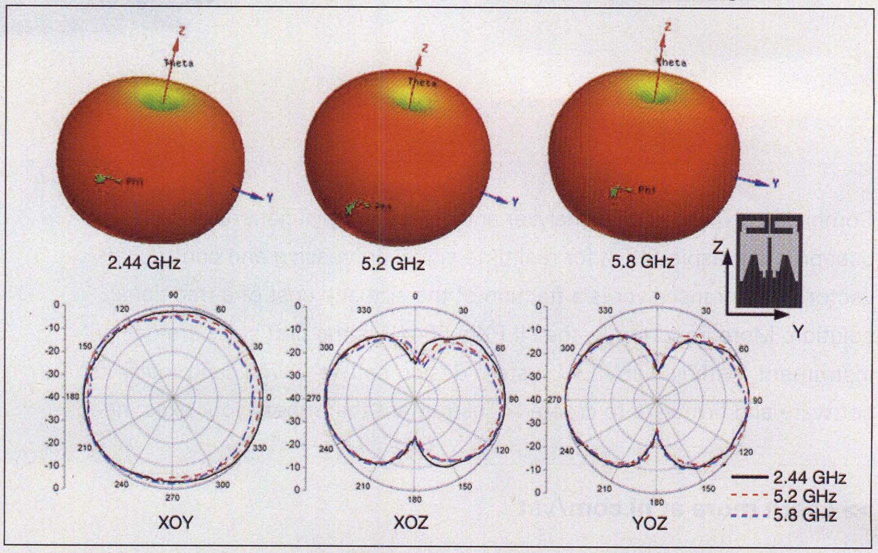
tenna. Some slight discrepancies may be attributed to the presence of the SMA feed connector and soldering the connector onto the antenna PCB, design elements that were not included in the simulation.

Figure 4 plots the frequency response of $|S_{11}|$ for the proposed antenna. As can be seen, for the case with dual side strips on the ground (ant 2), the lower-band resonance was effectively excited. The upper-band resonance matching conditions were obtained when dual protruding stubs were shorted to ground (ant 3). These results suggest that the dual side strips and dual protruding stubs can significantly affect the impedance matching of the lower and upper resonance bands. To achieve the bandwidth enhancement in the upper resonance band, the protruding stubs were tapered (ant 1) instead of rectangular. As **Fig. 4** shows, the impedance matching for the lower resonance band is degraded when the feed line is a uniform width without a thin stub (ant 4).

Figure 5 shows the excited current distributions obtained from HFSS simulations, both for the feed line and the ground for the optimized antenna. As expected, strong surface current densities were present at the lower and upper resonance bands along the dual side strips and protruding stubs, respectively.

According to the current distributions and frequency responses for $|S_{11}|$ in these cases, a number of parameters were investigated for their effects on the resonant frequency bands of interest. **Figure 6** shows the tuning effect of length L_5, with selected values from 7.2 to 8.8 mm, on the response of $|S_{11}|$. As can be seen, the lower band resonance is significantly impacted and shifted downward in frequency with increasing values of tuning length, while the upper band remains almost unchanged. The main reason for this is that for larger L_5 values, the longer dual side strips approximate one-quarter wavelength at the relevant resonant frequency and vice versa. Similarly, changing the tapering stub length, L_3, has impact on the upper resonant-frequency band; thus, the upper resonance can be tuned by adjusting the values L_3, as shown in **Fig. 7**.

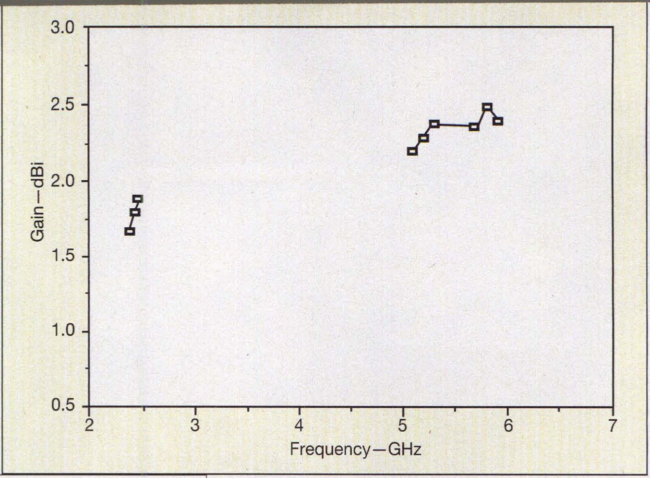
Figure 8 shows three-dimensional (3D) radiation patterns obtained from EM simulations at 2.44, 5.20, and 5.80 GHz. The symmetrical structure of the antenna design yields symmetrical and consistent radiation patterns, which are ideal for a multiband communications antenna. **Figure 8** also shows two-dimensional (2D) radiation patterns in the main cut planes of the antenna. The antenna yields nearly monopole-like radiation performance with conical patterns in the elevation planes and omnidirectional patterns in the azimuth plane. As **Fig. 9** shows, the



8. Radiation patterns for the three frequencies of interest are shown for the MGS antenna in 3D (top) and 2D (bottom) plots.

peak gains in the operating bands of interest are stable and reasonable.

In conclusion, the microstrip-fed antenna with MGS achieves quite acceptable performance in a small physical PCB format. Unlike an antenna with a conventional solid ground plane, the ground for this novel antenna is modified with dual meandered side strips and dual tapering protruding stubs. The feed line is also simply modified for enhanced impedance-matching performance. The antenna design exhibits monopole-like radiation pattern and acceptable peak gains across the operation bands. MWRF



9. These plots show the variations in peak gain in the 2- and 5-GHz frequency bands.

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OCXOs PROVIDE HOLDOVER TIMING FOR BASE STATIONS

FOR WIRELESS COMMUNICATIONS that use time-division-duplex (TDD) signaling, it is very difficult to maintain synchronization. In addition to providing real-time services, base stations must maintain accurate relative timing for successful call-signal handoff. Compounding this challenge, the more advanced wireless protocols demand relative timing accuracy ranging from 10 μs to 1 μs or less. In a seven-page white paper, Vectron International explains the need for wireless-communications systems to have a holdover timing element as a backup to their primary time source.

Titled "Simplifying Holdover Design in Synchronization Applications," the paper begins by providing the timing requirements for communications standards ranging from WCDMA to Long Term Evolution (LTE). To maintain synchronization accuracy, base stations utilize timing derived from navigation systems like the Global Positioning System (GPS). Because such signals are sometimes unavailable, a holdover timing source (i.e., an oscillator) with high short-term accuracy is needed to maintain base-station timing synchronization for periods ranging from hours to days.

Essentially, the base station uses the holdover oscillator as its timing source. The signal from the satellite-navigation system will continuously re-synchronize the holdover oscillator to maintain system timing accuracy. When that signal is unavailable, the holdover oscillator will provide system timing on its own. Such timing sources can now be based on oven-controlled crystal oscillators (OCXOs), given that today's devices provide sufficient accuracy. Yet their implementation can be tricky, as certain OCXO performance characteristics may influence holdover.

The paper walks the reader through the three ways that designers can implement holdover timing in their systems: by purchasing a standalone precision timing device that mounts in the equipment rack (like a rubidium standard); by purchasing a holdover timing module; or by designing and embedding within the system a holdover timing source based on a precision oscillator. The last approach allows designers to make holdover timing part of their designs while promising the greatest cost minimization. Yet it also invites a major challenge, due to the difficulty of relating an oscillator's datasheet specifications to the timing-source design's achievable holdover performance. By providing guidance on oscillator performance specifications and the design of a holdover solution, this paper coherently explains the OCXO option for modern wireless-communications base stations.

Vectron International, 267 Lowell Rd., Hudson, NH 03051; (888) 328-7661, www.vectron.com.

PLAN FOR THE 1000X DATA-TRAFFIC INCREASE

THE LAST FEW years have seen phenomenal growth in the global demand for mobile-broadband data services. This growth is expected to continue unabated. While mobile data traffic has been roughly doubling every year for the last few years, the industry is expecting a long-term 1000x increase. To meet this challenge, the wireless-communications industry will need new resources as well as different ways of acquiring, deploying, and managing those resources. A paper by Qualcomm, Inc., "Rising to Meet the 1000x Mobile Data Challenge," shares a vision of the efforts that are needed.

All of the efforts suggested in the 14-page paper fall into three main groups: more spectrum, small cells everywhere, and higher efficiency across the system. Yet those solutions invite many questions. For example, how much more spectrum will be made available in which bands? Will it be unlicensed or licensed? And will it be available in a timely manner? Similarly, people are wondering how dense small cells can get and whether they will be used indoors, outdoors, or both. Due to problems with indoor coverage, small cells are often discussed as the solution there. Does that mean a small cell in every house, shop, or office? If so, what about interference?

The paper delves into all of these issues. For example, it notes that there are three approaches to making new spectrum available: traditional licensing processes for third- and fourth-generation (3G and 4G) networks; the new Authorized Share Access (ASA) regime; and the unlicensed approach for Wi-Fi services. In cases when spectrum cannot be approved for licensing within a reasonable timeframe, Qualcomm and its partners are proposing the new approach called ASA.

Essentially, ASA proposes a regulatory framework for instances in which spectrum holders may not be using the entire block of allocated spectrum in every part of their geographic boundaries on a 24/7 basis. For military radar, for example, spectrum might be allocated on a countrywide basis. But the radar operations themselves may only be using the spectrum at certain locations. Or they may not always be using it on a 24/7 basis.

According to ASA, exclusive spectrum rights can be granted to qualified stakeholders to operate a commercial 3G/4G network in this underutilized spectrum—whenever and wherever it is available—subject to the usage needs and requirement of the incumbent spectrum rights holder. In this paper, ASA is one of many solutions put forth that can be used by the mobile wireless industry to cost-effectively face the 1000x challenge. At the same time, operators can provide an optimal mobile-broadband experience for users.

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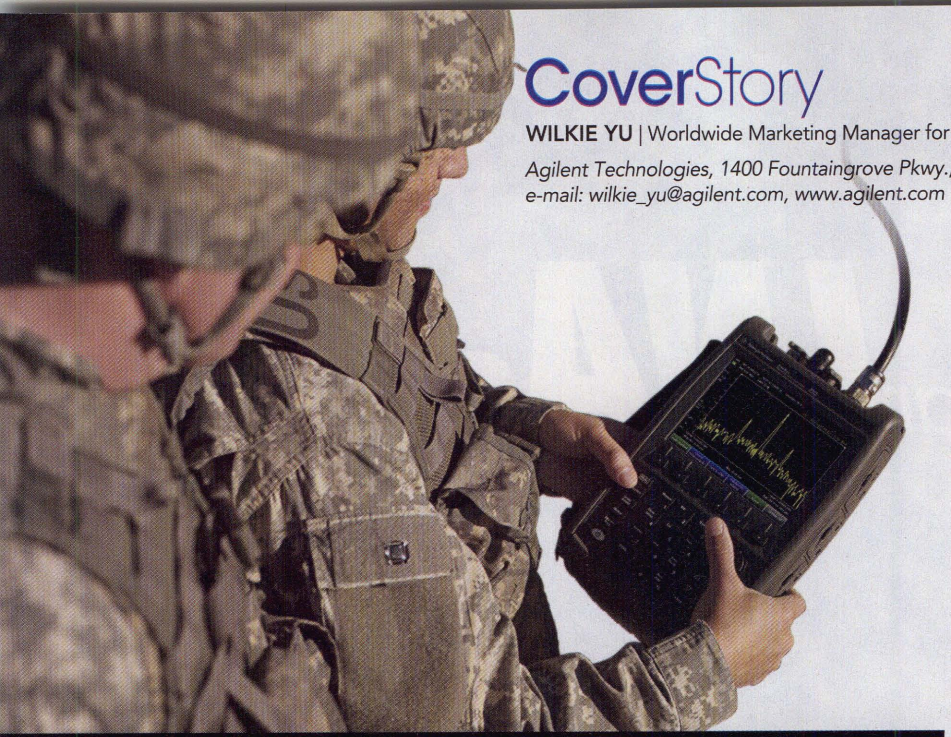


PORTABLE ANALYZERS Pack Lab Quality

These 14 new portable handheld RF/microwave analyzers bring the measurement power of a test laboratory to the field, with spectrum and vector-network analysis through 26.5 GHz.

MICROWAVE MEASUREMENTS are increasingly performed in the field, especially as RF/microwave communications infrastructure continues to expand. Unfortunately, in-field measurements have long been associated with portable test equipment of questionable performance and quality, at least when compared with laboratory-grade RF/microwave test instruments. However, the latest additions to the FieldFox family of portable analyzers from Agilent Technologies (www.agilent.com) may change more than a few opinions on portable RF/microwave test equipment; the 14 new members of the portable test line include spectrum analyzers, cable/antenna analyzers, and vector network analyzers operating to 26.5 GHz, with lab-worthy performance.

The new FieldFox portable analyzers **(Fig. 1)** are configured for flexibility. A user can start simply (with a cable and antenna analyzer) and later upgrade with additional measurement functions, such as a spectrum analyzer and/or a microwave vector network analyzer (VNA). The cable and antenna analyzer performs the types of measurements that are most useful to troubleshooters in wired communications systems as well as wireless antenna sites **(Fig. 2)**, including distance-to-fault, return-loss, and cable-loss measurements.

As the **table** shows, the FieldFox analyzers offer a wide range of frequency models through 26.5 GHz. In addition, they are built for the field, housed in sealed enclosures that are compliant with US MIL-PRF-28800F Class 2 requirements, to withstand the rigors of in-field testing. The instruments and their housings are type tested to meet MIL-STD-810G, Method 511.5 Procedure 1 requirements.

FieldFox analyzers are available in one of three base configurations: as a cable and antenna analyzer, as an RF/microwave VNA, or as a microwave spectrum analyzer. The cable and antenna analyzer can be expanded by means of optional add-on instrument functions, such as a spectrum analyzer, a VNA, a vector voltmeter, DC source, or a power meter. They can also be upgraded with any of these options at a later date through a simple license key process without the need to send the instrument to a service center. The base configuration with the RF/microwave VNA can be expanded with options for performing full two-port S-parameter measurements, time-domain analysis, a cable and antenna analyzer, a vector voltmeter, and a power meter. Finally, the base configuration with spectrum analyzer can be expanded with options for a full-band tracking generator, a full-band preampli-

1. A total of 14 new FieldFox analyzers provide users with a wide choice of frequency ranges and measurement functions.

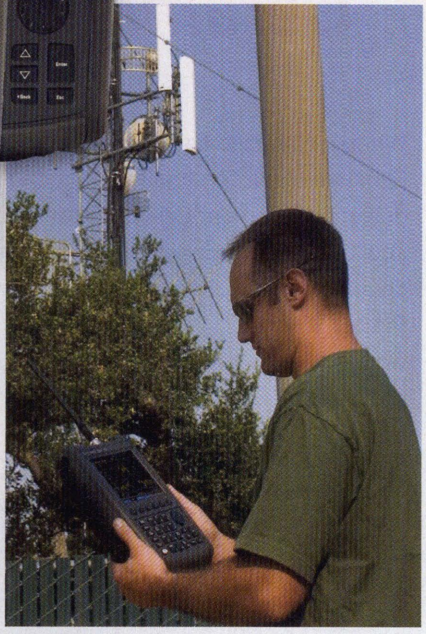
fier, an interference analyzer and spectrogram, reflection-measurement capability, a power meter, and even a frequency counter.

The FieldFox instruments (**Fig. 3**) are only 7.4 in. (188 mm) wide and easy to hold, boasting an easy-to-navigate control panel with large keys that can be controlled in the field, even when wearing gloves (**Fig. 4**). Data are shown on a 6.5-in. thin-film-transistor (TFT) display. The light-weight (6.6 lbs or 3.0 kg) analyzers run on rechargeable lithium-ion batteries. They draw about 14 W power during normal operation and run for about 3.5 h on a battery charge.

The RF/microwave VNAs in the FieldFox analyzers compare favorably with Agilent's PNA series of benchtop VNAs. In measurements of S_{21} forward transmission on a bandpass filter centered at 1.9 GHz, a side-by-side comparison of a FieldFox analyzer with a PNA reveals very little difference (**Fig. 5**).

The VNAs are full two-port instruments with four receivers, capable of measuring the phase and magnitude of all four S-parameters with a dynamic range to 100 dB at lower frequencies and 94 dB to 18 GHz. The FieldFox VNAs feature low trace noise of ±0.004 dB. They can also simultaneously display all four S-parameters, and perform gated time-domain analysis.

In addition, the VNAs feature several automatic calibration functions. For example, QuickCal is a built-in function that provides a means of performing a fast two-port calibration. It automatically corrects for phase shifts and loss of cables and adapters and electrically shifts the calibration plane of the VNA to the end of these interconnect components, and to

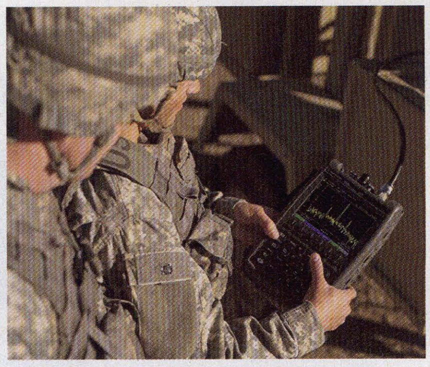


2. The light weight and small size of the FieldFox analyzers makes it a simple matter to bring laboratory-grade measurement power to wired and wireless communications antenna sites.

Sizing up the new FieldFox analyzers

Model	Function	Frequency range
N9913A	Combination analyzer	30 kHz to 4 GHz (cable/antenna) 100 kHz to 4 GHz (spectrum analyzer)
N9914A	Combination analyzer	30 kHz to 6.5 GHz (cable/antenna) 100 kHz to 6.5 GHz (spectrum analyzer)
N9915A	Combination analyzer	30 kHz to 9 GHz (cable/antenna) 100 kHz to 9 GHz (spectrum analyzer)
N9916A	Combination analyzer	30 kHz to 14 GHz (cable/antenna) 100 kHz to 14 GHz (spectrum analyzer)
N9917A	Combination analyzer	30 kHz to 18 GHz (cable/antenna) 100 kHz to 18 GHz (spectrum analyzer)
N9918A	Combination analyzer	30 kHz to 26.5 GHz (cable/antenna) 100 kHz to 26.5 GHz (spectrum analyzer)

Model	Function	Frequency range
N9925A	Vector network analyzer	30 kHz to 9 GHz
N9926A	Vector network analyzer	30 kHz to 14 GHz
N9927A	Vector network analyzer	30 kHz to 18 GHz
N9928A	Vector network analyzer	30 kHz to 26.5 GHz
N9935A	Spectrum analyzer	100 kHz to 9 GHz
N9936A	Spectrum analyzer	100 kHz to 14 GHz
N9937A	Spectrum analyzer	100 kHz to 18 GHz
N9938A	Spectrum analyzer	100 kHz to 26.5 GHz

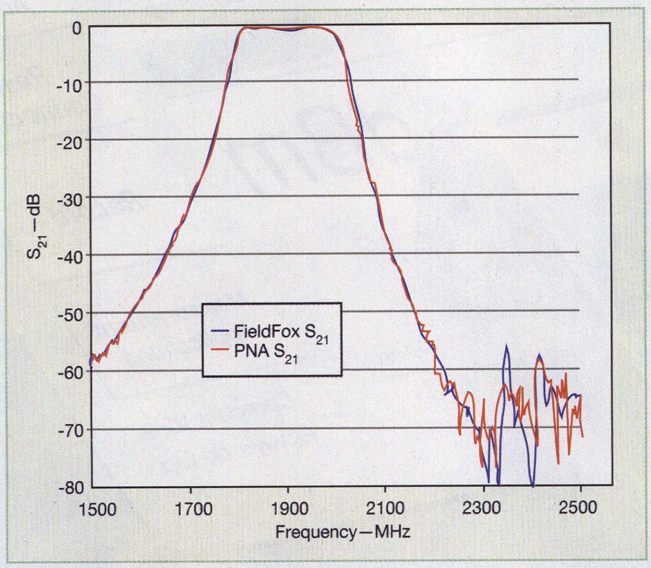


3. The small size of the FieldFox analyzers makes them easy to manage in rugged terrain and difficult environments, whether in commercial, industrial, or military measurement applications.

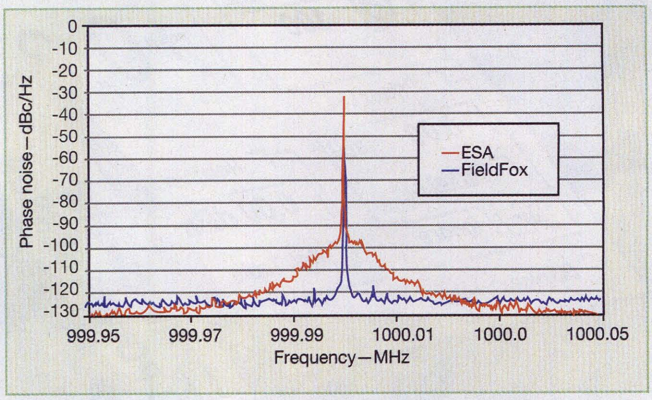
the ports of the device under test (DUT). With CalReady, the FieldFox's VNA is automatically calibrated to the instrument ports when power is turned on.

The FieldFox spectrum analyzers draw from Agilent's PSA line of microwave spectrum analyzers (**Fig. 6**). The spectrum analyzers provide amplitude accuracy of ±0.5 dB with no warmup time required, and offer a typical spurious-free dynamic range (SFDR) of 105 dB. The spectrum analyzers benefit from InstAlign, an automatic amplitude alignment that contributes to maintaining the ±0.5-dB amplitude measurement accuracy. The spectrum analyzers in the FieldFox portable instruments also leverage Agilent's PowerSuite one-button measurement functions from the firm's benchtop instruments. Looking closer at the performance for a combination analyzer with VNA and antenna and cable analyzer, such as a 26.5-GHz model N9928A, the portable instrument is equipped with a built-in frequency reference boasting typical accuracy of ±0.4 ppm from –10 to +55°C. That accuracy

4. The large keys used in the FieldFox analyzer front panel can be controlled even when wearing gloves.



5. This comparison of the S_{21} forward transmission response of a bandpass filter shows the performance similarities of a FieldFox analyzer versus a benchtop PNA vector network analyzer.



6. These two phase-noise plots show the outstanding performance of the FieldFox spectrum analyzer compared to an ESA benchtop spectrum analyzer at 1 GHz.

can be improved to ±0.010 ppm when the analyzer is locked to a Global Positioning System (GPS). The built-in frequency reference has an aging rate of ±1 ppm/year for 20 years. The measurement frequency resolution of the N9928A analyzer is 1 Hz to 5 GHz, 1.34 Hz to 10 GHz, 2.68 Hz to 20 GHz, and 5.36 Hz to 26.5 GHz. The VNA provides typical test port power of –1 dBm from 3.0 to 6.5 GHz, –2 dBm from 6.5 to 9.0 GHz, –4 dBm from 9 to 14 GHz, –6 dBm from 14 to 18 GHz, –10 dBm from 18 to 23 GHz, and –12 dBm from 23 to 26.5 GHz. Power can be set in 1-dB steps. The power level accuracy is typically ±1.5 dB. For the 26.5-GHz VNA is the model N9928A FieldFox analyzer, the typical dynamic range is 100 dB to 9 GHz, 97 dB to 14 GHz, 94 dB to 18 GHz, 90 dB to 20 GHz, 79 dB to 25 GHz, and 70 dB to 26.5 GHz.

The analyzers can be equipped with a built-in power meter, which is designed to make absolute power measurements when using one of the firm's U2000 Series Universal Serial Bus (USB) average power sensors. All of the FieldFox analyzers include local-area-network (LAN) and USB ports for transferring data, as well as a Secure Digital (SD) data card slot for data storage. MWRF

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JACK BROWNE | Technical Contributor

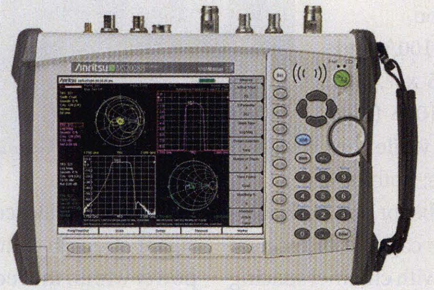
Portability Adds To Testing Versatility

High-frequency test equipment is getting smaller and lighter, yet sports increased functionality and battery life, allowing engineers to bring a full complement of measurements into the field.

PORTABLE TEST equipment has greatly improved over the past decade, narrowing the performance gap between portable and benchtop instruments. In terms of functionality, the number of choices for portability instruments has also increased. Portable RF/microwave instruments, once relegated to voltmeters and power meters, are now available for signal generation, spectrum analysis, and even vector network analysis in lightweight housings that make it possible to bring the test bench to the job site.

The current range of portable RF/microwave test instruments is wide, from pocket-sized power meter/sensors that connect to a computer via its Universal Serial Bus (USB) port to battery-powered, multifunction instruments. In almost all cases, these portable instruments compromise little or nothing in terms of accuracy and overall performance compared to their benchtop counterparts. In addition, as these portable testers evolve, they offer greater operating efficiency—and with it, the capability to run longer on a single battery charge.

A glance at this issue's cover and its associated story (p. 90) will show some of the measurement power possible from a portable instrument. The FieldFox family of portable analyzers from Agilent Technologies (www.agilent.com), which has been on the market for some time, now features 14 new instruments with a variety of analysis capabilities through 26.5 GHz. They are designed for ease of use, long battery life, and good screen visibility even in sunlight, but they sacrifice nothing in terms of performance and accuracy. Impressive instruments, for sure, but they are just one example of the many portable measurement solutions now on the market.



1. The MS2028B VNA Master is a fully featured 5-kHz-to-20-GHz two-port network analyzer is a compact, handholdable housing. [Photo courtesy of Anritsu Co. (www.anritsu.com).]

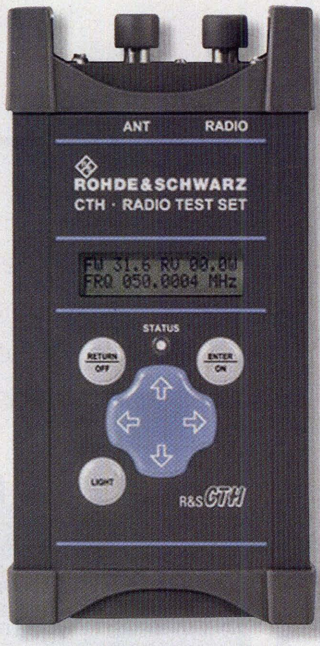
Of course, those needing RF/microwave measurements in the field can also count on the SiteMaster™ and VNA Master portable instruments from Anritsu Co. (www.anritsu.com) for different test functions. For example, the MS2028B VNA Master **(Fig. 1)** is a broadband, handheld solution for cable and antenna measurements in the field. It is a handheld, two-port vector network analyzer (VNA) that covers 5 kHz to 20 GHz with a 65-dB dynamic range to 20 GHz. This is an instrument developed for on-site testing, with a thin-film-transistor (TFT) color display that is clearly visible in daylight and a typically running time of two hours on a battery charge. It can store more than 4000 traces in memory and perform fast sweeps with a speed of 750 us/data point.

The MS2028B VNA Master features 1.5-ppm frequency accuracy and 1-kHz frequency resolution and only weighs 9.9 lbs (4.5 kg) with its rechargeable battery. It has been designed to perform as the equal of any benchtop two-port VNA covering its frequency range, and is ideal for cable loss and fault measurements at communications sites in the field. It is equipped with Ethernet and USB ports for ease of data transfer and boasts a large number of options—among them, for an internal bias tee (for active device testing), a vector voltmeter, a power monitor, and even an internal Global Positioning System (GPS) receiver for accurate identification of different test sites. It is just one of many portable instruments in Anritsu's "Master" lines, which also include the Site Master cable-and-antenna analyzers and spectrum analyzers with frequency coverage extending to 30 GHz.

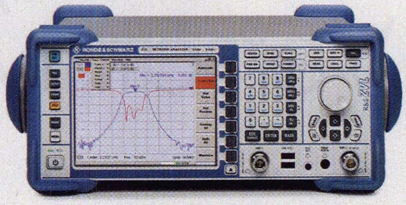
Another small RF/microwave instrument well suited for in-field measurements is the R&S® PR100 portable receiver from Rohde & Schwarz (www.rohde-schwarz.com). With a frequency range of 9 kHz to 7.5 GHz, it teams with the firm's R&S HE300 active directional antenna to form a compact receiving system for monitoring emissions, detecting interference, and locating transmitters. It is ideal (to give just one example), for detecting interference at airports and other remote locations. It weighs only 3.5 kg with its rechargeable lithium-ion battery, but is a full-featured spectrum analyzer with resolution bandwidths from 125 Hz to 100 kHz and scan speeds to 200 channels/s. Preselection can be set from 9 kHz to 30

MHz with a 30-MHz lowpass filter, from 20 MHz to 1.5 GHz with tuned bandpass filters, and from 1.5 to 7.5 GHz with highpass/lowpass filter combinations.

The R&S PR100 portable receiver runs for four hours on a single battery charge and automatically saves instrument settings when the receiver is shut off. It shows results on a bright 6.5-in. color screen and contains both 64 MB of random-access memory (RAM) and a built-in SD card for data storage. It also has an external SD card reader for moving information as needed. For in-field use, the instrument can display results on a digital map loaded within the receiver. An upgrade kit can turn the receiver into a portable direction-finding (DF) system, based on the firm's single-channel correlative interferometer DF method.



2. The R&S CTH100A and CTH200A radio test sets are hand-held instruments that operate from 30 to 512 MHz. [Photo courtesy of Rohde & Schwarz (www.rohde-schwarz.com).]



3. The ZVL line of compact VNAs is available with units operating to 13.6 GHz. Although somewhat heavy, they can operate from battery or vehicular 12-V power. [Photo courtesy of Rohde & Schwarz (www.rohde-schwarz.com).]

Even smaller, the company's R&S CTH100A and CTH200A radio test sets measure just 4.05 x 7.95 x 1.45 in. (102.9 x 202 x 36.8 mm). The CTH100A **(Fig. 2)** weighs 1.17 lb (532 g) without batteries while the CTH200A is 1.19 lb (539 g) without batteries; both instruments draw power from three rechargeable or non-rechargeable 4.5-V batteries. These devices are fully capable of receiver and transmitter testing from 30 to 512 MHz, with channel spacing of 5 MHz on the CTH100A and channel spacings of 100 kHz, 200 kHz, 500 kHz, 1 MHz, 2 MHz, and 5 MHz on the CTH200A. The CTH200A also provides frequency-modulation (FM) demodulation for FM transmitter testing, and both instruments are ideal for cable fault location. The CTH200A can measure and display the results of over-the-air (OTA) measurements (across a 60-dB dynamic range) on a bar graph on the small display screen. In addition, a cable fault locator in the CTH200A can locate faults through cables at distances to 480 m.

Rohde & Schwarz also supplies instruments such as the ZVL line **(Fig. 3)** of VNAs, which can also be equipped with a spectrum analyzer as an option. Available in models from 9 kHz to 3.0, 6.0, and 13.6 GHz, the ZVL instruments nominally appear as benchtop instruments. But they are equipped with a carrying handle, weigh only 9 kg, and can be powered by plug-in rechargeable batteries or run from +12-VDC vehicular power supplies for remote test requirements.

The 3500A portable radio communications test set from Aeroflex (www.aeroflex.com), which is in the process of being replaced by the firm's model 3550A portable test set, is designed for use from 2 MHz to 1 GHz. It is ideal for quick installed radio testing and for finding radio failures. The hand-held instrument includes a spectrum analyzer with –136 dBm noise level and a tracking signal generator with frequency range from 2 MHz to 1 GHz, power levels from 0 to –60 dBm, and 1-Hz resolution. It weighs less than 8 lbs (3.6 kg) and provides more than 5 hours on a single battery charge. The spectrum analyzer features phase noise of –80 dBc/Hz offset 20 kHz from the carrier, with harmonic levels of –30 dBc and spurious levels of –40 dBc. The 3500A offers a large number of options, including an audio frequency counter and audio oscilloscope. It can also be equipped with a received-signal-strength-indication (RSSI) meter, which indicates the RF power within the receiver's IF bandwidth. It has a display range of –120 to +43 dBm with measurement capability of –50 to +43 dBm at the instrument's transmit/receive (T/R) port.

Of course, not all RF/microwave instruments designed for portability are easy to transport or use while in motion. A growing number of compact instruments, such as the PWR-4RMS USB power sensor from Mini-Circuits, are designed for USB connections to a laptop or personal computer, with the computer providing control, programming, and display of results. The PWR-4RMS turns any computer running Microsoft Windows or Linux into a power meter capable of reading the power levels of modulated and continuous-wave (CW) signals. It measures just 4.89 x 1.74 x 0.95 in. and operates from 50 to 4000 MHz with a 55-dB dynamic range (–35 to +20 dBm).

In some cases, a small package size may house an instrument that can be easily carried, but may not be ideally suited for on-site or in-the-field measurements. For example, the DSA815 spectrum analyzer from Rigol Technologies (www.rigolna.com), reported on in the August issue of *Microwaves & RF* (p. 104) measures just 14.2 x 7.0 x 5.0 in. and weighs 9.4 lbs. With a frequency range of 9 kHz to 1.5 GHz, it covers a wide range of applications. Better still, it can be supplied with a full-range tracking generator to operate in the manner of a scalar network analyzer. But it has been designed for use with AC power, so an AC power source would be required in the field for any on-site measurements.

Still, for those seeking portable RF/microwave test instruments for on-site measurements, the number of choices has never been as large, and growing constantly. A wide range of RF/microwave instruments is available for use on battery power, many units with multiple measurement functions, and many that can be upgraded at any time with additional functions. MWRF

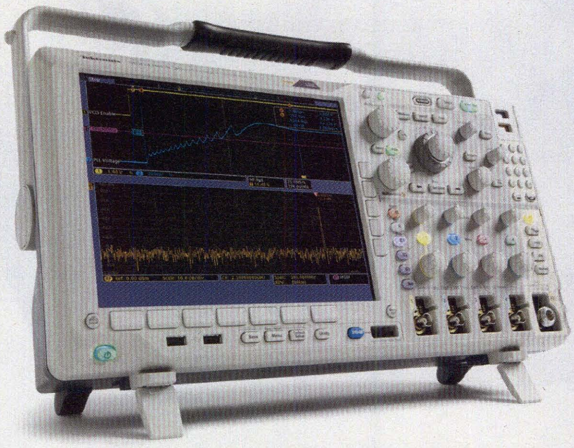
Scopes Include Spectrum Analyzers

Two low-cost additions to a line of versatile test instruments can work as oscilloscopes and spectrum analyzers simultaneously, providing a unique set of triggering functions to 3 GHz.

OSCILLOSCOPES ARE the work-horse test instruments of any electronic design bench, and the MDO4000 lines of mixed-domain oscilloscopes (MDOs) from Tektronix (www.tektronix.com) have brought extended capabilities to these invaluable instruments by including spectrum analyzers. To make them even more accessible, the firm recently announced two low-cost additions to the MDO4000 product line: models MDO4014-3 and MDO4034-3, with analog bandwidths of 100 and 350 MHz, respectively. These versatile test tools each offer 4 analog channels, 16 digital channels, and one RF channel, with an RF range that can extend to 3 GHz.

Each MDO4000 model **(see figure)** can capture time-correlated analog, digital, and RF signals across its operating bandwidth, but also tracks how the spectrum changes over time by using the spectrum-analyzer functionality. These combination testers provide support for as much as 3 GHz capture bandwidth in a single acquisition. In addition to triggering on events with the oscilloscope, the MDO4000 instruments can also trigger on RF signals to help isolate an event.

Both models MDO4014-3 and MDO4034-3 cover a spectrum analyzer (RF) range of 50 kHz to 3 GHz. The instruments differ by their analog bandwidths, as mentioned previously. Both integrate the functionality of an oscilloscope with that of a spectrum analyzer, logic analyzer, and protocol analyzer. They feature a maximum capture rate of 50,000 waveforms/s and provide more than 125



The models MDO4014-3 and MDO4034-3 are the two latest additions to the MDO4000 series of oscilloscopes/spectrum analyzers introduced last year. The new models have analog bandwidths of 100 and 350 MHz for the scopes and RF ranges of 50 kHz to 3 GHz for the spectrum analyzers.

trigger combinations. Their trigger acquisition system is fully integrated with the RF, analog, and digital channels.

A single trigger event coordinates signal acquisition across all channels. A variety of time-domain triggers are provided, including edge, sequence, timeout, video, and rise/fall time triggers. Triggering can be performed on the power level of the RF input signal, such as when a transmitter turns on.

The screen can show both time- and frequency-domain information. When the RF channel and any analog or digital channels are active, the display is split into two views: The upper half shows a traditional oscilloscope screen with a time-domain display, while the lower half shows the frequency-domain view of a spectrum analyzer.

The new instruments both include four Universal Serial Bus (USB) 2.0 ports, along with an RS-45 local-area-network connector. They show signal information on a 10.4-in. (264-mm) liquid-crystal TFT color display with resolution of 1024 x 768 pixels. The instruments are equipped with low-capacitance, wide-bandwidth passive probes, and are available with optional serial-bus analysis capability for studying USB, MIL-STD-1553, RS-232, and other serial buses.

In addition, the firm has announced the new model TRA-N-PRE preamplifier with bandwidth of 9 kHz to 6 GHz for improving the sensitivity of low-level measurements. It provides nominal gain of 12 dB.

Finally, the company has also introduced the SignalVu-PC vector signal analysis software for use with the oscilloscopes. The MDO4000 series instruments can save baseband In-phase (I) and quadrature (Q) data from complex modulated wireless signals into the .TIQ file format, ideal for import into SignalVu-PC running on a laptop or personal computer (PC) for analysis.—*JB*

TEKTRONIX, INC., 14150 S.W. Karl Braun Dr., P.O. Box 500, Beaverton, OR 97077; www.tek.com.

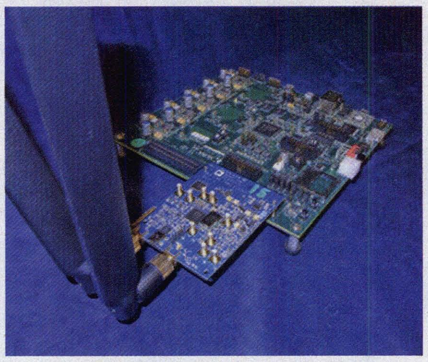
SDR Kit Helps Radio Designers

Design engineers wishing to incorporate software-defined-radio (SDR) technology in their systems can now get a head start, thanks to this radio board and included software tools.

SOFTWARE-DEFINED-RADIO (SDR) technology provides the extreme flexibility of software control of radio parameters. However, because it is so different from traditional analog, mixer-based radio architectures, knowing how to optimally incorporate an SDR in a commercial or military communications application requires something of a learning curve. To help expedite the process, Analog Devices (www.analog.com) and Avnet (www.avnet.com) have teamed on a new SDR kit.

The Zynq™-7000 SDR kit **(see figure)** from Analog Devices consists of the Avnet ZedBoard 7020 base board; the AD-FM-COMMS1-EBZFMC communications mezzanine-card module [which employs a field-programmable gate array (FPGA) from Xilinx (www.xilinx.com)]; a model-based design kit from The MathWorks (www.mathworks.com); HDL source code; Linux drivers; Gerber files; reference designs; schematic diagrams; and a pair of MMCX-to-MMCX coaxial cables. The FMCOMMS1-EBZ includes an analog front-end which can be quickly configured to operate with a variety of compute-intensive FPGA-based applications. It is also designed for use with the Xilinx Zynq® Software-Defined Radio Kit.

The SDR kit is suitable for wireless infrastructure, as well as for military and industrial radios. Featuring a 200-MHz bandwidth that can be tuned across a bandwidth of 400 MHz to 4 GHz, it allows operators to bypass the RF section for baseband sampling. It is also well suited for multiple-input, multiple-output (MIMO) antenna configurations. The SDR kit builds on the performance available from the AD-FMCOMMS1-EBZFMC, which is populated with a number of high-performance components from Analog Devices. These components include a 6-GHz model ADL5380 demodulator, a 6-GHz model ADL5375 modulator, a model AD9122 16-b digital-to-analog converter (DAC), and a model AD9643 14-b analog-to-digital converter (ADC).



The Zynq-7000 SDR kit provides all the hardware and software for a designer to program their own commercial or military radio over wide bandwidths to 4 GHz.

The SDR board and AD-FMCOMMS1-EBZFMC mezzanine card operate with four functional partitions: the transmit signal path, the receive path, clock generation and management, and register access. For transmission, the card converts in-phase (I) and quadrature (Q) baseband signals to modulated RF/microwave signals. The model AD9122 interpolates this data and applies frequency translation to the baseband signals. A complex analog output from the AD9122 DAC then feeds a model ADL5375 quadrature modulator where it is translated to the required RF output frequency. Following an image-reject filter, the signal is boosted by 20 dB through a model ADL5602 amplifier with 4-GHz bandwidth. The amplifier provides RF outputs to +7.5 dBm.

Upon receiving a signal, the card converts an RF signal to complex I and Q signal components. The RF signal is demodulated by the model ADL5380 demodulator to achieve an intermediate-frequency (IF) signal from 50 to 200 MHz. This I/Q IF signal is then filtered and passed to the AD8366 variable-gain amplifier (VGA), which provides as much as 15.75 dB gain. Following additional filtering, the signal is digitized with the AD9643 14-b ADC. The system can derive a clock signal from an on-board crystal or crystal oscillator at 50 MHz or from the FPGA.

The Zynq-7000 SDR kit is supplied with operator's manuals and software. The kit includes the ISE® Design Suite:WebPACK™ edition from Xilinx with a Chipscope Pro license node-locked to the embedded Xilinx XC7Z020 FPGA. The model-based design kit and evaluation tools from MathWorks help to quickly move conceptual designs to working code for the SDR kit. The kit includes two Fourth-Generation Long-Term-Evolution (4G LTE) antennas for use from 2500 to 2700 MHz.—*JB*

ANALOG DEVICES, INC., 3 Technology Way, Norwood, MA 02062; www.analog.com, **AVNET ELECTRONICS MARKETING**, 2211 S. 47th St., Phoenix, AZ 85034; (800) 408-8353, www.avnet.com.

Module Contains Vector Transceiver

This compact PXI Express module combines a vector signal generator and vector signal analyzer with an FPGA-based processing engine in a versatile 6-GHz vector signal transceiver.

VECTOR SIGNALS, with in-phase (I) and quadrature (Q) signal components, are part of modern wireless communications systems employing complex modulation. Testing those systems traditionally called for separate vector signal analyzers (VSAs) and vector signal generators (VSGs). But now, National Instruments (www.ni.com) has introduced its model NI PXIe-5644R vector signal transceiver (VST); a compact PXI Express module, it combines a VSG and VSA with a field-programmable gate array. The model features an instantaneous bandwidth of up to 80 MHz, at test frequencies from 65 MHz to 6 GHz.

The NI PXIe-5644R VST **(see figure)** combines multiple instruments a single three-slot PXI Express module. By mounting multiple NI PXIe-5644R into one PXI Express chassis, a compact test solution can be created for testing wireless systems with multiple-input, multiple-output (MIMO) antenna configurations. The analyzer offers 1-Hz tuning resolution and can process input signals from the average noise level of the receiver section to about 1 W (+30 dBm) input power. The transceiver settles to within 0.1 dB of a final amplitude value in typically 125 μs. At room temperature, the analyzer achieves a typical absolute amplitude accuracy of ±0.50 dB from 65 MHz to 375 MHz, ±0.35 dB from 375 MHz to 2 GHz, ±0.40 dB from 2 to 4 GHz, and ±0.55 dB from 4 to 6 GHz.

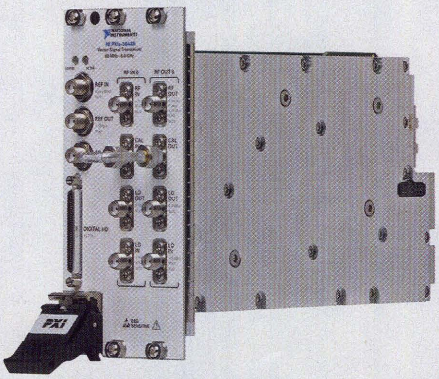
The NI PXIe-5644R receiver is based on a homodyne zero-intermediate-frequency (zero-IF) architecture, also known as a direct-downconversion receiver. Input signals are processed through frequency mixers, using local oscillator (LO) signals close in frequency to the input signals, yielding low-frequency (close-to-DC) IF signals. At baseband, the IF signals are separated into I and Q signal components and separately digitized, resulting in I and Q data. These data streams are combined in software to recreate the original signal.

The transmitter section incorporates two I/Q modulators, a filter bank, and additional signal conditioning. The two I/Q modulators, which are optimized for amplitude and phase balance, are the same ones used in the NI PXIe-5673E VSG. A low-phase-noise LO is included on the transmitter path for connecting multiple upconverters with a single LO source.

Although the analog portions of the NI PXIe-5644R VST are impressive, the role of the FPGA should not be overlooked. It is a Virtex-6 FPGA from Xilinx (www.xilinx.com), which can be readily programmed by means of the LabVIEW FPGA Module within the LabVIEW system software from National Instruments. The FPGA makes use not only of the signals from the NI PXIe-5644R VST's analyzer and generator, but also of its 24 digital input/output (I/Q) lines, which operate at data rates up to 250 Mb/s. The FPGA basecard within the NI PXIe-5644R VST includes the Virtex-6 FPGA, baseband clocking circuitry, 16-bit analog-to-digital converters (ADCs), 16-bit digital-to-analog converters (DACs), programmable digital I/O lines, a PXI Express interface, PXI triggers, and memory.

The NI PXIe-5644R contains a Xilinx Virtex-6 LX195T FPGA, which has direct connections to the ADCs, DACs, PCI Express bus, DRAM, SRAM, PFI 0, digital I/O, and PXI triggers. Multiple clocks are used with the FPGA, including sample clocks at rates of 1X (120 MHz), 2X (240 MHz), and 3X (360 MHz); a 100-MHz clock from the backplane; and free-running 40- and 125-MHz clock oscillators. The NI PXIe-5644R is available with three different PLL bandwidth options: high, medium, and low.

To help new users, a number of LabVIEW sample projects are available for the NI PXIe-5644R, as well as Instrument Design virtual instruments (VIs) that help understand how to program the FPGA. The firm has also produced several tutorial videos, available on its website.—*JB*

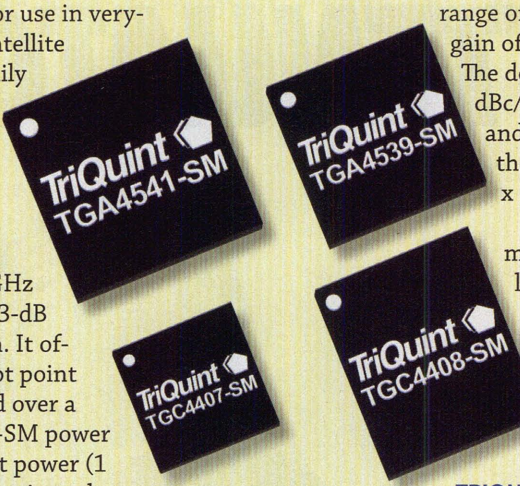


The NI PXIe-5644R is a vector signal transceiver (VST) that fits within a three-slot PXI Express module and features 80-MHz of instantaneous bandwidth across a frequency range of 65 MHz to 6 GHz.

NATIONAL INSTRUMENTS CORP., 11500 N. Mopac Expy., Austin, TX 78759-3504; (512) 683-0100, www.ni.com.

GaAs Chips Help VSAT Systems

A family of Ka-band GaAs chipsets has been developed by TriQuint Semiconductor for use in very-small-aperture-terminal (VSAT) satellite communications systems. The family includes a variable-gain amplifier, a 1-W power amplifier (PA), a subharmonic frequency upconverter, and a block frequency downconverter. The model TGA4541-SM variable-gain driver amplifier operates from 28 to 31 GHz with 33-dB maximum gain and +23-dB output power at 1-dB compression. It offers an output third-order intercept point of +31 dBm. The gain can be varied over a 30-dB range. The model TGA4539-SM power amplifier supplies +30-dBm output power (1 W) from 28 to 30 GHz with 20-dB gain and output third-order intercept point of +33 dBm. The model TGC4408-SM block downconverter has an input range of 18.3 to 20.2 GHz and an intermediate-frequency (IF) range of 950 to 1950 MHz with conversion gain of 8.5 dB and noise figure of 6.5 dB. The downconverter has phase noise of −73 dBc/Hz offset 10 kHz from the carrier and −126 dBc/Hz offset 1 MHz from the carrier. It is supplied in a 32-pin 5 x 6-mm QFN package.



The model TGC4407-SM subharmonic upconverter has an integrated local-oscillator (LO) buffer amplifier with an input frequency range of 21.5 to 32.5 GHz, wide IF range of DC to 7 GHz, and subharmonic LO frequency of 11 to 16 GHz. It accepts LO signals from 0 to +7.5 dBm and yields conversion gain of −9 dB.

TRIQUINT SEMICONDUCTOR, INC., 2300 NE Brookwood Pkwy., Hillsboro, OR 97124; (503) 615-9000, FAX: (503) 615-8900, ***www.triquint.com***.

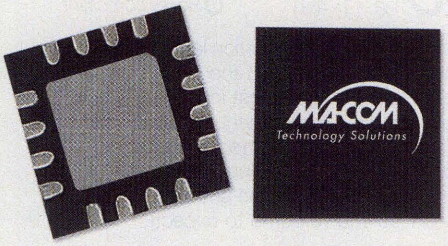
VCO Tunes From 1210 To 1230 MHz

Model USSP1217-LF is a RoHS-compliant voltage-controlled oscillator (VCO) designed for L-band applications from 1210 to 1230 MHz. It tunes with voltages from 0.5 to 3.0 VDC and tuning linearity of better than 1.1:1. It delivers output power of +3 dBm across the frequency range, with ±3-dB flatness, and exhibits phase noise of −102 dBc/Hz offset 10 kHz from the carrier. The oscillator is supplied in the company's compact USSP housing measuring just 0.2 x 0.2 x 0.06 in. and drawing only 13 mA current. Second harmonics are suppressed to better than −13 dBc. Ideal for mobile radio and satellite-communications (satcom) applications, the VCO is available in tape-and-reel packaging to meet production requirements.

Z-COMMUNICATIONS, INC., 14118 Stowe D., Ste. B, Poway, CA 92064; (858) 621-2700, FAX: (858) 486-1927, ***www.zcomm.com***.

Frequency Doubler Extends To 30 GHz

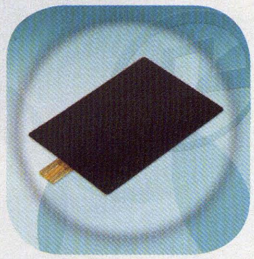
Model XX1010-QT is a GaAs monolithic-microwave-integrated-circuit (MMIC) frequency doubler from M/A-COM Technology Solutions that is well suited for satellite-communications (satcom) and point-to-point communications systems. The active frequency doubler integrates a gain stage, doubler, and driver amplifier into a single device. It accepts input signals from 14.625 to 15.000 GHz and delivers output signals from 29.25 to 30.00 GHz. It provides +20-dBm saturated output power with −35-dBc fundamental-frequency suppression. It is supplied in a RoHS-compliant, 16-lead, 3 x 3 mm plastic QFN package. Designed to operate from a single +5-VDC supply (it draws typically 200 mA current), the active doubler includes DC blocking and bypassing capacitors, eliminating the need for any external components.



M/A-COM TECHNOLOGY SOLUTIONS, 100 Chelmsford St., Lowell, MA 01851; (978) 656-2500, ***www.macomtech.com***.

Planar Antenna Captures NFC Data

A near-field communications (NFC) antenna enables mobile telephones to read data from a source at distances to 40 mm. The antenna sends and receives clear signals even when installed in close proximity to a battery or metal housing. The ferrite sheet antenna can be customized to different sized handset designs and enables safe, noncontact, wireless communications for mobile devices. The planar ferrite sheet-based antenna measures 35 x 50 mm with minimum thickness of 0.30 mm, including the ferrite/adhesive/antenna flex layers. The magnetic field strength can be optimized by the type and thickness of the ferrite material and the design of the radiator pattern. The NFC ferrite sheet antenna is RoHS compliant, comes packaged in trays, and is ready for volume production. It is available in a variety of sizes and can be custom configured to a customer's specifications.



PULSE ELECTRONICS CORP., 12220 World Trade Dr., San Diego, CA 92128; (858) 674-8100, FAX: (858) 674-8262, ***www.pulseelectronics.com***.

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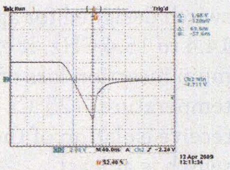

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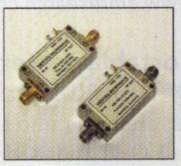

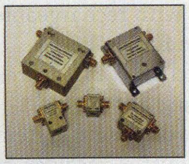

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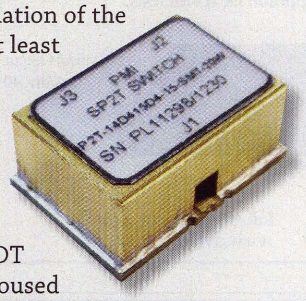
Switch Channels 14.4 to 15.4 GHz

Model P2T-14D415D4-15-SMT-20W is a driverless high-power single-pole, double-throw (SPDT) switch designed for applications from 14.4 to 15.4 GHz. It exhibits maximum insertion loss of 1.2 dB at room temperature (+25°C). The transmit/receive isolation of the switch is at least 10 dB. The switch can handle input power levels to 20 W. The rugged SPDT switch is housed in a surface-mount-technology (SMT) package measuring just 0.35 x 0.50 x 0.21 in.



PLANAR MONOLITHICS INDUSTRIES, INC. (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.*

Module Supports ISM Front Ends

Designed for applications in the 868/900-MHz Industrial-Scientific-Medical (ISM) band, model RFFM6904 is a single-chip front-end module (FEM) ideal for portable equipment. Based on GaAs HBT technology, the module contains a 2-W power amplifier, a transmit/receiver (T/R) transfer switch, a low-noise amplifier (LNA) with bypass mode, and impedance-matching components for optimum performance. It operates from a +5-VDC supply with 32-mA current consumption for the LNA and 1200-mA current consumption for the PA. The module delivers its rated performance at operating temperatures from −40 to +85°C. The PA provides +33.5 dBm output power at 1-dB compression with 30-dB typical gain from 02 to 928 MHz, while the LNA has typical noise figure of 1.3 dB and gain of 21 dB from 902 to 928 MHz. The T/R switch has 0.85-dB typical insertion loss from 902 to 928 MHz from its receive or transmit port to either of two antenna ports. The FEM is housed in a 32-pin, laminate package measuring 8.0 x 8.0 x 1.2 mm with backside ground.

RFMD, 7628 Thorndike Rd., Greensboro, NC 27409-9421; (336) 678-5570, *www.rfmd.com.*

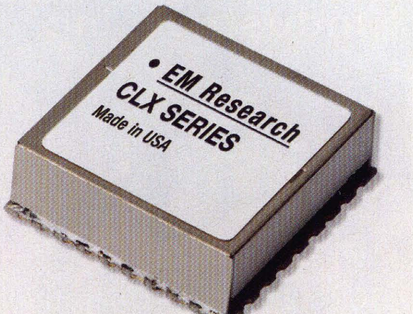
BUC Links Ku-band Satcom Systems

Model XTS-40KHE-B1 is a Ku-band block upconverter (BUC) that includes temperature compensation, gain control, harmonic filtering, receive-band filtering, and an output isolator in a compact unit weighing less than 10 lbs; it measures just 11.2 x 4.4 x 54. in. Suitable for commercial and military Ku-band satellite-communications applications, it provides 20 W linear output power and 40 W of output power at 1-dB compression. The feed-mountable amplifier features forced-air cooling and consumes only 210 W power. It features an L-band input port handles signals from 950 to 1700 MHz at maximum level of +10 dBm and a Ku-band output port that supplies +46 dBm output power at 1-dB compression and +47 dBm saturated output power from 13.75 to 14.50 GHz. The BUC achieves 50-dB small-signal gain from 13.75 to 14.50 GHz with gain variation of ±1.5 dB over the full operating band. It exhibits phase noise of −73 dBc/Hz offset 1 kHz from the carrier and −93 dBc/Hz offset 100 kHz from the carrier. The BUC includes Ethernet and RS-232/422/485 interfaces.

COMTECH XICOM TECHNOLOGY, INC., 3550 Bassett St., Santa Clara, CA 95054; (408) 213-3000, FAX: (408) 213-3001, e-mail: sales@xicomtech.com, *www.xicomtech.com.*

Oscillator Locks Onto 1030 MHz

Model CLX-1020-XA is a fixed-frequency, phase-locked oscillator with a stable output at 1030 MHz. It includes an internal reference with ±2 ppm stability and delivers +7 dBm output power with ±2-dB output-power flatness. Harmonics are better than −20 dBc while spurious content is better than −80 dBc. The phase noise is better than −97 dBc/Hz offset 1 kHz from the carrier, −109 dBc/Hz offset 10 kHz from the carrier, and −135 dBc/Hz offset 100 kHz from the carrier. The phase-locked oscillator draws less than 85 mA from a +5-VDC supply and has an operating temperature range from −30 to +70°C. It is supplied in a 0.75 x 0.75 in. surface-mount-technology (SMT) package.



EM RESEARCH, 1301 Corporate Blvd., Reno, NV 89502; (775) 345-2411, FAX: (775) 345-1030, e-mail: sales@emresearch.com, *www.emresearch.com.*

Portable Tester Scans To 1 GHz

The 3550 digital radio test system enables radio testing from 2 MHz to 1 GHz and is ideal for field testing of analog and digital systems. It weighs only 8.3 lbs with rechargeable battery and will run for about 4.5 hours on a battery charge. It features a color touchscreen and allows operators to test all parts of a radio system, including the transmitter, receiver, cables, and antennas. The 3550 includes a spectrum analyzer and built-in signal generator with range from 2 MHz to 1 GHz; it meets MIL-PRF-28800A specifications for humidity, shock, and vibration with an operating range of -0 to +50°C. As with many portable instruments, it offers laboratory-grade performance, with phase noise of −95 dBc/Hz and spectrum analyzer noise floor of −140 dBm.

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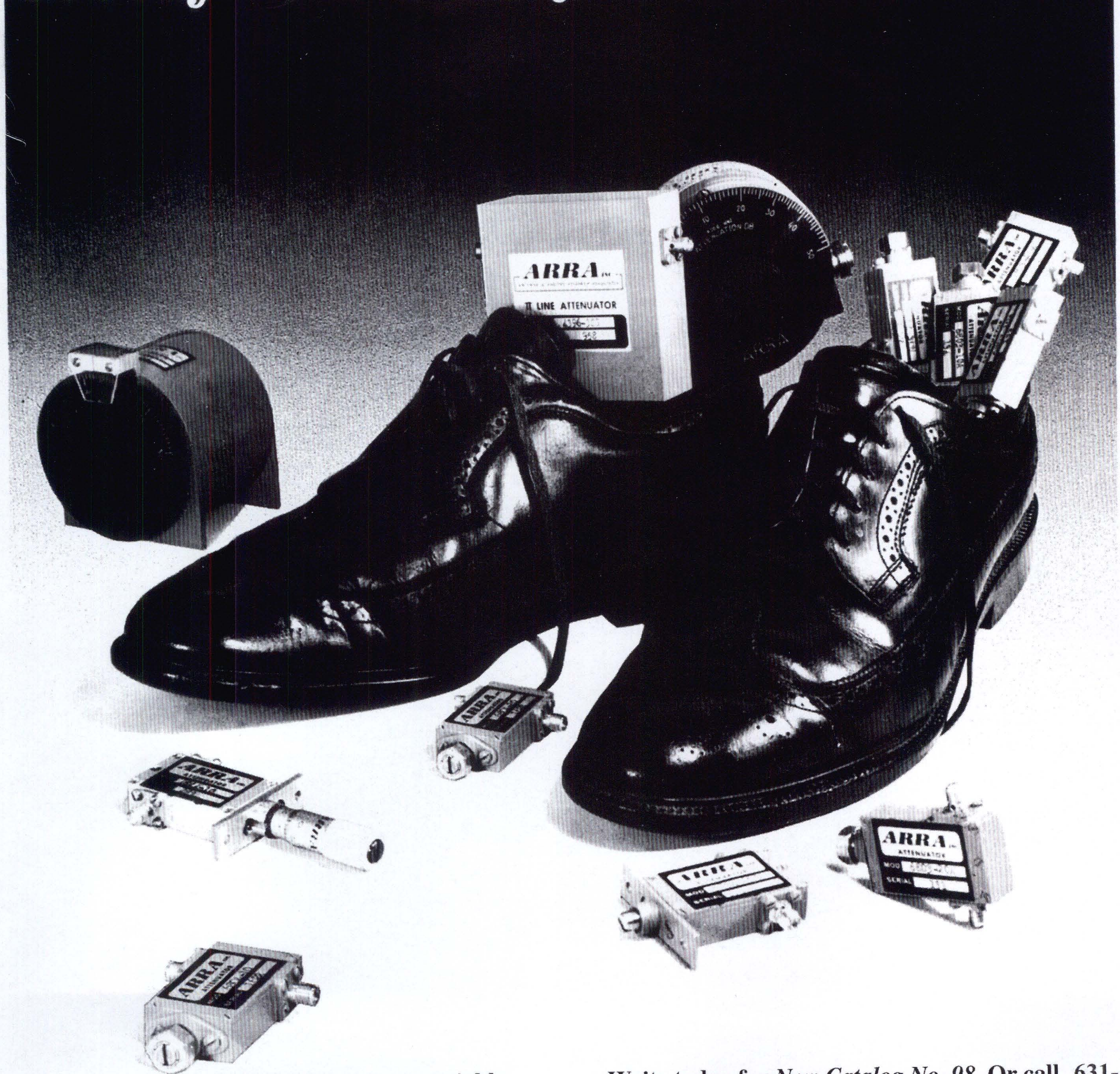

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